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CHAPTER 1

INTRODUCTION

Overview

In the United States, 80% of adults will experience back or neck pain that interferes with daily activities.(1, 2) Back and neck pain care result in $253 billion in total direct healthcare costs each year.(3) Societal costs for back pain account for 1% to 2% of the gross national product in some Western countries, with the majority of these costs caused by productivity loss and disability.(4-6) Surgical interventions may be indicated for those with prolonged symptoms. Recent estimates suggest around 1.6 million spinal procedures are performed annually in the United States, up 17% since 2011.(3, 7) Despite surgery successfully addressing the pathoanatomical cause of pain, up to 40% of patients still have pain at 1 and 2 years after surgery.(8-11)

An integral part of the determination of success and overall patient experience following spine surgery are patient-centric improvements related to pain relief, disability, and physical function as a result of their surgery.(12-14) Predictors of spine surgery outcomes have largely focused on factors such as patient sociodemographic and clinical characteristics of functional status, comorbidities, and pain (**Table 1.1)**. Several factors, including shorter duration of preoperative symptoms, younger age, and male gender are associated with lower levels of pain or disability after spine surgery. (15-17) Our research team and others have demonstrated that psychosocial factors, such as anxiety and depression, are associated with clinically meaningful differences in outcomes including disability after spine surgery.(18, 19) Recently, interest in understanding the importance of

patient expectations in evaluating a patient's satisfaction and their self-perceived outcomes of treatment have become significant components of patient-centered care.(20, 21)

Table 1.1: Factors associated with postoperative changes in pain and/or disability after lumbar or cervical spine surgery

Demographics	*Clinical & Surgical Symptoms*	*Psychosocial Factors*
†Male Gender (22)	*Higher Disability (23)	*Anxiety (24)
†Younger Age (25-27)	†*Increased Neck/Back Pain (28)	*Depression (24, 29, 30)
*Smoking (28, 31-33)	†*Increased Arm/Leg Pain (22, 28, 34, 35)	*Pain-Catastrophizing (36)
†Higher Income (37)	†Less severe baseline symptoms (38)	
*Active Liability Insurance (39)	†Symptoms < 6 months (27, 31)	
*Worker's Compensation (25, 28, 40-42)	*Reoperation/Revision (31-33, 43)	
*Comorbidities (44, 45)		

*represents factors negatively associated with pain and/or disability following spine surgery
†represents factors positively associated with improvements in pain and/or disability following spine surgery

Patient expectations can be defined as "future-directed beliefs that focus on the incidence or non-incidence of a specific event or experience."(46) Expectations of elective spine procedures can be major determinants in the decision to undergo surgery, where prediction of their future condition may affect their treatment choices and perceptions of postoperative outcomes.(20, 47-49) Prior research reveals that patients undergoing spine surgery generally have high expectations for the results of their surgical procedure; this includes an expected reduction in pain and disability as a result of surgery.(47, 50) While many clinicians would agree that establishing realistic expectations is an important part of the surgical process, the literature presents conflicting evidence regarding the association between preoperative expectations and postoperative outcomes.(47, 51-53) These inconsistent results are likely due, in part, to a paucity of validated, spine-specific

expectation measures and differences in how expectations are defined by both clinicians and their patients.

A significant gap exists in the characterization of patient expectations within spine surgery populations. Most literature has evaluated preoperative expectations using non-validated measures, such as visual analog scales,(52) ad-hoc physician-derived surveys,(54, 55) or individual questions from comprehensive preoperative surveys.(20, 34, 47) In other studies, expectations were defined and dichotomized as expectations for improvement or no improvement,(53) high or low expectations (56), or expectations for return to full health or not.(57) These types of differences in the variables considered and the methods of analysis used make it difficult to compare the true effect of expectations on spine surgery outcomes based on the existing literature. The Hospital for Special Surgery's (HSS) Lumbar Spine Surgery Expectations Survey (58) and the HSS Cervical Spine Surgery Expectations Survey (59) are two spine-specific expectations questionnaires that have been shown to be reliable and valid. Studies using these composite expectations scores have shown an association between preoperative expectations and preoperative factors including higher age and disability.(60, 61) However, these validated HSS measures have only been used within a single, tertiary-care orthopaedic surgery center's surgical population.(60-62) This provides the opportunity to expand the breadth of research that utilizes these surveys, while also assessing the relationship between preoperative expectations and important preoperative clinical characteristics such as patient-reported physical function and pain interference.(60, 61)

The predictive value of preoperative expectations for postoperative outcomes is frequently studied, but study results vary depending on how expectations are defined.(20,

63, 64) Much of the existing work assesses expectations using individual domain questions, including pain symptom improvement, functional improvement, numbness/weakness, and expectations for future work status. There is no consensus in the association between preoperative expectations and postoperative outcomes, as some studies have shown higher expectations are associated with improvement in patient-reported outcomes (PROs), including pain, disability, and satisfaction, despite the variety of methods utilized in their collection(64, 65). However, other studies have found that higher expectations result in lower satisfaction and higher pain postoperatively,(47, 53) while others failed to identify a relationship between preoperative expectations and postoperative outcomes.(13, 54, 55, 66) In separate systematic reviews, both Witiw et al and Ellis et al suggest that future research should utilize standardized expectations tools to assess patients prior to surgery and throughout recovery in order to better understand the true relationship between expectations and outcomes.(64, 65) Researchers have used the preoperative HSS expectations scores to predict psychological well-being, but not measures such as postoperative pain, disability, or satisfaction.(62, 67, 68) These relationships are potentially important as patients who are satisfied with their symptom state are less likely to seek additional treatment for the same problem.(69, 70)

Some authors suggest that it is fulfilled expectations that has an impact on postoperative outcomes including satisfaction rather than the preoperative expectations themselves.(20, 47, 54, 71) Prior work highlights the importance of fulfilled expectations as an effective measurement of the potential value of surgery to the patient.(20, 67) However, the definition and measurement of fulfilled expectations is widely variable within the spine surgery population. Common postoperative fulfilled expectation measurement includes

postoperative questions assessing if the patient's expectations were met (20), a pre-post comparison of a common scale (e.g., the visual analog scale for pain, Oswestry Disability Index)(72), or a global fulfilled expectations question.(13, 54, 55) Postoperative fulfilled expectations provide an opportunity for patients to express how surgery has met their goals and affords surgeons the opportunity to address these issues directly, particularly in the early postoperative time period.(73) Mannion et al. assessed fulfilled expectations at 2-months postoperatively with a non-validated questionnaire, but only utilized that data to assess the global effectiveness of their treatment at 12-months.(20) Limited research has utilized validated expectations measures to compare the amount of expected improvement to the improvement received postoperatively. Mancuso et al generated a novel measurement, the proportion of fulfilled expectations, using the HSS Lumbar or Cervical Spine Surgery Expectations Surveys, to assess the cross-sectional relationship with patient reported pain, disability, and health-related quality of life at 2 years post-operatively. However, the proportion of fulfilled expectations has not been used at an early postoperative time-point to predict long-term outcomes. Like preoperative expectations, the HSS Lumbar or Cervical Spine Surgery Expectations Surveys measurement of fulfilled expectations have not been utilized outside of the original sample. This research provides an opportunity to assess the generalizability of the HSS measures to other clinical settings.

This dissertation builds on prior work using the validated HSS Lumbar and Cervical Spine Surgery Expectations Surveys by 1) further characterizing preoperative expectations, 2) using preoperative expectations to predict outcomes at later time points, 3) characterizing fulfilled expectations in the early postoperative time period (e.g. 3-months postoperatively), and 4) using fulfilled expectations at early time points to predict

outcomes at longer term follow-up. This proposed study is an important step in understanding the characterization of patient expectations, as well as the role expectations and fulfilled expectations play in postoperative outcomes. Patients and surgeons need to share an understanding of what are possible, probable, and realistic expectations so that they can work toward the same goals.(74, 75) This study is well-positioned to evaluate the understudied relationship between expectations, their fulfillment, and PROs, including their relationship to clinically-relevant measures of disability, physical function, pain interference, pain intensity, and satisfaction. These findings will serve as a comprehensive summary of the association between preoperative expectations, fulfilled expectations, and multiple demographic and clinical characteristics. Additionally, by assessing the relationship between preoperative expectations and fulfilled expectations, this study sets the stage for future research to determine what are realistic, attainable expectations for both surgeons and patients undergoing elective spine surgery.

Patient Expectations: Conceptual Overview

Among the most prominent theoretical backgrounds for the conceptualization of expectations is the Social Cognitive Theory (SCT). SCT, neé Social Learning Theory, was developed by Albert Bandura in the 1960s, and posits that learning occurs in a social context with a dynamic interaction between the subject, environment, and behavior.(76) The unique feature of SCT is the emphasis on social influence and reinforcement from both external and internal sources. SCT considers both how individuals acquire and maintain behavior, while also considering the social environment in which individuals perform the behavior. These experiences influence reinforcements, expectations, and expectancies; together, these factors shape both 1) if a person will engage in a specific behavior and 2)

the reasons a person engages in that behavior. SCT distinguishes two primary concepts of expectations. Behavior outcome expectancies express the likelihood that a specific outcome will follow an action. These outcomes can be of a physical, social, or self-evaluative nature (**Figure 1.1**). Additionally, self-efficacy expresses an individual's expectation of being capable of executing a certain action.(46) It is necessary to consider generalized expectations, such as generalized self-efficacy and generalized outcome expectations (*i.e.,* optimism), as these have been shown to influence patient outcomes and are likely to influence specific aspects of expectations in patients undergoing medical treatment.(77, 78) Additional components of expectations include timeline expectations, temporal aspects of the disease, treatment, and health behavior. Finally, treatment related expectations consist of expectations regarding outcomes as well as the structural and process-related aspects that are likely to influence treatment outcomes. Most research on expectations within spine surgery focus on treatment related expectations.(46, 65)

Patients' expectations are important factors in shared decision-making for elective surgery.(79) High expectations can be motivating; they may also predispose patients to poor outcomes if they are unrealistic and cause patients to become discouraged with their recuperation time and ignore recommended lifestyle changes that avert progression of disease.(54, 80) Conversely, expectations that are too low may lead to poor outcomes if patients lack the motivation to participate in rehabilitation and follow postoperative precautions.(53, 81) It is not unreasonable to assume that patient expectations contribute crucial information in the preoperative assessment of spine surgery candidates as evidenced by the work of cognitive psychologists, who suggest that one's perception of an experience and their resulting satisfaction are a function of pre-existing expectations.(82)

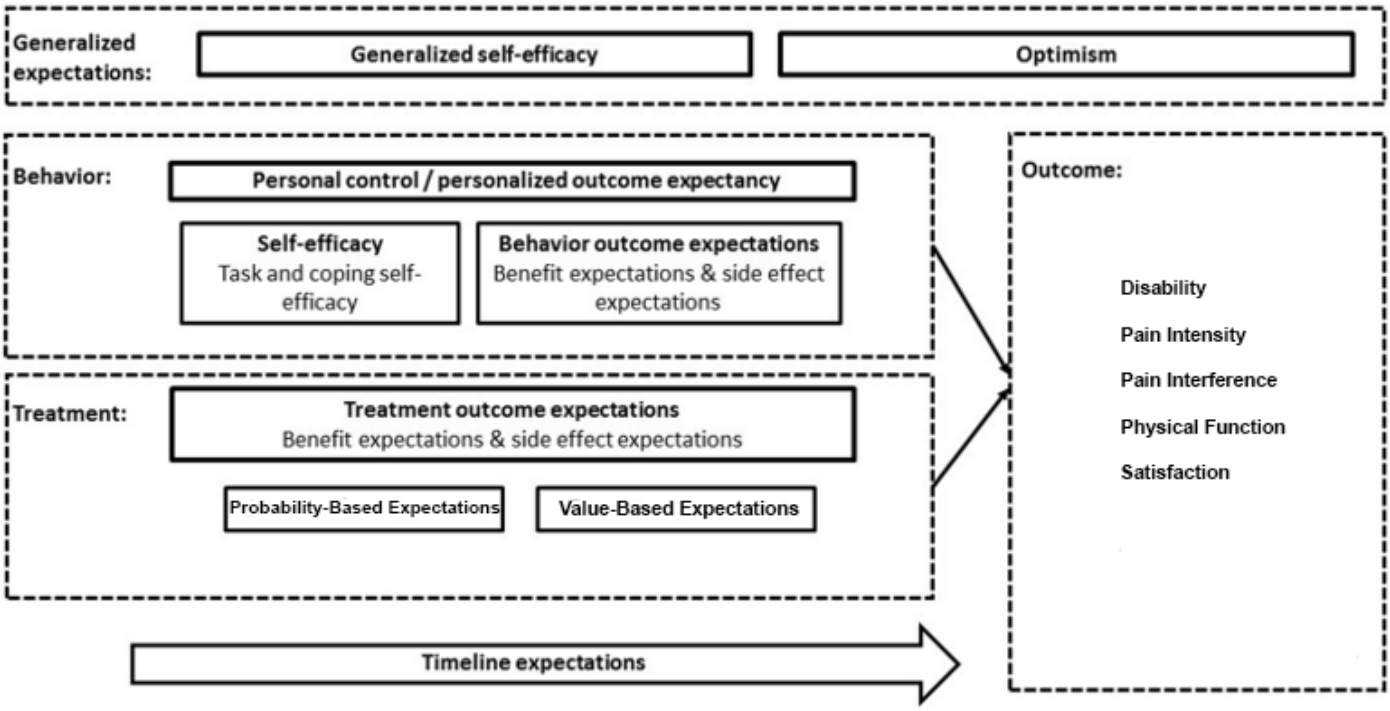

Figure 1.1: Conceptual Map of Patient Expectations of Medical Treatment, adapted from Laferton et al. (2017)

Previous orthopaedic research presents variability in the definition of "expectations;" this includes denoting a patient's estimation of the likelihood of reducing their pain because of surgery (54) or preventing future disability.(58, 59, 83) Other authors describe expectations as a patient's overall sense of optimism and pessimism(47, 84) or the belief that patient's will experience improvement in walking without assistance.(85) Reviews by both Cortes et al (86) and Zywiel et al (87) note that the variability in the definition of expectations among studies makes it difficult to interpret and compare study results. This is partially due to the complexity associated with defining and measuring expectations. Generally, expectations can be defined in at least two separate dimensions: 1) predictive (the perceived likelihood of a particular outcome) or 2) value-based (the

importance attached to a particular outcome or event).(71, 88) Thus, it important to consider the type of expectations measured prior to interpreting results as they relate to surgical characteristics and outcomes.

Many studies have investigated the role of expectations in determining treatment effectiveness, often defined as symptom relief and functional improvement. These studies report conflicting evidence, with some suggesting that higher preoperative expectations are associated with better general health,(54) greater satisfaction,(56, 57) and lower pain and disability after spine surgery.(66) Other research contradicts these findings, suggesting that higher expectations lead to less satisfied patients,(53, 89) or that expectations have no influence on postoperative outcomes(20, 57, 72) or return-to-work.(51) Systematic reviews in both general orthopaedic surgery and spine-specific studies note that this non-conclusive evidence is largely due to the wide range of untested instruments used in single studies, which severely limits the interpretation and comparison of data concerning patient expectations.(65, 86, 87)

The vast majority of expectations research in spine surgery lacks validated questionnaires that address broad expectations topics, such as improvement in daily activity or pain relief.(54, 90, 91) Previous literature presents the Musculoskeletal Outcomes Data Evaluation and Management System (MODEMS) questionnaires and the North American Spine Society (NASS) Lumbar Spine Questionnaire as valid and reliable measures (**Table 1.2**).(65) The MODEMS expectations scale is a six-item instrument that is included in multiple musculoskeletal assessment instruments, including projects through the American Academy of Orthopedic Surgeons and the North American Spine Society Lumbar Spine Outcome Assessment Instrument.(92, 93) Published information on the

results of the validation process is unavailable for the MODEMS expectations scale. Additionally, the verbiage used in the MODEMS expectations scale has been adapted to assess probability-based expectations rather than value-based expectations, essentially generating a new scale without re-validating.(87) Additionally, studies have used the patient expectations questions within the NASS Lumbar Spine Questionnaire to assess patient expectations; researchers have noted the lack of validation for this expectations subscale.(20, 63, 94) Another expectations tool, the Schedule of the Individual Quality of Life-Direct Weighting, was used in one study to assess patient expectations of quality of life.(71) However, the authors note that this instrument was modified from a previous study assessing the relationship between quality of life and depression, and thus may have validity issues. While many other studies have investigated the role of expectations in spine surgery populations, they have used a combination of physician-derived, non-validated visual analog scales, numeric rating scales, and multiple-choice questions without any explicit description of the methodology, rationale, or sources for the instrument.(51, 55-57, 80)

Table 1.2: Expectation measurement tools in elective spine surgery procedures

Assessment Tool	Expectation Type	Applicable Population	Source of Items	Validated ?
HSS Cervical Spine Surgery Expectations Survey[59, 60, 62, 73]	Probability-Based	Elective Cervical Spine Surgery	Patient-derived, physician verified	✓
HSS Lumbar Spine Surgery Expectations Survey[58, 61, 67, 68, 74, 95]	Probability-Based	Elective Lumbar Spine Surgery	Patient-derived, physician verified	✓
MODEMS Questionnaire: Expectations Domain [47]	Probability-Based	Musculoskeletal Conditions	Unclear	†
NASS Lumbar Spine Questionnaire* [20, 63, 94, 96]	Probability-Based	General Spine Surgery	Unclear	-
SEIQOL- Direct Weighting [71]	Value & Probability	General	Unclear	-

Abbreviations: Hospital for Special Surgery (HSS); Musculoskeletal Outcomes Data Evaluation and Management System (MODEMS); North American Spine Society (NASS); Schedule of the Individual Quality of Life (SEIQOL)

† MODEMS reports to be a valid and reliable scale, but was modified to assess probability-based rather than value-based expectations and the new version was not revalidated

* The complete NASS scale reports to be a valid and reliable scale. To date, the expectations subscale has not been independently assessed.

Hospital for Special Surgery (HSS) Expectations Surveys

The variability in studies of expectations within spine surgery outcomes research is partially explained by the large number of expectations measured with non-validated measurements.(64, 65, 97) Our study is designed to build upon existing literature through the use of the validated HSS Lumbar and Cervical Spine Surgery Expectations Surveys to assess probability-based expectations.(46) These surveys are similar to previously validated HSS surveys that were developed to assess patient expectations for elective hip replacement (98), knee surgery and knee replacement (99), and shoulder surgery (100) populations; however, previous iterations assessed value-based expectations rather than probability-based expectations. Thus, the lumbar and cervical spine surgery surveys inherently measure different components of expectations; a patient may believe that improving their ability to exercise for general health is very important (value-based), but very unlikely (predictive). This is an important distinction and may result in different findings between previous iterations of the HSS surveys and the more recent Lumbar and Cervical Spine Surgery Expectations Surveys. The HSS Cervical and Lumbar Spine Surgery Expectations Surveys address a range of expectations for patients undergoing surgery, including expectations related to pain, personal daily activities, psychosocial issues, physical function, and skeletal function.(58, 59)

HSS Spine Surgery Expectations Surveys

In 2013, Mancuso et al built upon their previous surveys by developing and validating a probability-based expectations survey for patients undergoing lumbar or cervical spine surgery.(58, 59) These patient-derived, physician-confirmed scales are 20-

item questionnaires with scores ranging from 0-100. Together, the HSS Lumbar or Cervical Spine Surgery Expectations Surveys represent the only validated measurement tools for assessing preoperative expectations in the respective lumbar or cervical spine population.

During the development of the HSS Lumbar Spine Surgery Expectations Survey, principal components analysis with varimax rotation revealed four factors that accounted for 67% of the variance, including personal daily activities, psychosocial issues, physical function, and skeletal function.(58) Each item in the scale has a loading > 0.5 and is included in only one factor.(58) When the survey is forced to a single factor and presented as a composite score, the scale presents an acceptable preoperative Cronbach's alpha coefficient (0.92) and test-retest reliability (intraclass correlation coefficient (ICC) = 0.86).(58) Including the development study, seven published studies have utilized the HSS Lumbar Spine Surgery Expectations Survey to measure preoperative expectations.(58, 61, 62, 67, 73, 95, 101). However, only two of these studies have assessed the relationship between demographic factors and preoperative expectations and in patients undergoing spine surgery using the spine specific HSS tools.(60, 61) Mancuso et al. (61) found that younger age (OR: 1.02), undergoing preoperative chiropractic care (OR: 1.8), worse disability, as measured by the Oswestry Disability Index (OR: 2.3), worse SF-12 mental score (OR: 1.8), and not being widowed (OR: 4.9) were associated with higher expectations prior to lumbar spine surgery. However, this study dichotomized the expectations score based on the group mean rather than assessing the score continuously, which may have led to some loss of data at low-and-high ends of the score.

During the development of the HSS Cervical Spine Surgery Expectations Survey, principal components analysis with varimax rotation revealed five factors that accounted

for 70% of the variance, including pain relief, activities of daily living, symptom relief, regaining function, and emotional improvement.(59) Each item in the scale has a loading > 0.5 and is included in only one factor. When the survey is forced to a single factor, the scale presents an acceptable preoperative Cronbach's alpha coefficient (0.93) and test-retest reliability (intraclass correlation coefficient (ICC) = 0.9).(59) Including the development study, four articles have utilized the HSS Cervical Spine Surgery Expectations Survey.(59, 60, 62, 73) Mancuso et al (60) found that younger age (OR:2.8) and worse disability, as measured by the Neck Disability Index (OR: 6.0), were associated with higher expectations based on the composite HSS Cervical Spine Surgery Expectations Survey score. Similar to the work with the HSS lumbar expectations survey, this analysis split the score at the group mean rather than assessing the composite score continuously.

Preoperative Expectations and Patient Demographic and Clinical Characteristics

Limited research addresses the association between patient demographics and clinical characteristics and expectations preoperatively. Yee et al. found that male gender, higher SF-36 General Health, and lower SF-36 Physical Component scores were associated with higher preoperative expectations.(54) Additionally, Canizares et al (63) utilized a two-factor scale adapted from the NASS Lumbar Spine Questionnaire (20, 93) related to expectations of pain relief and overall functional well-being. In their study, female gender, current employment, lower self-rated health, higher pain, and higher disability were significantly associated with higher expectations of pain relief (63). Additionally, younger age, inclusion in the labor force (either working or on disability), more depressive symptoms, higher pain and disability, and longer disease duration (> 1 year) were

significantly associated with higher expectations of overall functional well-being based on multivariable linear regression.

Preoperative Expectations and Their Role in Postoperative Outcomes

Preoperative expectations have been associated with postoperative outcomes following spine surgery **(Table 1.3)**. These results are difficult to generalize due to differences in the methodology behind the collection of expectations, with many studies addressing expectations related to single outcomes such as disability,(102) return to work,(54) and satisfaction(56). Soroceanu et al(47) found that higher preoperative expectations led to improved functional outcomes (ODI and SF-36 questionnaires) based on the MODEMS expectation scale. Additionally, they noted no correlations between the expected improvement based on the MODEMS expectation survey and leg numbness, usual activities, and the SF-36 measure of general health. Yee et al and Iversen et al both found that higher preoperative expectations were associated with greater improvement in SF-36 Physical Health scores (54) and greater functional improvement; however, these studies used ad hoc, physician derived measures that addressed probability based expectations.(53) The positive relationship between preoperative expectations and improvement in disability or physical health measures seems logical in that people with higher preoperative disability would also have more room for improvement as a result of their surgery, thus resulting in higher expectations. Unfortunately, this illustrates a potential problem; patients who undergo surgery with such high expectations, but very high levels of disability, may not receive the level of postoperative relief they are expecting from surgery, which may result in a belief that their surgery was unsuccessful. This may be

the reason some studies suggest a negative relationship between preoperative expectations and patient satisfaction with their surgical procedures.(64, 103)

Both Toyone et al and Lutz et al showed that high expectations are independent predictors of improved satisfaction one year after spine procedures.(55, 57) Iversen et al noted conflicting results, with higher physical function expectations predicting more satisfaction and higher pain relief expectations predicting less satisfaction 6-months after surgery.(53) Likewise, Soroceanu et al found that higher general expectations were associated with decreased postoperative satisfaction in their large, multi-center trial.(47) Mannion et al noted no significant correlations between either the expectation for return to health state or the expectations for general health and satisfaction at 12 months.(20) The discrepancy in results likely arise from differences in the measurement of both expectations and satisfaction within these studies, where expectations range from general (47, 55) to specific expectations for pain relief, social contacts, and mental well-being. (20, 53)

Table 1.3: Selection of associations between preoperative expectations and postoperative satisfaction, patient reported pain and/or physical function related outcomes

Surgical Indication	Preoperative Expectation Measure	Satisfaction	Back/Neck Pain	Arm/Leg Pain	Disability, Function, and Physical Health
Single level lumbar disc herniation					
Johansson et al.(104)	Physician Derived	NR	S+	S+	NR
Lutz et al.(57)	Physician Derived	S+	NR	NR	NS
Rönnberg et al.(13)	Physician Derived	S+	NR	NR	NR
Toyone et al.(55)	Physician Derived	S+	NR	NR	NR
Lumbar spinal stenosis					
Gepstein et al.(56)	Physician Derived	S+	NR	NR	NR
Iversen et al.(53)	Physician Derived	S+/S-	S-	NR	NR
Toyone et al(55).	Physician Derived	NS	NR	NR	NR
Degenerative cervical spine pathology					
Carr et al.(52)	Adapted VAS	S+	S+	S+	NS
Mixed cohort (multiple indications)					
Abbott et al.(34)	BBQ	NR	NS	NR	NS
Cobo Sorianio et al.(66)	Physician Derived	NR	NS	S+	S+
de Groot et al.(51)	Physician Derived	S+	NS	S+	NR
Mannion et al. (20)	NASS Lumbar	NS	NS	NS	NS
McGregor et al. (89)	Physician Derived	NS	NR	NR	NR
Soroceanu et al. (47)	MODEMS	S-/NS	NR	NR	NS
Yee et al. (54)	Physician Derived	NR	NR	NR	NS
Mancuso et al.*(61)	Physician Derived	NR	S+	S+	NR
Saban et al.(71)	SEIQOL-DW	S+	NR	NR	NR

Abbreviations: Back Beliefs Questionnaire (BBQ); North American Spine Surgery (NASS) lumbar spine questionnaire; Musculoskeletal Outcomes Data Evaluation and Management System (MODEMS) expectation survey; Hospital for Special Surgery Lumbar Spine Expectation Questionnaires (HSS-C); Hospital for Special Surgery Cervical Spine Expectation Questionnaires (HSS-C). S+ Significant positive association; S- Significant negative association; NS Non-significant association; NR not reported; *took single item from validated questionnaire

Postoperative Fulfilled Expectations

Evaluation of the impact of meeting expectations and their relationship with pain, disability, or satisfaction provides an opportunity to address said needs to help improve outcomes for future populations. As previously noted, patients generally tend to have high expectations for surgery; however, those expectations often far exceed the actual results achieved.(20, 55, 80) If unmet expectations play a role in the relative success of an operation, future studies should assess what establishes efficacious shared decision-making between the surgeon and patient preoperatively, and how this may impact surgical outcomes. Previous literature has assessed fulfilled expectations by using global measures related to functional status, pain and disability.(13, 54, 55, 105) Previous studies have suggested that fulfilled expectations are a more important predictor of patient satisfaction than preoperative expectations; however, due to the variation in definition of "fulfilled expectations," these results may be obscured.(20, 54, 71) Multiple studies are in agreement that fulfilled expectations play a role in achieving higher satisfaction at time points ranging from 6-weeks to 4 years postoperatively.(20, 47, 89)

Mannion et al utilized the NASS lumbar expectations scale and investigated a lumbar spine cohort undergoing decompression without fusion for disc herniation or stenosis; they found that patients who met their predicted expectations were more likely to report satisfaction, regardless of the magnitude of expectations or symptom change.(20) Likewise, Saban et al utilized the SEIQOL-DW tool to compare predicted postoperative satisfaction with the reported postoperative satisfaction; they found that a lower discrepancy between predicted and actualized outcomes were more likely to report higher satisfaction.(71)

Conversely, Licina et al found that the fulfilled expectations did not significantly predict satisfaction scores in patients undergoing primary, single-level surgery for degenerative lumbar conditions.(72) However, this may be due to only 7% of patients being "less than satisfied," leading to questions about the sensitivity of their metric to detect changes in satisfaction. Other studies have noted that the majority of patients report satisfaction with their surgical procedure despite large discrepancies between postoperative scores for leg and back pain compared to the level of pain the patient expected to achieve preoperatively.(80) Only a few other prospective studies have attempted to measure fulfilled expectations during spine surgery; however, these results are difficult to compare due to non-standardized, ad hoc measurements and different definitions of fulfilled expectation.(52-55, 106)

Proportion of Fulfilled Expectations

Recently, Mancuso et al proposed a new method for assessing postoperative fulfilled expectations: the proportion of fulfilled expectations using the HSS Lumbar and Cervical Spine Expectation Surveys. This methodology uses preoperative expectations and postoperative fulfilled expectations (based on the same scale) to assess the total proportion of fulfilled expectations at the timepoint the survey was administered. To date, this scoring method has only been utilized at 2-years postoperatively.(73) Mancuso et al found that 90% and 91% of lumbar and cervical patients, respectively, had some of their expectations fulfilled. When using satisfaction as the primary outcome, 60% of fulfilled lumbar expectations (sensitivity 0.90, specificity 0.79) and 62% of fulfilled cervical expectations (sensitivity 0.91, specificity 0.80) are considered a clinically important proportion of fulfilled expectations. Additionally, Mancuso et al (74) measured the

concordance between surgeons' and patients' preoperative expectations of lumbar spine surgery outcomes. Patients then completed the survey again at 2-years post-operatively, and the authors compared which of the preoperative pair better predicted the fulfilled expectations at 2-years postoperatively. They found that 84% of patients had higher preoperative expectations than surgeons among the 402 patient-surgeon matched pairs; this was largely due to patients expecting complete improvement, while surgeons often expected a lot/moderate/little improvement. The patients' mean proportion of fulfilled expectations was lower (0.79) than the surgeons (1.01), indicating that surgeons' expectations more closely reflect the patients' fulfilled expectations postoperatively. This work aims to improve the body of knowledge and expand the utilization of this unique measurement by evaluating postoperative fulfilled expectations at an important short-term time point and assess its relationship to long-term postoperative outcomes.

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CHAPTER 2
RATIONALE AND AIMS OF THE STUDY

Motivation

The primary objectives of this proposal are to 1) obtain an in-depth understanding of patient's preoperative expectations and early postoperative fulfilled expectations and 2) examine the role of preoperative expectations and early postoperative fulfilled expectations on long-term postoperative outcomes in patients undergoing spine surgery. Recent reviews by Witiw et al and Zywiel et al call for future research to assess the role of expectations in surgical outcomes using standardized and validated assessment tools.(1, 2) Thus, the reliable and valid HSS Lumbar and Cervical Spine Surgery Expectations Surveys will be used to assess patient expectations from a probability-based perspective. One overall expectations score will be used based on items related to activities of pain, personal daily activities, psychosocial issues, physical function, and skeletal function for patients undergoing lumbar or cervical spine surgery.(3, 4) We will leverage the Vanderbilt Spinal Surgery Quality and Outcomes Registry, which has preoperative and postoperative expectations data on over 600 lumbar and 500 cervical patients undergoing elective spine surgery.

The overarching hypotheses for this study are that preoperative expectations are related to PROs at 12 months after surgery, specifically in the areas of disability (Oswestry and Neck Disability Index), physical function (PROMIS), pain interference (PROMIS), pain intensity (Numeric Rating Scales), and satisfaction (North American Spine Society Satisfaction). Additionally, fulfilled expectations in the early postoperative time-period (e.g., 3 months) will be an important determinant of patient-reported disability, physical

function, pain interference, pain intensity, and satisfaction at 12-months postoperatively. These findings will be integral in determining if preoperative expectations and/or fulfilled expectations are more appropriate for future interventions to improve patient outcomes following spine surgery.

Aim 1: Characterize preoperative expectations of patients undergoing elective lumbar or cervical spine surgery.

<u>Aim 1A</u>: To describe preoperative expectations based on the HSS Cervical and Lumbar Spine Surgery Expectation Surveys for patients undergoing elective spine surgery. Descriptive statistics will be used to individually assess each item of the 20-item HSS Cervical and Lumbar Spine Surgery Expectations Surveys and report on the mean, range, and variability of the items of the scale. The surveys will be internally validated within their respective lumbar and cervical spine populations prior to calculating a preoperative composite expectations score, a sum of all item responses where a higher score represents higher expectations.

<u>Aim 1B</u>: To characterize the relationship between preoperative demographic, clinical, and surgical characteristics, validated patient-reported measures, and preoperative expectations for spine surgery. Bivariate analyses will be used to assess the relationship between demographic/clinical/surgical covariates, preoperative patient-reported measures of disability, physical function, pain interference, and pain intensity and the preoperative composite expectations scores. Multivariable linear regression will evaluate the association between the patient-reported measures and the preoperative composite expectations scores after controlling for *a priori* covariates. *Hypothesis:* Higher levels of preoperative disability, pain interference, and pain intensity

and decreased preoperative physical function will be associated with higher preoperative expectations scores.

Aim 2: Characterize postoperative fulfilled expectations in patients who underwent elective lumbar or cervical spine surgery. Fulfilled expectations will be defined two separate ways: as a continuous composite score, and as a proportion of fulfilled expectations (the composite 3-month score divided by the composite preoperative score).

<u>Aim 2A</u>: To describe fulfilled expectations at 3-months postoperatively based on the HSS Cervical and Lumbar Spine Surgery Expectation Surveys in patients undergoing elective spine surgery. Descriptive statistics will be used to individually assess the 20 items of the scales for fulfilled expectations to better understand specific improvement across multiple domains of expectations during the early postoperative time-period. A composite, summed score will be generated to reflect fulfilled expectations, where higher scores reflect more fulfilled expectations. A second expectations score, the proportion of fulfilled expectations, will be calculated as $\frac{post-operative\ fulfilled\ expectations}{pre-operative\ expectations}$ and used as an additional expectations score in the postoperative period.

<u>Aim 2B</u>: To characterize the relationship between preoperative expectations, pre-operative and 3-month patient-reported measures, and demographic/clinical/surgical characteristics and fulfilled expectations at 3-months postoperatively. Bivariate correlations will be used to assess the relationship between the composite preoperative expectations scores and the composite 3-month fulfilled expectations scores. Correlation coefficients will also be used to assess the

relationship between both preoperative and 3-month postoperative measures of disability, physical function, pain interference, pain intensity, and fulfilled expectations at 3-months. T-tests will compare both the composite fulfilled expectations scores and the proportion of fulfilled expectations by satisfaction at 3-months postoperatively. Additional analyses will evaluate the relationship between demographic/clinical/surgical covariates and the fulfilled expectations scores at 3-months. Separate multivariable linear regressions will evaluate the association between preoperative and postoperative patient-reported measures and the fulfilled expectations composite scores at 3-months after controlling for *a priori* covariates. Additional multivariable linear regression models will assess the relationship between preoperative and postoperative patient-reported measures and the proportion of fulfilled expectations at 3-months postoperatively. *Hypotheses:* Higher levels of preoperative disability, pain interference, and pain intensity and lower postoperative physical function will be associated with higher composite fulfilled expectations and a higher proportion of fulfilled expectations at 3-months postoperatively. Additionally, lower levels of postoperative disability, pain interference, and pain intensity and higher postoperative physical function and satisfaction will be associated with both higher postoperative fulfilled expectation composite scores and higher proportions of fulfilled expectations at 3-months postoperatively.

<u>Aim 3</u>: Determine the association between preoperative expectations and early postoperative fulfilled expectations on patient-reported outcomes at 12-months postoperatively. Hierarchical regression modeling will be used to assess the longitudinal relationship between expectations and patient-reported outcomes of disability, physical

function, pain interference, and pain intensity, (linear regression) and satisfaction (logistic regression). Multivariable models will be used to assess the role of 1) preoperative expectations as a composite score, 2) fulfilled expectations at 3-months as a composite score, and 3) the proportion of fulfilled expectations on these 12-month patient-reported outcomes. *Hypotheses:* Higher preoperative expectations, fulfilled expectations, and the proportion of fulfilled expectations will be associated with lower disability, pain interference, and pain intensity, as well as higher physical function and satisfaction at one-year postoperatively.

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CHAPTER 3

STUDY POPULATION & DESIGN

Study Site & Data Source

Vanderbilt Spine Surgery Outcomes Registry

Vanderbilt University Medical Center has long been a leader in the collection of prospective outcomes for patients undergoing elective spine surgery performed by both orthopaedic surgeons and neurosurgeons.(1) Vanderbilt also served as a vanguard site for the National Neurosurgery Quality and Outcomes Database (N^2QOD), a prospective clinical registry developed to address the need for high-quality outcomes data related to care of patients with neurosurgical disorders.(2, 3) In 2018, the Vanderbilt Spine Registry started collecting the HSS Lumbar and Cervical Spine Surgery Expectation Surveys. As of October 2021, there are over 5000 patients undergoing elective cervical or lumbar spine surgery with baseline data in the registry, of which over 1100 patients have recorded expectations data.

This research is a retrospective analysis of prospectively collected registry data of patients undergoing elective spine surgery at a single academic center (**Figure 3.1**). Data are collected preoperatively and at 3 months (± 14 days) and 12 months (± 30 days) postoperatively. All eligible patients are recruited and consented prior to inclusion into the spine surgery registry (**Table 3.1**). Trained research analysts collect data related to patient demographics, clinical characteristics, surgery-related information, and validated patient-reported measures of disability, physical function, pain interference, pain intensity, and satisfaction. (**Tables 3.2 & 3.3**). Data collection occurs at a preoperative (baseline) visit and at 3- and 12-months postoperatively. Data are collected through multiple methods

based on patient preference, including the use of an iPad or paper survey at a clinic visit, or by phone or email. Spine registry coordinators use Research Electronic Data Capture (REDCap), a secure, web-based application designed for supporting data capture and management.(4) Where indicated, REDCap enabled Clinical Data Pull (CDP) tools are used for the transfer of relevant study-related data from eSTAR (Vanderbilt's Epic platform) or the Vanderbilt Research Derivative directly into REDCap. The protocol and data collection procedures are approved by the Vanderbilt Institutional Review Board (IRB# 100388).

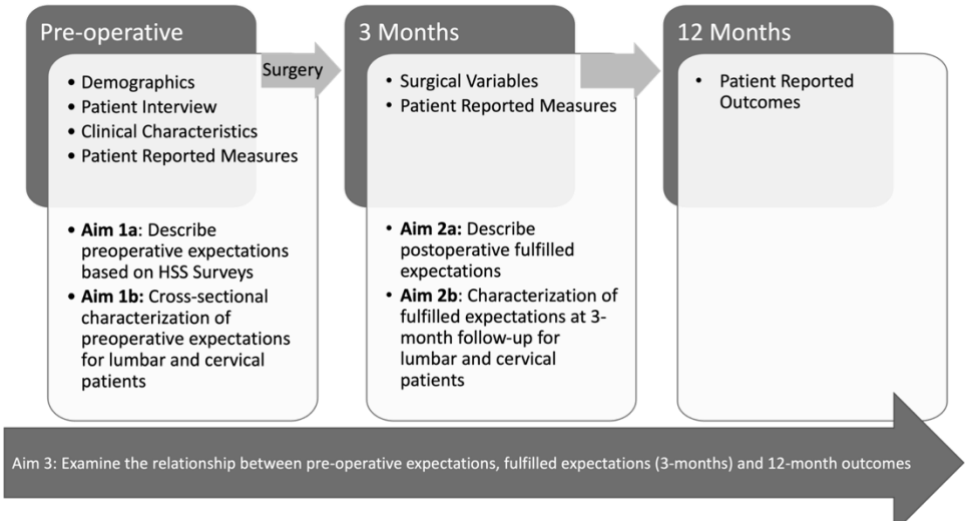

Figure 3.1: Study design, including overview of data collection and aims at each time point

Table 3.1: Eligibility criteria for our enrolled cohort.

Inclusion Criteria	Exclusion Criteria

• Age > 18 years *and*
• Undergoing primary surgery for:
  ○ Spondylolisthesis
  ○ Stenosis
  ○ Disc herniation
  ○ Symptomatic mechanical disc collapse
• *Or* undergoing revision surgery for:
  ○ Same-level disc herniation
  ○ Adjacent segment disease
	• Undergoing surgery for:
	  ○ Spinal Infection
	  ○ Tumor
	  ○ Fracture
	  ○ Traumatic Dislocation
	  ○ Deformity
	  ○ Recurrent, multilevel stenosis
	  ○ Neurologic paralysis due to preexisting disease/ injury
	• Incarceration
	• Declines participation in registry

Table 3.2: Candidate covariates based on known associations with preoperative measurements and postoperative outcomes

Covariate	Measurement	Definition
Age	Continuous	Age at date of surgery
Ambulation	Dichotomous	1) Independently 2) With Assistance
Body Mass Index (BMI)	Continuous	(Weight (lbs) * 703) / height (in^2))
Depression	Continuous	PROMIS Depression (5)
Diagnosis/Etiology	Categorical	1) Stenosis 2) Spondylolisthesis 3) Disc Herniation 4) Pseudarthrosis
Education	Dichotomous	1) High School or Less 2) Greater than High School
Elixhauser Score	Continuous	Continuous comorbidity score (6)
Employment	Dichotomous	1) Currently Working 2) Not Currently Working
Ethnicity	Dichotomous	1) Hispanic or Latino 2) Not Hispanic or Latino
Insurance	Dichotomous	1) Public 2) Private
Preoperative Myelopathy (Cervical Only)	Dichotomous	1) Yes 2) No
Preoperative Neurogenic Claudication (Lumbar Only)	Dichotomous	1) Yes 2) No
Preoperative Opioid Use	Dichotomous	1) Pre-operative opioid use 2) Non-user
Preoperative Radiculopathy	Dichotomous	1) Yes 2) No
Race	Dichotomous	1) Non-White 2) White
Revision Surgery	Dichotomous	1) Yes 2) No

Sex	Dichotomous	1) Male 2) Female
Smoking Status	Dichotomous	1) Current Smoker 2) Non-Smoker
Surgical Approach	Categorical	1) Anterior 2) Posterior 3) Lateral
Surgical Procedure, Cervical	Categorical	1) Decompression 2) Decompression + Fusion 3) Other
Surgical Procedure, Lumbar	Categorical	1) Microdiscectomy 2) Fusion 3) Laminectomy w/o Fusion 4) Other

Table 3.3: Outcome measurement properties in proposed study

	Measurement	*Items*	*Range*	*MCID*	*Internal Consistency*
Lumbar Spine	Oswestry Disability Index	10	0-50	30% Change	Cronbach's α: 0.78 (7)
	Numeric Rating Scale, Back Pain Intensity	1	0-10	30% Change	–
	Numeric Rating Scale, Leg Pain Intensity	1	0-10	30% Change	–
Cervical Spine	Neck Disability Index	10	0-50	30% Change	Cronbach's α: 0.5-0.98 (8, 9)
	Numeric Rating Scale, Neck Pain	1	0-10	30% Change	–
	Numeric Rating Scale, Arm Pain	1	0-10	30% Change	–
PROMIS	Pain Interference	4	41.6-75.6	1-8 points	Cronbach's α: 0.92 (10)
	Physical Function	4	22.5-57.0	2-8 points	Cronbach's α: 0.86 (10)
	North American Spine Society Patient Satisfaction Index	1	1-4	–	–

†Measures reported based on final scale
Abbreviations: PROMIS: Patient Reported Outcomes Measurement Information System

Preoperative Expectations Measurement

Patients will complete the HSS Lumbar(11) or Cervical(12) Spine Surgery Expectations Survey preoperatively (**Table 3.4**). These separate 20-item questionnaires measure expectations for pain, personal daily activities, psychosocial issues, physical function, and skeletal function for patients undergoing lumbar or cervical spine surgery **(Appendix 3.1 and 3.2)**. (11, 12) While there is some item overlap between the cervical and lumbar questionnaires, previous literature recommends treating lumbar and cervical patients as separate cohorts due to underlying differences in both the preoperative state (i.e. disability and pain) and the amount of expected improvement between groups.(13, 14) Each item assesses how much improvement the patient expects, ranging from "back to normal or

complete improvement" (4 points) to "I do not have this expectation, or this expectation does not apply to me" (0 points). A total score is calculated by summing the item scores, resulting in a composite score ranging from 0-100 with higher scores representing higher expectations (Appendix 3.1 & 3.2). Although the HSS Cervical and Lumbar Spine Surgery Expectation Surveys note the four and five factors, respectively, that explain the variance in the scale, both surveys use a single, continuous score rather than subscales.

Table 3.4: Measurement properties of Expectations Scales in proposed study

Measurement	***Internal Consistency***	***Reliability***	***Content Validity***
HSS Lumbar Expectations Scale†	Cronbach's α: 0.92	ICC = 0.86	Patient-derived, physician verified for clinical relevance
HSS Cervical Expectations Scale†	Cronbach's α: 0.93	ICC = 0.90	Patient-derived, physician verified for clinical relevance

†Measures reported based on final scale
Abbreviations: intraclass correlation coefficient (ICC)

Postoperative Fulfilled Expectations Measurement

The 3-month HSS Lumbar and Cervical Spine Surgery Expectations Surveys are modified versions of the preoperative survey, with the questions' phrasing adjusted to how much improvement the patient *receives* for each survey item. The results for each item range from "back to normal or complete improvement" (4 points) to "no improvement at all" (0 points). At the 3-month postoperative time period, two separate methods can be used for fulfilled expectations. A composite score can be generated by summing the value of points based on the number of questions answered, resulting in a continuous variable. Additionally, the proportion of fulfilled expectations can be calculated as $\frac{3\ month\ post-operative\ fulfillment}{pre-operative\ expectation}$. The proportion of fulfilled expectations represents the ratio of the total improvement received (postoperative) to the total amount of

improvement expected (preoperative), with scores ranging from 0 to >1 **(Table 3.5).** A proportion of expectations fulfilled equal to zero can be interpreted as a patient who has experienced no improvement for any item as a result of their surgery. Patients with some fulfilled expectations would have a proportion between 0 and 1. Patients who meet or exceed their preoperative expectations yield a proportion greater than one. Rather than assessing the proportion of fulfilled expectations based on the composite scores alone (15), we will take the average of the individual proportion of fulfilled expectations for each question. This generates the same proportion of fulfilled expectations as previous work, but it provides more nuanced information on fulfilled expectations at the item level.(15) A clinically important threshold value for the proportion of fulfilled expectations is 0.60.(15)

Table 3.5: Scoring scale for fulfilled expectations

Proportion of Expectations Fulfilled	Score
No Improvement for any item	0
Some Improvement	0.01-0.99
Expected Improvement	1
Exceeded Expectations	>1

Patient-reported Outcomes Measurement

PROs were collected at baseline, 3-months, and 12 months after surgery (**Table 3.3**). These included Oswestry Disability Index (ODI)(16) or Neck Disability Index (NDI)(8, 9) for disability, Patient Reported Outcomes Measurement Information System (PROMIS) scales for Physical Function and Pain Interference,(8, 17) 11-point Numeric Rating Scales for back/neck and leg/arm pain intensity.(18) The North American Spine Society (NASS) Patient Satisfaction Index for satisfaction was collected only at the postoperative time-points.(19)

DISABILITY

ODI and NDI

These 10-item scales are standard measures of condition-specific disability that assesses the impact of spinal disorders on daily living **(Appendix 3.3 and 3.4)**. Each item is rated from 5 (low functioning) to 0 (high functioning), resulting in higher scores representing greater disability.(8, 16) ODI/NDI is often cut into 5 clinically meaningful categories, including minimal disability (0%-20%), moderate disability (21%-40%), severe disability (41%-60%), crippled (61%-80%), and bed-bound or exaggerated symptoms (81%-100%).(9, 16) A 30% change from the baseline score is an appropriate measurement of a clinically meaningful change in these measures. (20)

PHYSICAL FUNCTION

PROMIS Physical Function-4a

The 4-item short form assesses the ability of an individual to perform routine daily physical functions. Each item is scored from 1 (unable to do) to 5 (without any difficulty), with higher standardized t-scores representing better physical function **(Appendix 3.5)**. A t-score of 50 (SD = 10) represents the score of an average U.S. person. T-scores can be binned to represent severely limited (20-30), moderately limited (31-40), mildly limited (41-45), and within normal limits for physical function (46-80).(21) The PROMIS Physical Function-4a is estimated to have a minimal clinically important difference (MCID) of 1-2 points from the t-score.(22)

PAIN INTERFERENCE

PROMIS Pain Interference.

The 4-item short form evaluates how much pain interfered with an individual's ability to perform routine activities. Each item is scored from 5 (interfered a lot) to 1 (no interference), with higher standardized t-scores representing more pain interference. A t-score of 50 represents the score for an average U.S. person. T-scores can be binned to represent severe (71-80), moderate (61-70), mild (55-60), and within normal limits for pain interference (20-54).(21) It is estimated to have an MCID of 2-3 points around the t-score.(23)

PAIN INTENSITY

Numeric Rating Scale (NRS)

NRSs in this study are 11-point scales which ask patients to rate their pain on a scale of 0 to 10, with 0 signifying no pain and 10 the worst pain imaginable. The lumbar cohort answers NRSs related to back and leg pain, while the cervical cohort's questions relate to neck and arm pain. NRS cut-points are no/mild (0-4), moderate (5-6), and severe (7-10). (24) The MCID for these NRS scales is a 30% change from the baseline score. (20, 25)

SATISFACTION

NASS Patient Satisfaction Index.

Participants are asked to rate their satisfaction with their spine surgery using the following choices from 1 to 4: (1) 'Surgery met my expectations', (2) 'I did not improve as much as I had hoped but I would undergo the same operation for the same results', (3)

'Surgery helped but I would not undergo the same operation for the same results', or (4) 'I am the same or worse as compared to before surgery' **(Appendix 3.6)**.(19, 26) In the present study, patients were defined as satisfied if the patient selected answer choice '1' or '2,' and dissatisfied if '3' or '4' were selected.

Covariates for Multivariable Regression

For both the lumbar and cervical cohorts, confounders were assessed through directed acyclic graphs (DAGs) and a priori knowledge (**Appendix 3.7**). Based on this simplified DAG, the minimally sufficient adjustment set of confounders for total effect of patient expectations on post-operative outcomes include age, ambulation, comorbidities, mental health scores (including depression), preoperative pain and disability, and preoperative physical function. For each aim, covariates (sociodemographic, clinical, and surgical characteristics) have been selected based on a combination of *a priori* candidate variables and the minimally sufficient set of confounders identified through the DAG **(Table 3.6).**

Table 3.6: Items selected as *a priori* covariates for multivariable modeling

Demographic Characteristics	*Clinical Characteristics*	*Surgical Characteristics*
Age	Elixhauser Comorbidities Index (6)	Surgical Approach
Sex	Diagnosis	Surgical Procedure
BMI	Myelopathy	Revision Status
Race/Ethnicity		
Working Status		
Smoking Status		
Insurance Payer		
PROMIS Depression **(5)**		

Abbreviations: Body Mass Index (BMI); Patient Reported Outcome Measurement Outcome Information System PROMIS
#Will appear in cervical models only
*Will appear in lumbar models only

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CHAPTER 4

UNDERSTANDING PREOPERATIVE EXPECTATIONS IN PATIENTS UNDERGOING CERVICAL AND LUMBAR SPINE SURGERY

INTRODUCTION

Cervical and lumbar spine disorders can cause debilitating pain and are associated with physical and psychological disability.(1-4) Although these conditions can be life-altering, they are rarely life-threatening and patients undergo treatment to alleviate their symptoms and restore their quality of life. Patient expectations—contextual factors associated with perceived benefit from surgery—have received greater attention as modifiable determinants of patient-reported outcomes.(5, 6) Expectations of elective spine procedures can be major determinants in the decision to undergo surgery, where patient's prediction of their future condition may affect their treatment choices and perceptions of postoperative outcomes.(7-10) Understanding patients' expectations of their elective spine procedure can help the provider direct patient education, foster shared decision making, and help the patient set recovery goals.(11)

Prior research in patients undergoing spine surgery has yielded mixed results on the influence of pre-operative expectations on postoperative outcomes of spine surgery. (7, 12-15) Inconsistent findings may be due to differences in how expectations are defined and measured across studies. In order to better understand preoperative expectations in patients undergoing lumbar and cervical spine surgery, the Hospital for Special Surgery (HSS) Lumbar Spine Surgery Expectations Survey and HSS Cervical Spine Surgery Expectations Survey were developed based on mixed qualitative-quantitative methods; all items were chosen following patient input and verified by surgeons. (16-20) However,

despite being the lone, validated expectations instrument in spine surgery, these surveys have not been assessed outside of the sample in which the surveys were developed. (21, 22) Additional psychometric work is needed to better understand the clinical relevance of this measure to the spine surgery patient population.

Overall, the role of patient's preoperative expectations are potentially important determinants in spine surgery outcomes that warrant further investigation. However, prior to investigating the role of patient expectations in postoperative outcomes, it is important to further examine the psychometric properties of these measures in a different sample. The goals of this study were to further assess the reliability and construct validity of the HSS Lumbar and Cervical Spine Surgery Expectations Surveys and examine associations between expectations, demographic and clinical characteristics, and patient-reported measures in patients undergoing elective cervical or lumbar spine surgery.

METHODS

We conducted a cross-sectional analysis of preoperative data from patients enrolled in a spine surgery registry from a single academic center. Patients over 18 undergoing elective spine surgery for a degenerative condition between 2018 and 2021 were eligible for inclusion in the study. Patients were ineligible if they were undergoing surgery for spinal infection, tumor, fracture, traumatic dislocation, deformity correcting surgery, recurrent, multi-level stenosis, or neurologic paralysis due to preexisting disease or injury. Spine registry coordinators used Research Electronic Data Capture (REDCap), a secure, web-based application, for data capture and management. Pre-operative patient demographics, clinical characteristics, and patient-reported measures were collected via

phone interview or web-based questionnaire.(23) Where indicated, REDCap enabled Clinical Data Pull (CDP) tools were used for the transfer of relevant study-related data from the electronic health record (EHR) directly into REDCap. All studies conducted using this registry are IRB-approved.

Variables

Demographics, including age, body mass index (BMI), sex, self-reported race, ambulation status, insurance type, education, employment status, smoking status and pre-operative opioid use were collected using CDP or patient interview/survey. Clinical characteristics of previous spine surgery, radiculopathy, neurogenic claudication for lumbar patients and myelopathy for cervical patients, anticipated spine surgery, and the Elixhauser comorbidity index were collected through CDP. The Elixhauser item weights range from -7 (drug abuse) to +14 (metastatic cancer); the continuous variable is calculated for each patient by summing the individual weights of all present comorbidities, with negative weights reflecting a protective relationship with in-hospital mortality; this algorithm ranges from -29 to 99.(24)

Measures

Preoperative patient-reported measures included disability (Neck Disability Index (NDI) for cervical, Oswestry Disability Index (ODI) for lumbar)(25-27), numeric rating scales for pain intensity (neck and arm pain for cervical, back and leg pain for lumbar), and the Patient-Reported Outcomes Measurement Information System (PROMIS) physical function(28), pain interference(29), and depression(30) 4-item subscales. ODI and NDI scales also have well established thresholds for mild (0-20), moderate (21-40), or severe disability (41-60), crippling back pain (61-80), and bed-bound/exaggeration of their

symptoms (81-100).(31) PROMIS measures are reported as t-scores; based on the general United States population, they have a mean score of 50 and standard deviation of 10.(32) Higher scores on the NDI, ODI, pain scales, and PROMIS indicate higher levels of the measured construct.

Preoperative Expectations

Patients completed the 20-item HSS Lumbar(20) or Cervical(19) Spine Surgery Expectations Survey preoperatively to measure their expectations for pain, personal daily activities, psychosocial issues, physical function, and skeletal function for their elective spine surgery. Because patients undergoing lumbar or cervical surgery completed separate surveys with different items, they were evaluated as a lumbar or cervical cohort rather than as a unified "spine surgery" population. For both questionnaires, each item assesses how much improvement the patient expects, with answers including "I do not have this expectation, or this expectation does not apply to me" (0 points), "not back to normal, but a little improvement" (1 point), "not back to normal, but a moderate amount of improvement" (2 points), "not back to normal, but a lot of improvement" (3 points), or "back to normal or complete improvement" (4 points). A total, composite expectations score is calculated by summing the item scores and ranges from 0 to 100; higher scores represent higher expectations.

Statistical Analysis

Each item of the HSS Lumbar or Cervical Spine Surgery Expectations Survey is reported using the number and percentage. Distribution of item responses were examined, and items with at least 80% of respondents expecting complete improvement or a lot of improvement were identified as items where patients had high expectations for individual

items. Scale reliability was assessed with Cronbach's alpha, while exploratory factor analysis (EFA) was used to investigate the construct validity with 0.3 set as the value to suppress factor loadings.(33, 34) Because the individual items of the scales utilize Likert scoring with ordinal categories, Spearman's correlations were used to assess the correlations and among each of the 20 scored items of the scales to explore relationships among the individual survey items and help establish construct validity. Inter-item correlations for the scales were conducted as a complete case analysis. The composite expectations score was generated as the $\frac{summed\ score\ from\ items\ answered}{total\ number\ of\ items\ answered}$ and assessed for distribution. Because EFA is insufficient to establish the validity of the use of an instrument, it is important to combine EFA with other validity evidence to ensure the results as representing the construct the instrument purports to measure.(35)

The relationships between the pre-operative demographic and clinical characteristics and the composite expectations scores were assessed using t-tests for dichotomous covariates, ANOVA for categorical covariates, and Spearman's correlations for continuous covariates. The relationship between preoperative expectations and preoperative disability, pain intensity, pain interference, physical function, and depression were assessed through Spearman's correlations to help establish construct validity in this population. Cohen's guidelines for assessing the strength of correlation coefficients were used for this study, with 0.1-0.29, 0.3-0.49, and greater than 0.5 representing small, medium, and large correlations, respectively.(36) Multivariable linear regression analyses were used to assess the relationship between preoperative demographic and clinical characteristics, and patient-reported measures with the composite preoperative expectations scores. Models were initially fit with restricted cubic splines on continuous

variables; model selection proceeded by comparing nested models with a likelihood ratio test to assess model fit. Splines are automatically set at the 10th, 50th, and 90th percentiles in the RMS package.(37) Variable importance to the final multivariable model was assessed using Chi-squared statistics minus degrees of freedom.

Less than 5% of data were missing for all variables except anticipated surgery, where patients undergoing lumbar and cervical procedures were missing 13% and 14% of data, respectively. The missing values of variables were multiply imputed using a flexible additive imputation model with predictive mean matching (aregImpute from Hmisc package). A P value of 0.05 was considered statistically significant, and all confidence intervals are 95%. Analyses were conducted using R 4.1.0 and the rms and Hmisc packages.(37-39)

RESULTS

We identified 1,271 patients with completed HSS Expectations Survey scores in the Vanderbilt Spine Registry, including 693 patients with preoperative lumbar expectation scores and 578 with preoperative cervical expectation scores **(Table 4.1)**. Patients undergoing lumbar surgery ranged in age from 19-84 (mean 58.2, standard deviation (SD) 13.5), while patients undergoing cervical spine surgery ranged from 23-82 (mean 56.6, SD 11.9). Both populations were overwhelmingly white (86% white – lumbar, 85% white – cervical) and slightly more males participated than females (52% lumbar, 54% cervical).

Table 4.1: Characteristics of patients with preoperative expectations data from lumbar and cervical spine surgery cohorts, Vanderbilt Spine registry, 2018-2021

	Lumbar (n=693)	Cervical (n=578)
Patient Demographics	Mean [SD] or N (%)	Mean [SD] or N (%)
Age	58.2 [13.5]	56.6 [11.9]
BMI	31.3 [6.5]	30.3 [6.6]
Sex		
Female	325 (47%)	257 (4%)
Male	361 (52%)	312 (54%)
Missing	7 (1%)	9 (2%)
Race		
White	594 (86%)	493 (85%)
Non-White	74 (10%)	66 (12%)
Missing	25 (4%)	19 (3%)
Ambulation		
Independently	499 (72%)	468 (81%)
Require Assistance	183 (26%)	99 (17%)
Missing	11 (2%)	11 (2%)
Insurance		
Private	377 (54%)	328 (57%)
Public	311 (45%)	247 (42%)
Missing	5 (1%)	3 (1%)
Education		
High School or Less	310 (45%)	268 (47%)
Some College or More	370 (53%)	300 (52%)
Missing	13 (2%)	10 (2%)
Employment		
Working	249 (36%)	226 (39%)
Not Currently Working	440 (63%)	352 (61%)
Missing	4 (1%)	0 (0%)
Smoker		
Non-Smoker	577 (83%)	468 (81%)
Current Smoker	112 (16%)	110 (19%)
Missing	4 (1%)	0 (0%)
Clinical Characteristics		
Elixhauser Comorbidity Index [range]	-2.6 [-18 – 31]	-2.2 [-14 – 22]
Previous Surgery		
No	531 (77%)	443 (77%)
Yes	162 (23%)	135 (23%)
Radiculopathy	525 (76%)	358 (62%)
Neurogenic Claudication	212 (31%)	-
Myelopathy	-	204 (35%)
Anticipated Surgery		
Anterior Fusion	33 (5%)	308 (53%)
Posterior Fusion	322 (46%)	155 (27%)

Posterior Decompression	250 (36%)	34 (6%)
Missing	88 (13%)	81 (14%)
Patient Reported Measures		
Disability (ODI/ NDI)	48.8 [15.9]	44.1 [16.9]
Back/Neck Pain Intensity (NRS)	6.6 [2.4]	5.9 [2.8]
Leg/Arm Pain Intensity (NRS)	6.8 [2.4]	5.6 [2.9]
PROMIS		
Pain Interference	67.9 [6.6}	64.7 [8.1]
Physical Function	33.8 [5.8]	37.8 [6.6]
Depression	51.9 [9.6]	52.3 [52.3]

Abbreviations: Body Mass Index (BMI), Patient-Reported Outcomes Measurement Information System (PROMIS), Numeric Rating Scale (NRS), Oswestry Disability Index (ODI), Neck Disability Index (NDI)
Note: PROMIS measures are reported as t-scores; the standardized t-scores have a population mean of 50, and a standard deviation of 10.

Individual Expectations Based on the HSS Lumbar or Cervical Spine Surgery Expectations Surveys

In both the lumbar and cervical spine cohorts, patients consistently had high expectations for individual items (**Figures 4.1 and 4.2**). Items generally followed a similar trend, with most participants expecting complete improvement or a lot of improvement (3 or 4 point answers) for questions related to removing the control the spine condition has on their life (86%), back pain (85%), walking (85%), preventing the spine condition from worsening (85%), standing (83%), remove the restrictions (83%) leg strength (82%), exercise (82%), and activities (82%). No questions eclipsed an 80% threshold for either expecting complete improvement or a lot of improvement in the cervical cohort. For both the lumbar and cervical cohorts, there were instances of a bimodal distribution, where patients either had high expectations or no expectations for that individual item, such as expectations related to sexual activity, ability to participate in sports, and work status.

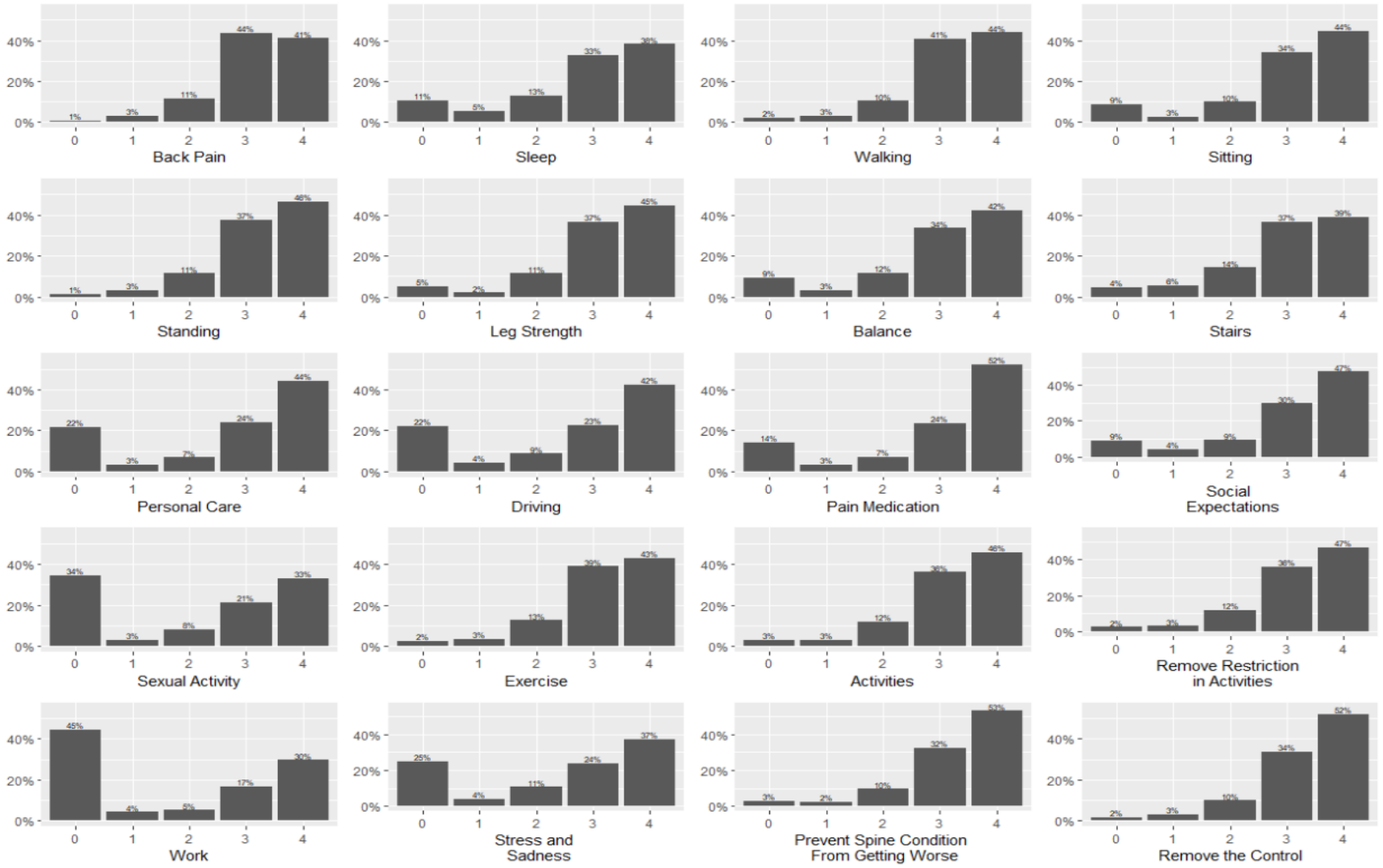

Figure 4.1: Histograms of Individual Items of HSS Lumbar Spine Surgery Expectations Survey, where 0 represents no expectation and 4 is the expectation to return to normal or show complete improvement. Item answers include "I do not have this expectation, or this expectation does not apply to me" (0 points), "not back to normal, but a little improvement" (1 point), "not back to normal, but a moderate amount of improvement" (2 points), "not back to normal, but a lot of improvement" (3 points), or "back to normal or complete improvement" (4 points).

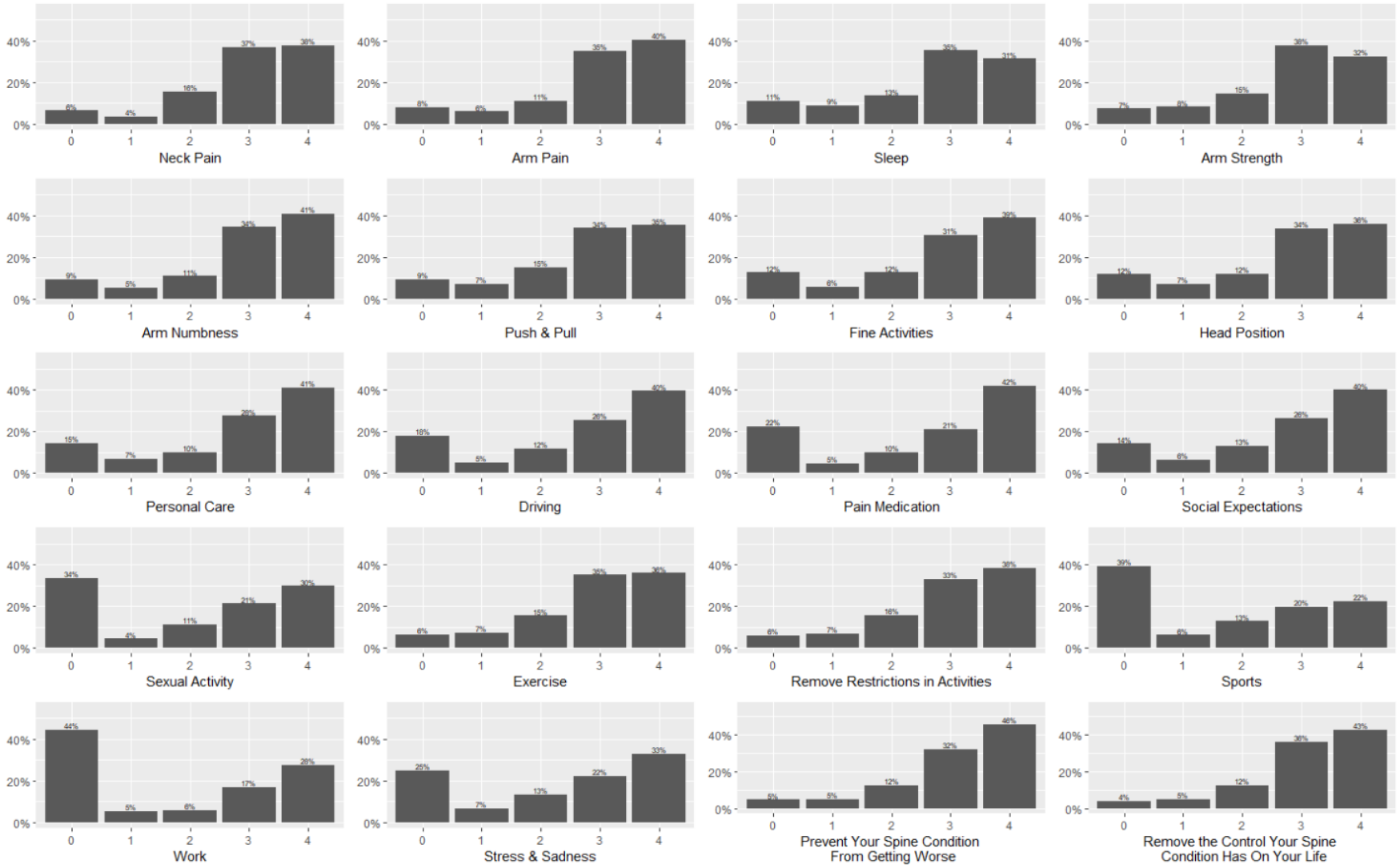

Figure 4.2: Histograms of Individual Items of HSS Cervical Spine Surgery Expectations Survey, where 0 represents no expectation and 4 is the expectation to return to normal or show complete improvement. Item answers include "I do not have this expectation, or this expectation does not apply to me" (0 points), "not back to normal, but a little improvement" (1 point), "not back to normal, but a moderate amount of improvement" (2 points), "not back to normal, but a lot of improvement" (3 points), or "back to normal or complete improvement" (4 points).

Inter-Item Correlations, Scale Reliability, and Scale Validity

For the lumbar and cervical cohorts, individual item correlations ranged from 0.18-0.77 and 0.23-0.72 and correlations between the composite scores and individual items ranged from 0.50-0.79 and 0.56-0.77, respectively (**Tables 4.2 and 4.3**). For the lumbar cohort, expectations related to improving walking, standing, climbing stairs, interacting with others, exercising, performing daily activities, removing restrictions in activities, and removing the control that the spine condition has on their life were all individually greater than 0.7. For the cervical cohort, expectations related to improving arm strength, pushing/pulling ability, driving, interacting with others, exercise, performing daily activities, and reducing arm pain were all individually greater than 0.7. The Cronbach's α for the full cohort with missing values dropped was 0.94 and 0.93 for lumbar and cervical, respectively. The sensitivity analysis with missing data converted to zero resulted in a Cronbach's alpha value of 0.91 for lumbar and 0.92 for cervical. Based on explanatory factor analysis with principal axis factors and items forced to a single scale, all 20 items loaded at 0.3 or above (lumbar range: 0.38 – 0.83; cervical range: 0.48 – 0.80), showing that each scale item is associated with the full-scale factor and that it is appropriate for both scales to be treated as a single measurement tool.

Table 4.2: Correlation matrix for individual items of HSS Lumbar Spine Surgery Expectations Survey

	Pain	Sleep	Walk	Sit	Stand	Leg St.	Blnce	Stairs	P.C	Drive	Pain Med	Social	Sex	Exer	Activ	Restr Activ	Work	Stress	Worse	Control	Scale Score
Pain	1																				
Sleep	0.51	1																			
Walk	0.59	0.41	1																		
Sit	0.42	0.46	0.51	1																	
Stand	0.61	0.43	0.77	0.55	1																
Leg St.	0.47	0.38	0.54	0.4	0.57	1															
Blnce	0.42	0.34	0.44	0.42	0.46	0.58	1														
Stairs	0.55	0.43	0.61	0.44	0.64	0.53	0.57	1													
P.C	0.24	0.42	0.33	0.42	0.34	0.33	0.43	0.45	1												
Drive	0.26	0.36	0.36	0.46	0.38	0.3	0.41	0.44	0.64	1											
Pain Med	0.32	0.28	0.36	0.28	0.36	0.3	0.35	0.38	0.36	0.41	1										
Social	0.41	0.37	0.53	0.38	0.51	0.39	0.44	0.56	0.49	0.55	0.49	1									
Sex	0.24	0.3	0.28	0.33	0.28	0.23	0.25	0.32	0.3	0.35	0.27	0.36	1								
Exer	0.58	0.39	0.67	0.44	0.67	0.55	0.47	0.61	0.35	0.38	0.44	0.56	0.3	1							
Activ.	0.53	0.41	0.65	0.45	0.7	0.48	0.5	0.7	0.43	0.46	0.44	0.64	0.35	0.69	1						
Restr. Activ.	0.52	0.4	0.67	0.45	0.7	0.51	0.47	0.61	0.4	0.43	0.43	0.6	0.29	0.69	0.77	1					
Work	0.24	0.26	0.26	0.23	0.26	0.3	0.24	0.32	0.3	0.24	0.25	0.27	0.47	0.35	0.29	0.3	1				
Stress	0.2	0.36	0.27	0.34	0.29	0.29	0.34	0.37	0.56	0.52	0.37	0.51	0.27	0.3	0.38	0.38	0.18	1			
Worse	0.54	0.37	0.46	0.33	0.48	0.43	0.35	0.42	0.24	0.24	0.29	0.37	0.18	0.49	0.47	0.49	0.24	0.25	1		
Control	0.58	0.38	0.57	0.38	0.62	0.52	0.44	0.5	0.29	0.32	0.37	0.54	0.27	0.67	0.59	0.6	0.25	0.32	0.68	1	
Scale Score	0.65	0.62	0.73	0.65	0.75	0.66	0.66	0.76	0.66	0.67	0.59	0.75	0.54	0.76	0.79	0.77	0.5	0.59	0.58	0.7	1

Abbrev: Sit (sitting), Stand (standing), Leg St. (Leg Strength), Blnce (Balance), P.C (Personal Care), Drive (Driving), Pain Med (remove need for Pain Medication), Social (Social Expectations), Sex (Sexual Activity), Exer (Exercise), Activ (Activities), Restr. Activ (Remove Restrictions from activities), Stress (Reduce emotional stress or sad feelings), Worse (Stop the spine condition from getting worse), control (remove the control that the spine condition has on my life), Scale Score (Composite Expectations Score)

Table 4.3:: Correlation matrix for individual items of HSS Cervical Spine Surgery Expectations Survey

	Neck Pain	Arm Pain	Sleep	Arm St	Arm Numb	Push	Fine	Read	P.C.	Drive	Pain Med	Social	Sex	Exer	Activ	Sports	Work	Stress	Worse	Control	Scale Score
Neck Pain	1																				
Arm Pain	0.63	1																			
Sleep	0.48	0.45	1																		
Arm St.	0.52	0.6	0.44	1																	
Arm Numb	0.4	0.6	0.35	0.61	1																
Push	0.54	0.6	0.44	0.69	0.53	1															
Fine	0.38	0.48	0.27	0.58	0.56	0.55	1														
Read	0.46	0.45	0.39	0.47	0.41	0.52	0.47	1													
P.C.	0.36	0.44	0.33	0.52	0.4	0.52	0.58	0.51	1												
Drive	0.41	0.46	0.37	0.47	0.45	0.48	0.42	0.59	0.56	1											
Pain Med	0.48	0.44	0.42	0.44	0.37	0.43	0.37	0.41	0.39	0.44	1										
Social	0.41	0.42	0.4	0.43	0.39	0.41	0.4	0.47	0.51	0.54	0.51	1									
Sex	0.3	0.29	0.34	0.3	0.27	0.29	0.29	0.35	0.33	0.4	0.37	0.46	1								
Exer	0.49	0.5	0.46	0.55	0.46	0.5	0.42	0.42	0.4	0.49	0.5	0.51	0.37	1							
Activ	0.48	0.51	0.47	0.58	0.47	0.54	0.47	0.44	0.5	0.54	0.5	0.61	0.36	0.72	1						
Sports	0.29	0.28	0.37	0.32	0.26	0.3	0.23	0.32	0.24	0.35	0.32	0.32	0.39	0.52	0.39	1					
Work	0.36	0.37	0.36	0.35	0.33	0.38	0.28	0.31	0.31	0.42	0.36	0.38	0.44	0.44	0.41	0.5	1				
Stress	0.34	0.32	0.31	0.37	0.3	0.38	0.39	0.38	0.43	0.43	0.35	0.5	0.41	0.4	0.45	0.36	0.33	1			
Worse	0.32	0.31	0.34	0.42	0.37	0.38	0.27	0.38	0.3	0.33	0.3	0.32	0.24	0.44	0.45	0.3	0.32	0.28	1		
Control	0.39	0.39	0.35	0.45	0.45	0.41	0.34	0.45	0.33	0.43	0.39	0.39	0.26	0.54	0.59	0.33	0.34	0.39	0.67	1	
Scale Score	0.66	0.7	0.62	0.74	0.66	0.73	0.65	0.69	0.67	0.72	0.67	0.71	0.58	0.75	0.77	0.57	0.62	0.62	0.56	0.65	1

Abbrev: Arm St. (Arm Strength), Arm Numb (Arm Numbness), Push (ability to push or pull), Fine (use hands for fine activities), Read (position head to read P.C (Personal Care), Drive (Driving), Pain Med (remove need for Pain Medication), Social (Social Expectations), Sex (Sexual Activity), Exer (Exercise), Activ (Activities), Sports(improve ability to participate in sport), Stress (Reduce emotional stress or sad feelings), Worse (Stop the spine condition from getting worse), control (remove the control that the spine condition has on my life), Scale Score (Composite Expectations Score)

Expectations Composite Score and Univariate Analysis

For the lumbar sample, the mean expectations composite score was 73.5 (SD: 19.5), the median was 75.0 (Interquartile Range (IQR): 61.3-89.5), and the scores ranged from 0-100 (**Figure 4.3a**), while the mean expectations composite score was 66.8 (SD: 23.1), the median was 67.5 (IQR: 50.0-85.0), and the scores ranged from 0-100 for the cervical cohort (**Figure 4.3b**). Based on univariate analysis in the lumbar cohort, significant differences in preoperative expectations were found for radiculopathy (yes vs. no) (mean difference= 3.4, 95% CI: 2.5 – 9.7), insurance (public vs. private) (mean difference= -4.6, 95% CI: -7.5 – -1.7), race (non-white vs. white) (mean difference= 4.9, 95% CI: 0.6 – 9.0), employment (unemployed vs employed) (mean difference= -5.1, 95% CI: -8.2 – -2.0), and ambulation (independently vs. with assistance) (mean difference= -3.3, 95% CI: -6.6 – -0.5) **(Table 4.4)**. Significant differences in preoperative expectations for the cervical cohort were found for radiculopathy (yes vs. no) (mean difference= 10.6, 95% CI: 6.7 – 14.4), revision surgery (yes vs. no) (mean difference= 7.1, 95% CI: 2.8 – 11.4), insurance (private vs. public) (mean difference= 7.6, 95% CI: 3.9 – 11.4), education (high school or less vs. more than high school) (mean difference= 4.4, 95% CI: 0.6 – 8.2), employment (employed vs. unemployed) (mean difference= 11.1, 95% CI: 7.4 – 14.8), myelopathy (yes vs. no) (mean difference= 7.7, 95% CI: 3.7 – 11.6), and anticipated procedure performed (anterior fusion vs. posterior fusion vs. posterior decompression) (mean difference= -12.6, 95% CI: -17.7 – -7.5) **(Table 4.3)**. In both cohorts, continuous expectations scores were weakly correlated with all patient-reported measures and continuous demographic factors (Lumbar cohort range: ρ= -0.15 – 0.16, Cervical cohort range: ρ= -0.25 – 0.18). (Appendix 4.1)

Figure 4.3a. Distribution of Preoperative HSS Lumbar Spine Surgery Expectations Survey Composite Score

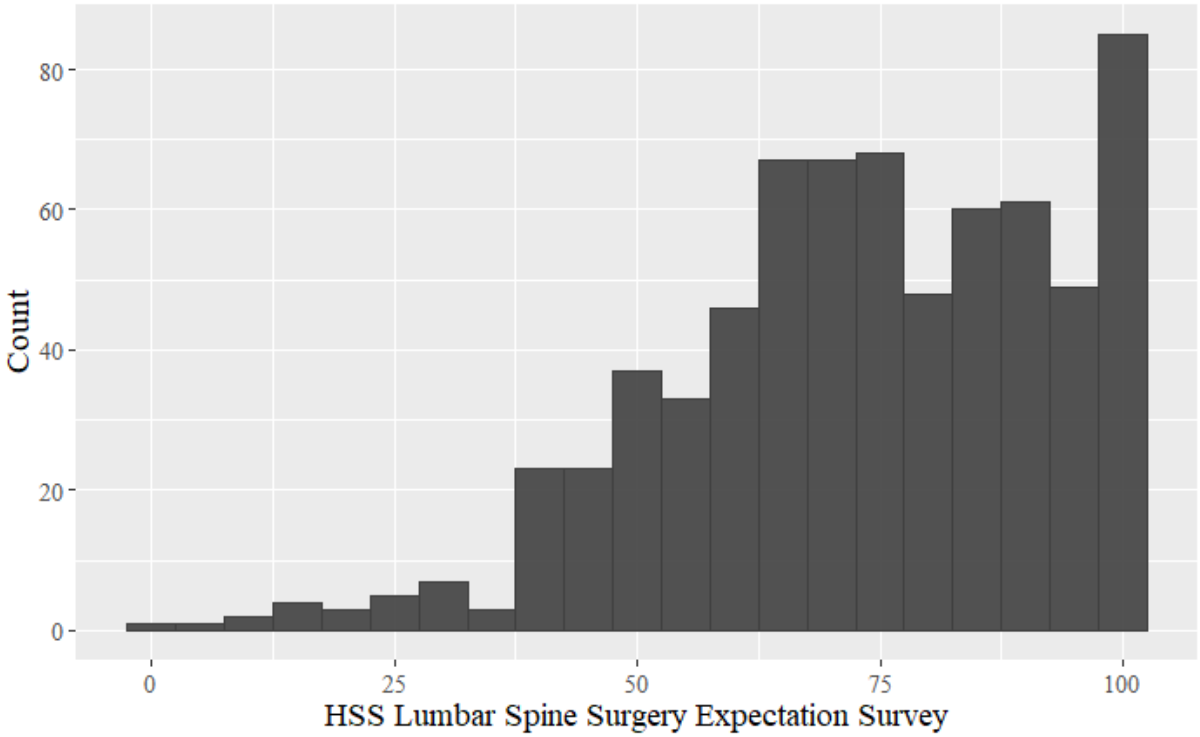

Figure 4.3b: Distribution of Preoperative HSS Cervical Spine Surgery Expectations Survey Composite Score

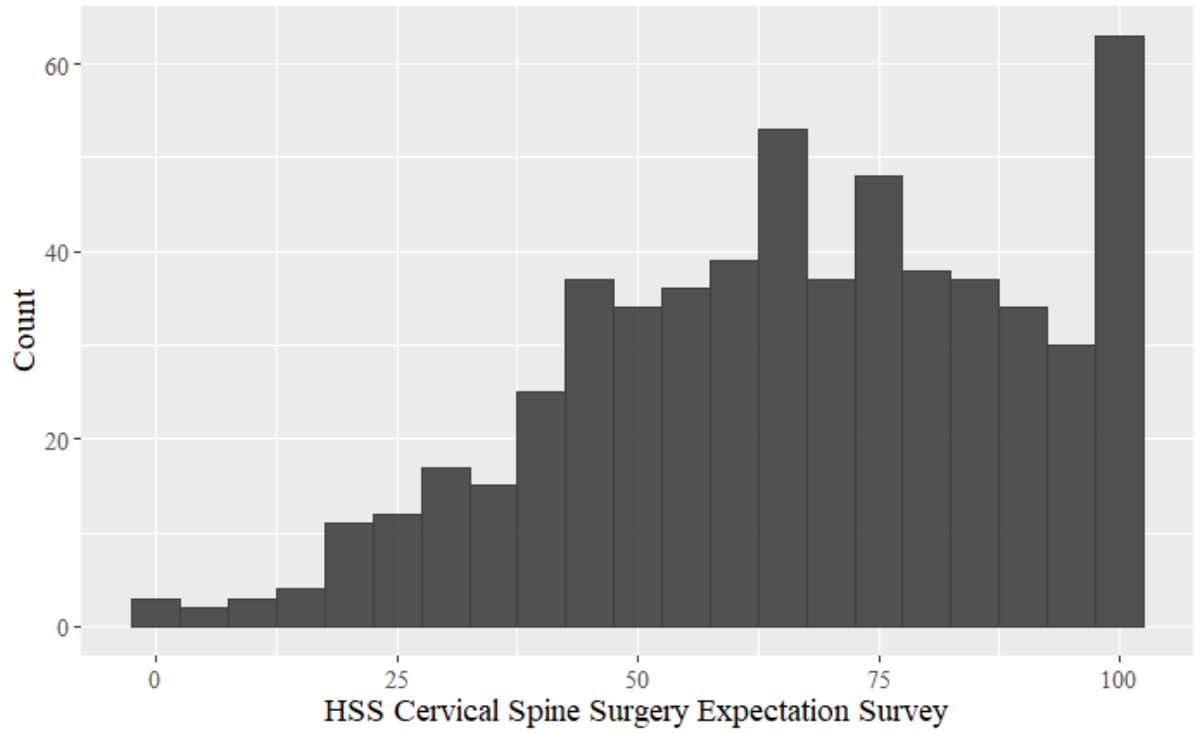

Table 4.4. Univariate analysis of demographics and clinical characteristics

	Lumbar			Cervical		
	Mean Expect. Score	Mean Difference	95% CI	Mean Expect. Score	Mean Difference	95% CI
Sex						
Female	74.4			67.2		
Male	72.9	-1.5	[-4.3 – 1.4]	66.6	-0.6	[-4.5 – 3.2]
Liability or Disability Claim						
Yes	74.2			67.5		
No	73.4	-0.8	[-5.1 – 3.5]	66.7	-0.8	[-6.4 – 4.7]
Insurance type						
Private	75.5			70.1		
Public	70.9	-4.6	[-7.5 – -1.7]	62.5	-7.6	[-11.4 – -3.9]
Race						
White	72.7			66		
Non-White	77.6	4.9	[0.6 – 9.0]	70.4	4.4	[1.8 – 10.7]
Education						
High School or Less	72.8			64.3		
Some College or Greater	73.8	1.0	[-1.9 – 3.9]	68.7	4.4	[-0.6 – 8.2]
Employment						
Currently Working	76.7			73.5		
Not Currently Working	71.6	-5.1	[8.2 – -2.0]	62.4	-11.1	[-14.8 – -7.4]
Tobacco						
Non-Smoker	73.5			67		
Current Smoker	73.3	-0.2	[-4.1 – -3.8]	65.7	-1.3	[-6.0 – 3.2]
Ambulation						
Independently	74.3			-		
With Assistance	71	-3.3	[-6.6 – -0.5]	-		-
Revision Surgery						
No	73.8			68.4		
Yes	72.7	-1.1	[-4.5 –2.3]	61.3	-7.1	[-11.4 – -2.8]
Radiculopathy						
No	71.5			60.2		
Yes	74.9	3.4	[2.5 – 9.6]	70.8	10.6	[6.7 – 14.4]
Claudication / Myelopathy						
No	73.7			69.5		
Yes	73	-0.7	[-3.7 – 2.3]	61.8	-7.7	[-11.6 – 3.7]
Anticipated Surgery						
Anterior Fusion	77.4			72.1		

Posterior Fusion	72	-5.4	[-13.3 – 2.7]	59.5	-12.6	[-17.7 – -7.5]
Posterior Decompression	75.8	-1.6	[-9.7 – 6.5]	63.3	-8.8	[-18.2 – 0.5]
Preoperative Opioids						
Yes	72.8			64.8		
No	74.2	1.4	[-2.5 – 4.2]	67.4	2.6	[1.7 – 6.8]

Multivariable Linear Regression

In multivariable linear regression for the patients undergoing lumbar surgery, higher leg pain (Beta Coefficient (β): 1.39, 95% Confidence Interval (95% CI): 0.64 - 2.15), higher disability (β: 0.34, 95% CI: 0.04 - 0.64), and race (non-white compared to white) (β: 4.67, 95% CI: 0.04 - 9.29) were statistically associated with higher preoperative expectations, while higher physical function (β: -0.74, 95% CI: -1.45 – -0.02), increased age (β: -0.22, 95% CI: -0.44 – -0.01), higher levels of depression (β: -0.20, 95% CI: -0.37 – -0.03), and employment (not working compared to working) (β: -3.57, 95% CI: -6.93 – -0.11) were statistically associated with lower preoperative expectations **(Table 4.5a)**.

Within the cervical cohort, higher arm pain (β: 1.63, 95% CI: [0.82 – 2.43]), higher disability (β: 0.35, 95% CI: [0.06 - 0.64]), and higher physical function (β: 0.44, 95% CI: [0.06 – 0.83]) were associated with higher preoperative expectations, while higher levels of depression (β: -0.26, 95% CI: [-0.47 – -0.06]), undergoing revision surgery (β: -5.35, 95% CI: [-9.36 – -0.34]), and anticipating undergoing Posterior Decompression (vs. Anterior Decompression) (β: -5.35, 95% CI: [-9.84 – -0.86]) were statistically associated with lower preoperative expectations. **(Table 4.5b)**

For the lumbar model, the final model included a smooth relationship using restricted cubic splines with 3 knots for age, disability, pain interference, and physical function. Of these, the cubic spline term was significant for both disability and physical

function. The relationship between disability and preoperative expectations is positive until the ODI score approaches 50, at which point the relationship inverts and higher disability scores are associated with lower preoperative expectations **(Figure 4.4)**. For physical function, higher physical function is associated with lower expectations until the physical function t-score approached 35, at which point an increased physical function was associated with an increased preoperative expectation score. For the cervical model, a smooth relationship was modeled for both age and disability using a restricted cubic spline with 3 knots. Of these, only disability was statistically significant in the final model. The relationship between preoperative disability and preoperative expectations is positive until the NDI score approaches 50, at which point the relationship inverts and higher disability scores are associated with lower preoperative expectation scores.

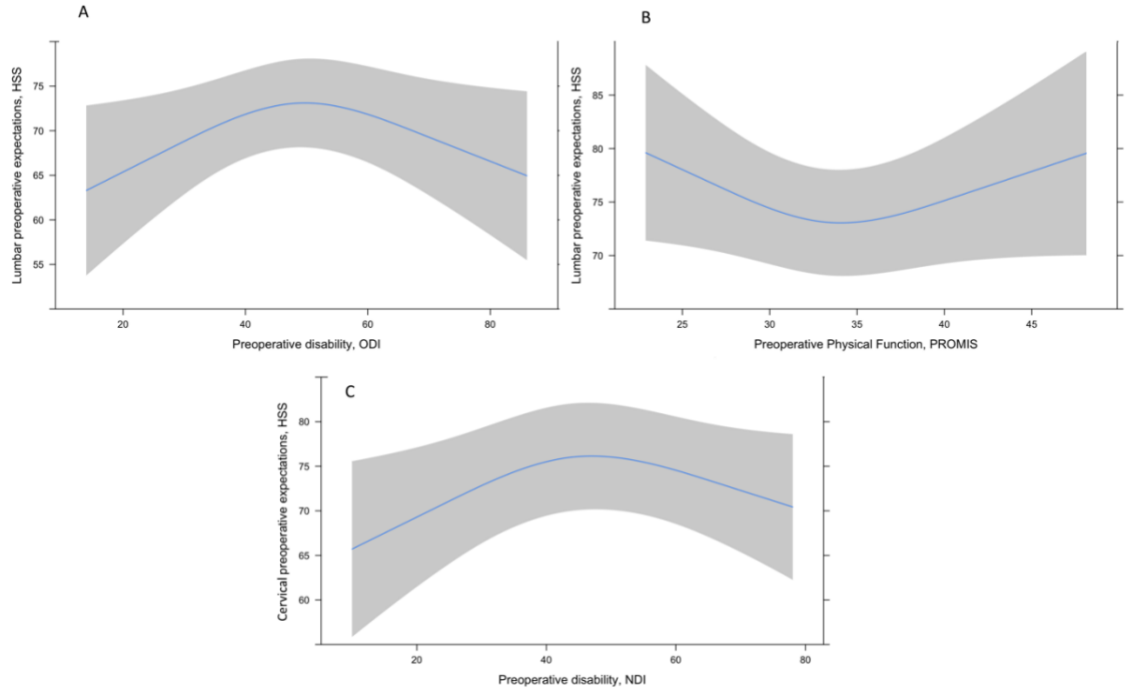

Figure 4.4 Graphs showing the relationship between (a) preoperative disability score and (b) preoperative physical function score (b) and preoperative expectations when fit with restricted cubic spline with 3. Graph (c) represents the relationship between the preoperative cervical disability score and preoperative expectations when fit with a restricted cubic spline with 3 knots.

The importance of each variable based on its contribution to the chi-square statistic is shown in Figure 4.5. These results demonstrate that extremity pain, disability, depression, and physical function are consistently among the variables associated with preoperative expectations after adjusting for other covariates.

Table 4.5a. Results of the multivariable linear regression model showing associations between demographic, clinical, and patient reported variables and preoperative expectations in patients undergoing lumbar spine surgery

Variables	Coefficient	95% CI	P Value
Demographic			
Age	-0.22	[-0.44 - 0.01]	0.06
Age'	0.13	[-0.13 – 0.39]	0.34
BMI	-0.17	[-0.43 – 0.08]	0.18
Male Sex (vs. Female)	-1.19	[-4.17 – 1.79]	0.43
Liability Claim (vs. No Claim)	1.61	[-3.55 – 6.76]	0.54
Public Insurance (vs. Private)	-2.52	[-5.90 – 0.87]	0.15
Non-White Race (vs. White)	4.67	[0.04 – 9.29]	0.05
Some College Education or Greater (vs. High School or Less)	0.26	[-2.75 – 3.26]	0.87
Not Currently Working (vs. Currently Working)	-3.52	[-6.93 – -0.11]	**0.04**
Current Smoker (vs. Non-Smoker)	-0.82	[-4.84 – 3.20]	0.69
Require Assistance Ambulating (vs. Independently)	-2.8	[-6.68 – 1.07]	0.16
Clinical			
Revision Surgery (vs. Primary)	-1.04	[-4.55 – 2.47]	0.56
Anticipated Procedure (vs. Anterior Fusion)			
Posterior Fusion	-4.97	[-12.00 – 2.06]	0.17
Posterior Decompression	-3.33	[-10.15 – 3.50]	0.34
No Preoperative Opioid Use	1.17	[-2.17 – 4.50]	0.49
Elixhauser Comorbidity Index	-0.22	[-0.51 – 0.07]	0.14
Neurogenic Claudication	1.12	[-2.11 – 4.35]	0.50
Patient Reported			
Back Pain, NRS	0.01	[-0.78 – 0.81]	0.97
Leg Pain, NRS	1.39	[0.64 – 2.15]	**<0.001**
Disability, ODI	0.34	[0.04 – 0.64]	**0.03**
Disability, ODI'	-0.39	[-0.67 – -0.11]	**<0.01**
Pain Interference, PROMIS	0.4	[-0.19 – 0.99]	0.18
Pain Interference, PROMIS'	-0.15	[-0.89 – 0.60]	0.70
Physical Function, PROMIS	-0.74	[-1.45 – -0.02]	**0.04**
Physical Function, PROMIS'	0.89	[0.16 – 1.63]	**0.02**
Depression, PROMIS	-0.2	[-0.37 – -0.03]	**0.02**

Abbreviations: Body Mass Index (BMI), Numeric Rating Scale (NRS), Neck Disability Index (NDI), Patient Reported Outcome Measurement Information System (PROMIS)
Age', ODI', and PROMIS' scores were modeled with a non-linear relationship with expectations. Coefficients are not directly interpretable and are included here for reporting purposes only.

Table 4.5b. Results of the multivariable linear regression model showing associations between demographic, clinical, and patient reported variables and preoperative expectations in patients undergoing cervical spine surgery

Variables	Coefficient	95% CI	P value
Demographic			
Age	0.05	-0.30 – 0.39	0.80
Age'	-0.36	-0.79 – 0.08	0.11
BMI	-0.15	-0.46 – 0.15	0.33
Male Gender (vs. Female)	1.13	-2.49 – 4.75	0.54
Liability Claim (vs. No Claim)	1.77	-3.25 – 6.79	0.49
Public Insurance (vs. Private)	2.16	-2.36 – 6.68	0.35
Non-white Race (vs. White)	4.54	-0.99 – 10.07	0.11
Some College or Greater (vs. High School or Less)	3.01	-0.59 – 6.61	0.10
Not Currently Working (vs. Currently Working)	-3.69	-8.19 – 0.81	0.11
Current Smoker (vs. Non-Smoker)	-2.79	-7.38 – 1.80	0.23
Clinical			
Revision Surgery (vs. Primary)	-4.85	-9.36 – -0.34	**0.04**
Cervical Procedure (vs. Anterior Fusion)			
Posterior Decompression	-5.35	-9.84 – -0.86	**0.02**
Posterior Fusion	-3.46	-11.65 – 4.73	0.41
No Preoperative Opioid Use	3.16	-1.09 – 7.41	0.15
Elixhauser Comorbidity Index	0.03	-0.32 – 0.39	0.85
Preoperative Myelopathy	-3.06	-7.04 – 0.93	0.13
Patient Reported			
Neck Pain, NRS	0.03	-0.93 – 1.00	0.95
Arm Pain, NRS	1.63	0.82 – 2.43	**<0.001**
Disability, NDI	0.35	0.06 – 0.64	**0.2**
Disability, NDI'	-0.41	-0.71 – -0.12	**<0.01**
Pain Interference, PROMIS	0.22	-0.11 – 0.56	0.19
Physical Function, PROMIS	0.44	0.06 – 0.83	**0.02**
Depression, PROMIS	-0.26	-0.47 – -0.06	**0.01**

Abbreviations: Body Mass Index (BMI), Numeric Rating Scale (NRS), Neck Disability Index (NDI), Patient Reported Outcome Measurement Information System (PROMIS)
Age' and NDI' scores were modeled with a non-linear relationship with expectations. Coefficients are not directly interpretable and are included here for reporting purposes only.

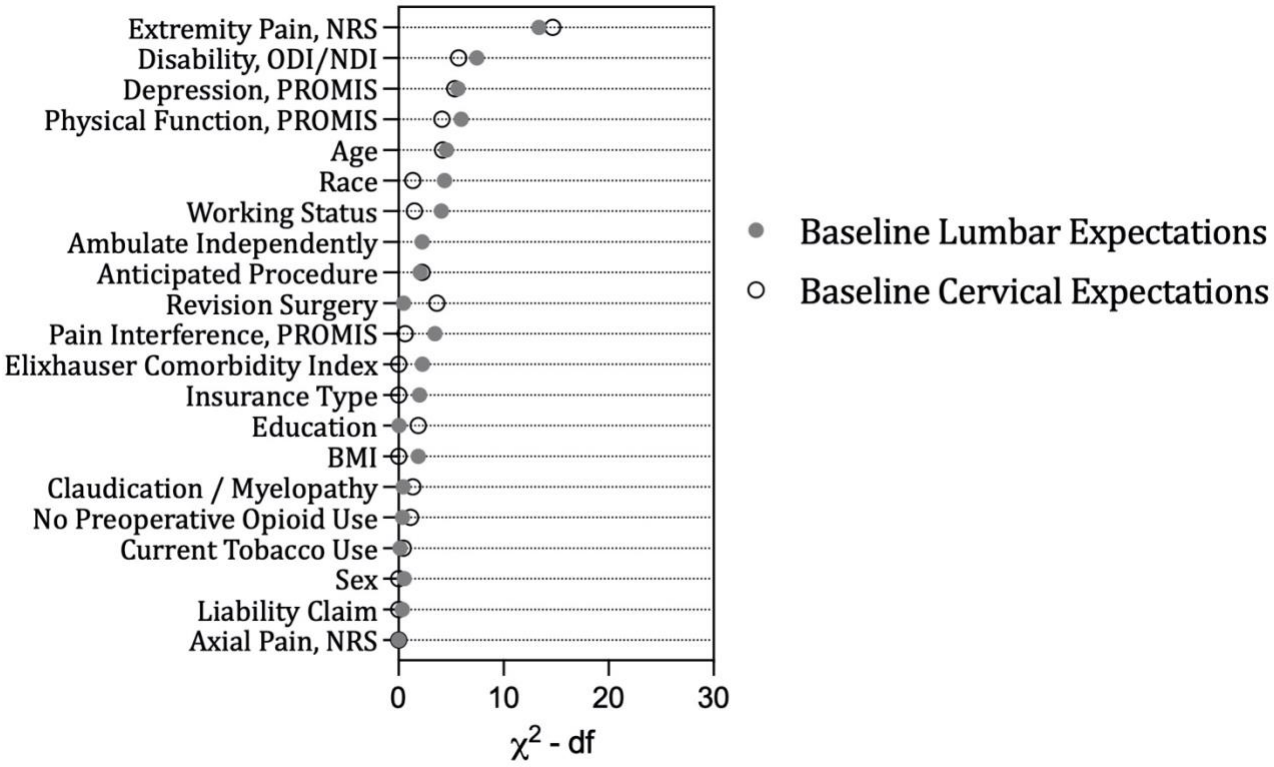

Figure 4.5. Variable importance plot depicting the strength of cross-sectional association for demographic, clinical, and patient reported variables.

Abbreviations: Numeric Pain Rating Scale (NRS), Oswestry Disability Index (ODI), Neck Disability Index (NDI), Patient Reported Outcome Measurement Information System (PROMIS), Body Mass Index (BMI). Reference Groups (denoted with *): race (white* vs. non-white), working status (currently working* vs. not currently working), anticipated procedure (anterior fusion* vs. posterior fusion vs. posterior decompression), insurance type (public* vs. private), education (high school or less* vs. some college or more).

DISCUSSION

This cross-sectional analysis of spine surgery registry data from patients undergoing elective lumbar and cervical spine surgery assesses the psychometric properties of the HSS Expectations Surveys and examines their association with demographic and clinical characteristics and patient-reported measures. The results demonstrated good distribution in item responses, acceptable inter-item correlations, good distribution in composite scores, and excellent internal consistency. The multivariable models from the lumbar and cervical cohorts found statistically significant associations

between preoperative expectations and extremity pain, disability, physical function, and depression. However, there was divergence between lumbar and cervical models in demographic and surgery characteristics that may have important clinical implications.

The individual scale items in the HSS Expectations Surveys demonstrate good distribution across the majority of items as patients' answers covered the full range of possible scores. Exceptions were noted for improved sexual activity and work-related expectations in both cohorts, as well as expectations for sports related activities in the cervical cohort. During the development of both the lumbar and cervical expectations surveys, questions related to sexual activity (endorsed 68% lumbar, 60% cervical) and work (endorsed 43% lumbar, 73% cervical among those currently unemployed) were among the least frequently endorsed questions that were retained for the final surveys.(19, 20) These items were not removed because the weighted kappa for concordance between overall survey scores was greater than 0.6, indicating good agreement (Lumbar) or were rated as clinically relevant by surgeons (Cervical). Additionally, our findings are in contrast to work by Canizares et al. who found that 86% of patients expected to be "much better" or "better" in their ability to do sporting activities in a population undergoing surgery for degenerative spine conditions.(40) This discrepancy may be due to the phrasing of the question, where the North America Spine Society Lumbar Spine Questionnaire assesses sporting activity and recreation in a single question, whereas the HSS Expectations Surveys ask about sports participation alone.

Based on the multivariable models, extremity pain (i.e., leg and arm) was significantly associated with patient expectations in both populations, with higher extremity pain related to higher expectations. While the cervical questionnaire asks

multiple questions related to the extremities (*i.e.* arm pain, strength in arms, numbness in arms, etc.), only leg strength is specifically addressed in the lumbar questionnaire. Previous work has shown that, on average, patients with higher leg pain than back pain have a higher mean preoperative expectations score compared to those with back pain greater than leg pain.(41) Additional work suggests that arm/leg pain relief are among the highest-ranked areas for expectations of improvement.(42) Neither back nor neck pain were associated with preoperative expectations. While this diverges from prior work by Canizares (40), who found that patients with higher back and neck pain and disability had higher expectations, other studies have shown no association between the level of back and neck pain and preoperative patient expectations.(21, 22)

It is important to note that this study utilized restricted cubic splines to model potential non-linear relationships between preoperative disability and expectations and results demonstrated a statistically significant curvilinear shape between disability and expectations in both cohorts. Patient expectations and disability were positively associated until they reach 48.9 and 44 in the ODI and NDI, respectively, at which point expectations and disability were negatively related. These findings are in contrast to prior work, which note a relationship between higher preoperative disability and patient expectations; however, these papers all modeled the relationship linearly (43-45) or dichotomously (21, 22).

Higher depression scores were associated with lower preoperative expectations in the multivariable models for patients undergoing both cervical and lumbar spine surgery; this is inconsistent with findings in other elective spine surgery populations. Mancuso et al. noted a relationship between higher levels of anxiety and depression and higher

expectations scores based on both the HSS Lumbar and Cervical Expectations Surveys, while Canizares and colleagues found a positive relationship between higher levels of depression and expectations of overall functional well-being.(21, 22, 40) However, work by Urban-Baeza et al found no significant differences in expectations between patients with and without depression among patients with spinal stenosis. (46)Additionally, work in other orthopaedic specialties shows a conflicting relationship between depression and expectations. Although some studies support our findings that higher levels of depression are associated with lower expectations (47, 48), others have shown that higher levels of depression are associated with higher expectations.(49) To address the conflicting relationship, depression was initially modelled using a restricted cubic spline term; however, this relationship was eliminated during the model building process to avoid overfitting the multiple linear regression model.

This study addresses important gaps in knowledge relating physical function and pain interference to preoperative expectations. Physical function and pain interference are commonly overlooked outcomes in the spine surgery literature. This study found an association between higher preoperative physical function and higher preoperative expectations in the lumbar and cervical populations, and no association between pain interference and expectations in either cohort. Based on the significant, non-linear relationship between physical function and patient expectations, patients on the low and high ends of physical function measured by the PROMIS scale have higher preoperative expectations than those in the middle of the scale. While expectations and physical function has not been assessed in a spine specific population, prior work by Tolk et al and Lizzio et al in total joint replacement populations found no significant relationship between

expectations and physical function.(50, 51) This discrepancy is likely due to differences in how both physical function and expectations are measured across studies. Although this study found no significant association between pain interference and expectations, previous work has shown higher pain interference is related to higher preoperative expectations in a shoulder surgery population.(51)

The models diverged with regards to other statistically significant covariates. In the cervical model, revision surgery was associated with lower patient expectations. Although there is a paucity of literature assessing the relationship between revision spine surgery cases and expectations, Feucht et al. (52) identified a significant relationship between lower expectations and revision anterior cruciate ligament reconstruction (compared to primary reconstruction cases). Patients scheduled for posterior cervical decompression surgery also had lower expectations than those scheduled for anterior decompression and fusion (ACDF). This finding may be due to differences in arm pain across groups. Patients undergoing a posterior approach had significantly lower preoperative arm pain than patients undergoing ACDF, which was found to be related to lower preoperative expectations. Additionally, patients not currently employed had lower pre-operative expectations than those who were currently employed among individuals undergoing lumbar spine surgery. This is similar to other findings among patients undergoing elective spine procedures, where work by Mancuso (21) and Canizares (40) et al demonstrated that employed patients had higher preoperative expectations in both a lumbar-specific and general degenerative spine surgery population.

A primary limitation of this study reflects the inability to measure the “value” of an expectation to the patient. Previous studies suggest that highly valued expectations may

dominate some individuals' reasons for undergoing surgery.(43, 53) However, the purpose of this research is to better understand generalized expectations of elective spine surgery rather than patient's motivating factors. Second, small betas from multivariable linear regression reflect statistical significance, but may not reflect clinical significance. This may limit the interpretability of this work, particularly as clinically meaningful differences in expectations have not yet been established using the HSS Expectations Surveys.

This study provides an in-depth characterization of preoperative patient expectations of lumbar and cervical spine surgery and identifies a significant association with preoperative extremity pain, disability, depression, and physical function. Additionally, results of this study suggest that patients expect improvements across multiple domains, including pain, function, mental well-being, and anticipated spine condition. A better understanding of patient's preoperative expectations and the factors influencing them may lead to surgeons helping patients set realistic expectations for the outcome of their surgery, resulting in higher satisfaction for the patient. Future prospective research should address the fulfillment of patients' expectations post-operatively and determining the role of preoperative expectations in post-operative surgical outcomes.

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CHAPTER 5

THE PROPORTION OF FULFILLED EXPECTATIONS IN THE EARLY POSTOPERATIVE PERIOD FOLLOWING SPINE SURGERY

INTRODUCTION

Lumbar and cervical spine surgeries are expected to increase over the next several decades largely as a result of an aging population in the United States.(1, 2) Because most spine surgeries are elective and driven by patients' desire to relieve symptoms and improve quality of life, their expectations about what surgery can accomplish for them are important factors in the decision to undergo surgery.(3-6) Some authors suggest that it is fulfilled expectations that has an impact on postoperative outcomes including satisfaction rather than the preoperative expectations themselves.(5, 7-9) Prior work highlights the importance of fulfilled expectations as an effective measurement of the potential value of surgery to the patient.(5, 10) However, the definition and measurement of fulfilled expectations is widely variable within the spine surgery population.

Prior studies have quantified fulfilled expectations across a number of domains, including fulfilled improvements in disability, pain, and social roles, and compared these preoperative expectations with the patients' perceived outcomes across the same domains.(5, 7, 11-13) Mancuso et al utilized the Hospital for Special Surgery's Lumbar and Cervical Spine Surgery Expectations Survey to produce a proportion of expectations fulfilled, a novel method to report expectation fulfillment as a patient-reported outcome measure (PROM).(14) However, this outcome has not been assessed outside of the sample in which the surveys were developed. Additional work is needed to better understand the clinical relevance of this fulfilled expectations measure to the spine surgery patient population.

This goal of this study is to describe fulfilled expectations at 3-months postoperatively based on the HSS Cervical and Lumbar Spine Surgery Expectation Surveys in patients undergoing elective spine surgery. Additionally, we will characterize the relationship between preoperative expectations, pre-operative and 3-month patient-reported measures, and demographic/clinical/surgical characteristics and fulfilled expectations at 3-months postoperatively. A better understanding of fulfilled expectations in the early post-operative time period can help inform postoperative management in this patient population, such as the decision to refer for physical therapy.(15)

METHODS

This study is a retrospective analysis of prospectively collected data from the Vanderbilt Spine Registry at the preoperative and 3-months post-operative time-points. An in-depth description of the Vanderbilt Spine Registry and the demographic, clinical, and surgical covariates collected from the registry are presented in Chapter 4.

Fulfilled Expectations at 3 Months

Similar to prior work by Mancuso et al, fulfilled expectations at 3-months postoperatively was measured using a postoperative version of the 20-item Lumbar or Cervical Spine Surgery Expectations Survey.(14) Each item on the postoperative questionnaires assesses how much improvement the patient has received, with answers ranging from "I did not have this expectation, or this expectation did not apply to me" (0 points) to "back to normal or complete improvement" (4 points). The postoperative version of these surveys examines how much improvement a patient has experienced following surgery, allowing patients to consider their improvement in areas such as pain, personal

daily activities, psychosocial issues, physical function, and skeletal function following their elective spine procedure.

For this study, the proportion of expectations fulfilled is calculated as $\frac{3-month\ expectation\ fulfillment}{pre-operative\ expectation\ score}$ and scaled by a factor of 100 in order to create a more interpretable outcome score (i.e. a 1 point increase is equal to a 1% increase in the proportion of expectations fulfilled).(14) Here, scores can range from 0 to greater than 100, where zero represents patients who have experienced no improvement for any item, scores between 0 and 100 represent patients who have received some improvement for some items, and scores greater than or equal to 100 represent patients who have had their expectations met or exceeded. A composite, continuous score has also been used by Mancuso et al. to define fulfilled expectations and was used for sensitivity analyses.

Statistical Analysis

Each survey item was reported using a histogram to assess data distribution for the proportion of fulfilled expectations at 3 months postoperatively for both the lumbar and cervical cohorts. Spearman's correlations were used to assess the correlations among each of the 20 scored items of the HSS Lumbar or Cervical Spine Surgery Expectations Survey to explore the relationships among the individual survey items. Inter-item correlations for the scales were conducted as a complete case analysis. Cohen's guidelines for assessing the strength of correlation coefficients were used for this study, where greater than 0.5, 0.3-0.49, and 0.1-0.29 represent large, medium, and small correlations, respectively.(16)

To compare the proportion of fulfilled expectations between variables, Mann-Whitney u tests were used for dichotomous and Kruskal Wallis tests for categorical

demographic/clinical/surgical covariates. Spearman correlations were used to assess the relationships between baseline and 3-month measurements of disability, pain intensity, pain interference, and physical function and the proportion of fulfilled expectations. Mann-Whitney U tests were used to compare satisfaction at 3 months and the proportion of expectations fulfilled at 3-months postoperatively.

Hierarchical multivariable linear regression modeling was used to assess the relationship between *a priori* variables, including relevant demographic, clinical and surgical characteristics, and patient reported measures at either the 3-month postoperative or preoperative timepoint, and the proportion of expectations fulfilled. Two separate models for the lumbar and cervical cohorts were developed for the preoperative and 3-month patient reported outcomes, respectively. Patient reported measures of disability, pain intensity, physical function, pain interference, depression, and satisfaction (3-month only) were entered in the first block, followed by a second block containing demographic, clinical, surgical variables, and preoperative expectations. To normalize the distribution in both cohorts, all models were restricted to the patient population that had a proportion of expectations fulfilled of less than or equal to 200 to avoid violating linearity assumptions. Non-parametric tests were used to compare the reduced cohort (N=475 lumbar, N=382 cervical) to the full cohort (N=483 lumbar, N=393 cervical). As a sensitivity analysis, the same models were run with all survey responders, including those with a proportion of expectations fulfilled greater than 200.

All linear regression models were initially fit with restricted cubic splines on continuous variables to allow for potential non-linear relationships between the variables and the proportion of expectations fulfilled outcome. Age, preoperative expectations, and

all patient reported measures were initially fit with 3 knots at the 10th, 50th, and 90th percentiles as automatically selected in the RMS package. (17) Reduction of the models proceeded by comparing reduced, nested models with a likelihood ratio test to assess model fit between models including linear and non-linear terms. Variable importance to the final multivariable model was assessed using Chi-square statistics minus degrees of freedom.

Sensitivity analyses were conducted for all models with the outcome as a composite, continuous score. Results were consistent and only the models with the proportion of expectations fulfilled as the outcome are reported below. Sensitivity analysis models are presented in appendices.

Less than 5% of data were missing for all variables. Missing values were multiply imputed using a flexible additive imputation model with predictive mean matching (aregImpute from the Hmisc package in R). A p-value of 0.05 was considered statistically significant, and all confidence intervals are set to 95%. Analyses were conducted using R 4.1.0 with the rms and Hmisc packages.(17-19)

RESULTS

At baseline, 1,111 patients undergoing lumbar or cervical spine surgery and enrolled in the Vanderbilt Spine Registry completed the HSS Expectations Survey prior to surgery. Of these, 483 and 393 patients also completed the 3-month lumbar and cervical surveys **(Appendix 5.1)**. For the final population under consideration for analysis, 475 and 382 patients undergoing lumbar or cervical spine surgery, respectively, had a proportion of expectations fulfilled equal to or less than 200 **(Table 5.1)**. Patients undergoing lumbar surgery ranged in age from 19-84 (mean 59.0, standard deviation (SD) 13.5), while patients

undergoing cervical spine surgery ranged from 23-82 (mean 56.8, SD 11.6). The majority of patients in both populations were white (85% – lumbar, 86% – cervical) and slightly more males participated than females (51% lumbar, 53% cervical).

Table 5.1: Lumbar and cervical cohort characteristics, including patient demographics, clinical and surgical characteristics, and patient reported measures for patients with proportion of expectations fulfilled less than or equal to 200

	Lumbar Cohort (n=475)	Cervical Cohort (N=382)
Patient Demographics	Mean [SD] or N (%)	Mean [SD] or N (%)
Age	59.0 [13.5]	56.8 [11.6]
Body Mass Index	31.3 [6.4]	30.3 [6.7]
Gender		
Female	234 (49%)	180 (47%)
Male	251 (51%)	202 (53%)
Missing	2 (0%)	2 (1%)
Race		
White	406 (85%)	330 (86%)
Non-White	55 (11%)	44 (11%)
Missing	18 (4%)	10 (3%)
Ambulation		
Independently	347 (72%)	-
Require Assistance	125 (26%)	-
Missing	7 (2%)	-
Insurance		
Private	250 (52%)	223 (58%)
Public	226 (47%)	160 (42%)
Missing	3 (1%)	1 (0%)
Education		
High School or Less	213 (44%)	161 (42%)
Some College or More	258 (54%)	215 (56%)
Missing	8 (2%)	8 (2%)
Employment		
Working	170 (35%)	149 (39%)
Not Currently Working	306 (64%)	235 (61%)
Missing	3 (1%)	0 (0%)
Tobacco		
Non-Smoker	410 (86%)	314 (82%)
Current Smoker	66 (14%)	70 (18%)
Missing	3 (1%)	0 (0%)
Clinical and Surgical Characteristics		
Comorbidity Index, Elixhauser	-2.8 [5]	-2.5 [5.2]
Preoperative Opioid Use	120 (25%)	93 (24%)
Revision Surgery	120 (25%)	91 (24%)
Radiculopathy	372 (78%)	242 (63%)
Neurogenic Claudication or Myelopathy	148 (31%)	137 (36%)
Procedure		

Anterior Fusion	22 (5%)	237 (62%)
Posterior Fusion	267 (56%)	28 (7%)
Posterior Decompression	186 (39%)	117 (30%)
Missing	4 (1%)	2 (1%)
3-Month Patient Reported Measures		
Disability, ODI and NDI	29.8 [19.1]	31.0 [19.0]
Axial Pain Intensity, NRS	3.5 [2.7]	3.4 [2.7]
Extremity Pain Intensity, NRS	2.8 [3.0]	2.6 [2.8]
PROMIS		
Pain Interference	57.6 [10.0]	57.7 [9.8]
Physical Function	41.0 [8.7]	41.8 [8.7]
Depression	48.8 [8.6]	49.9 [9.7]
Patient Satisfaction		
Satisfied	399 (83%)	319 (83%)
Unsatisfied	72 (15%)	63 (16%)
Missing	8 (2%)	2 (1%)
Preoperative Patient Reported Measures		
Disability, ODI and NDI	48.9 [15.0]	44.4 [16.5]
Back/Neck Pain Intensity, NRS	6.7 [2.3]	6.0 [2.7]
Arm/Leg Pain Intensity, NRS	7.0 [2.2]	5.6 [2.9]
PROMIS		
Pain Interference	68.1 [6.2]	64.8 [7.9]
Physical Function	33.5 [5.4]	38.0 [6.5]
Depression	52.0 [9.6]	52.2 [9.6]

Abbreviations: Body Mass Index (BMI), Patient-Reported Outcomes Measurement Information System (PROMIS), Numeric Rating Scale (NRS), Oswestry Disability Index (ODI), Neck Disability Index (NDI)
Note: PROMIS measures are reported as t-scores; the standardized t-scores have a population mean of 50, and a standard deviation of 10.

Fulfillment of Individual Expectation Items

Based on individual survey items, patients varied in their proportion of expectations fulfilled (**Figure 5.1a**). The distributions of individual items were split into two categories, those with a relatively equal distribution of fulfillment (including standing, leg strength, and exercise), or questions with a bi-modal distribution in the tails, where patients either experienced high levels of fulfillment or no fulfillment of their expectations, including personal care, sexual activity, work, and stress and sadness. Items which had higher percentages of completely unfulfilled included work and sexual activity. (**Appendix 5.1a).**

For the proportion of expectations fulfilled in the cervical cohort, patients generally were bimodal around 0 (completely unfulfilled) and 1 (completely fulfilled) (**Figure 5.1b).** A few notable exceptions to this include the proportion of fulfilled expectations related to work, sexual activity, and sports, which had higher percentages completely unfulfilled than completely fulfilled. For individual items of the postoperative survey, patients undergoing cervical spine surgery showed a relatively uniform distribution, with the exceptions relating to the expectations for improving their ability to participate in sports, sexual activity, and work (**Appendix 5.1b)**.

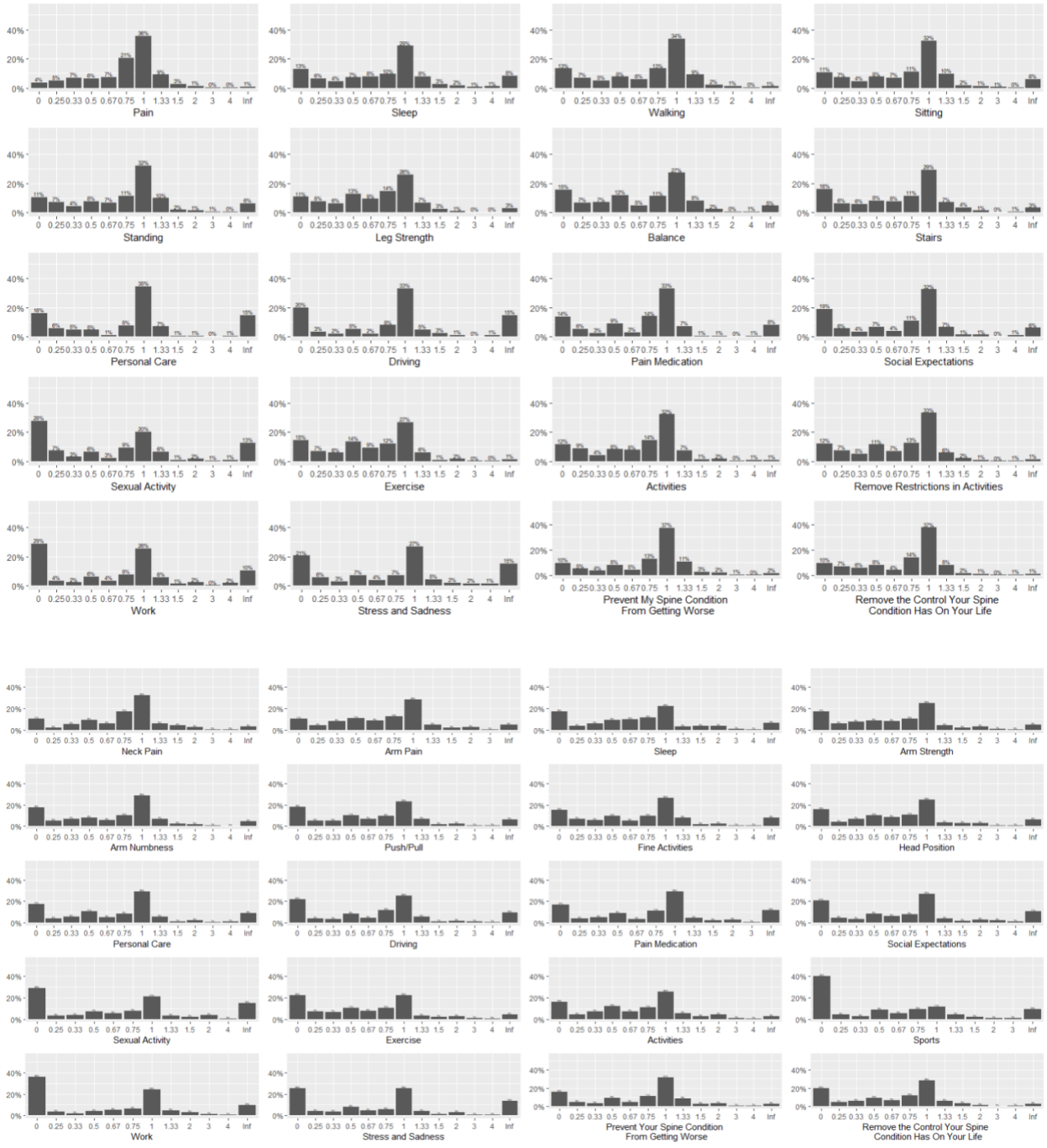


Figure 5.1: Histogram of Proportion of Expectations Fulfilled for patients undergoing lumbar (a) and cervical (b) procedures. Scores range from 0 (no expectations met) to greater than 1 (expectations met or exceeded)

Inter-Item Correlations

Individual item correlations for the proportion of expectations fulfilled (continuous) at 3-months postoperatively ranged from 0.39 – 0.80 and 0.26 – 0.73 for the lumbar and cervical cohorts, respectively. Spearman's correlations between the total proportion of expectations fulfilled and individual items ranged from 0.66 – 0.83 and 0.62 – 0.85 for the lumbar and cervical cohorts, respectively (Appendix 5.2a and 5.2b). For both the lumbar and cervical cohorts, the correlation between the proportion of expectations fulfilled for individual items and the proportion of expectations fulfilled as a scale score were all greater than 0.5. As a confirmatory analysis to ensure the scale was appropriate in our population, we found that Cronbach's alpha was 0.91 and 0.88 for the lumbar and cervical cohorts, respectively.

Figure 5.2. Distribution of 3 Month HSS Lumbar Spine Surgery Expectations Survey Proportion of Expectations Fulfilled Score

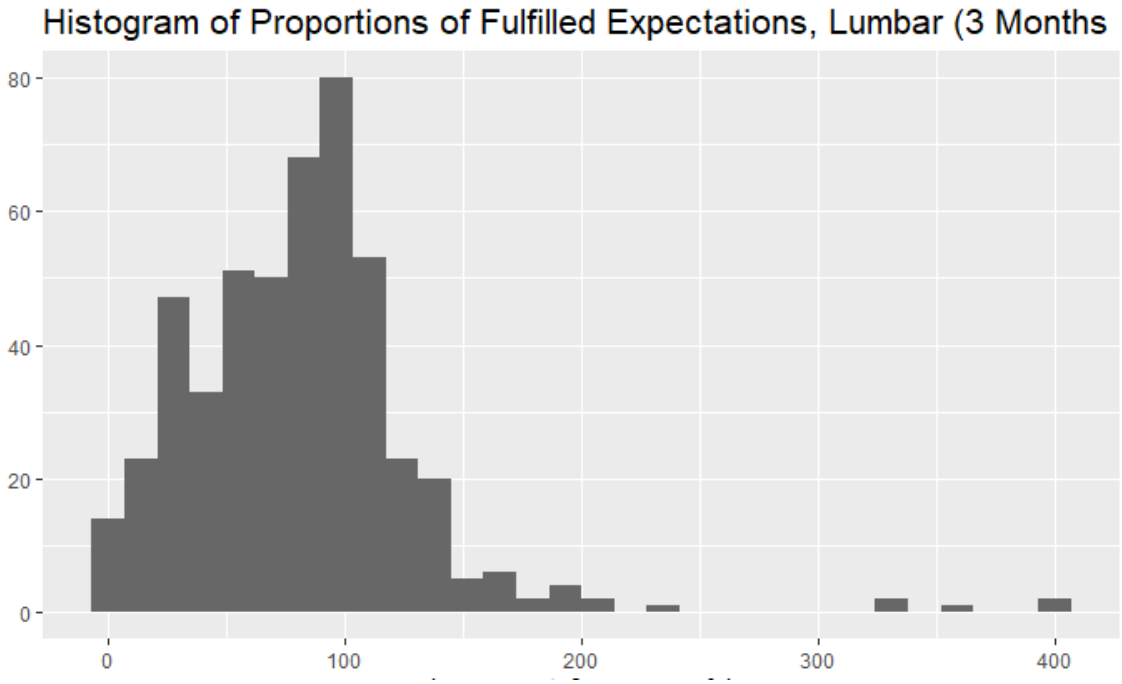


Figure 5.3. Distribution of 3 Month HSS Cervical Spine Surgery Expectations Survey Proportion of Expectations Fulfilled Score

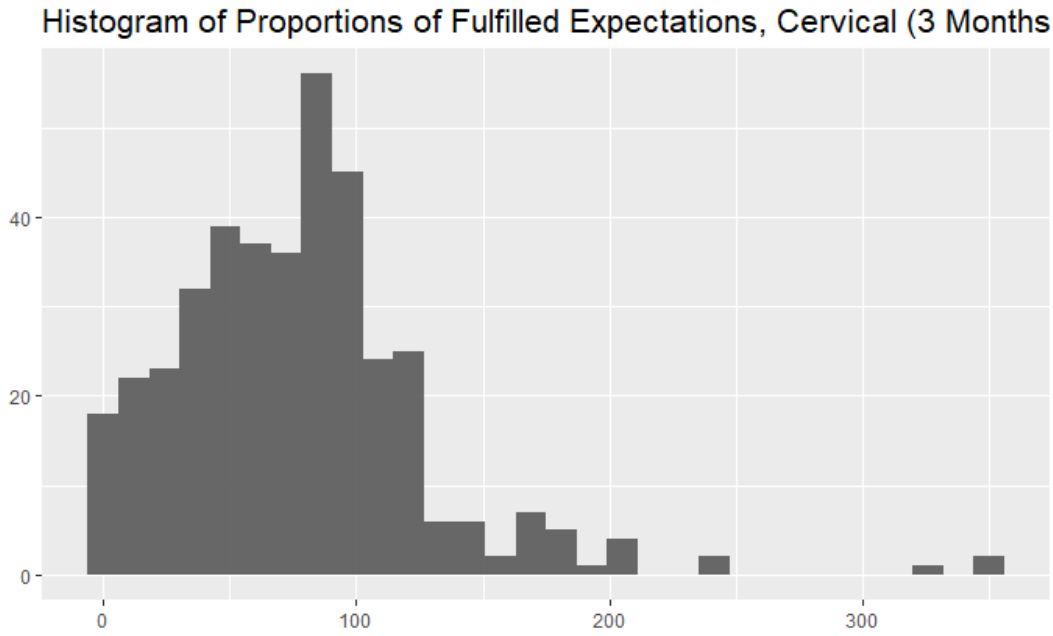


Table 5.2 Univariate analysis comparing the proportion of expectations fulfilled at 3 months by demographic, clinical and surgical characteristics, and patient reported measures

	Lumbar		Cervical	
	Median Proportion of Expectations Fulfilled [IQR]	*p*	Median Proportion of Expectations Fulfilled [IQR]	*p*
Gender		0.3		0.9
Male	84% [45 - 103]		75% [41 – 96]	
Female	80% [53 - 100]		74% [46 - 96]	
Liability or Disability Claim		0.23		0.06
Yes	80% [26 - 98]		59% [40 - 96]	
No	81% [51 - 101]		76% [43 - 97]	
Insurance type		0.21		0.79
Public	78% [49 - 100]		75% [38 - 97]	
Private	83% [52 - 102]		74% [46 - 96]	
Race		0.04		0.005
White	83% [52 - 102]		76% [44 - 99]	
Non-White	69% [40 - 97]		53% [32 - 86]	
Education		0.07		0.057
High School or Less	75% [41 - 98]		69% [37 - 91]	
Some College or Greater	85% [51 - 104]		76% [47 - 101]	
Employment		<0.001		<0.001
Currently Working	90% [63 - 106]		86% [54 - 103]	
Not Currently Working	74% [44 - 100]		63% [38 - 90]	
Tobacco		0.1		0.09
Current Smoker	77% [32 - 97]		69% [31 - 89]	
Non-Smoker	81% [51 - 101]		75% [44- 99]	
Ambulation		<0.001		
Independently	88% [54 - 107]		-	
With Assistance	64% [37 - 90]		-	
Procedure		0.61		0.23
Anterior Fusion	91% [59 - 102]		79% [50 - 99]	
Posterior Fusion	75% [47 - 105]		73% [28 - 92]	
Posterior Decompression	85% [49 - 98]		60% [35 - 93]	
Primary or Revision		<0.001		0.19
Primary	85% [54 - 104]		75% [45 - 98]	
Revision	62% [33 - 95]		70% [37 - 94]	
Radiculopathy		0.12		0.01
Yes	85% [49 - 103]		81% [50 - 100]	
No	74% [50 - 93]		60% [32 - 89]	
Neurogenic Claudication / Myelopathy		0.09		<0.001
Yes	74% [45 - 98]		65% [32 - 89]	
No	85% [51 - 103]		77% [52 - 100]	

Pre-operative Opioids		<0.01		0.08
Yes	70% [38 - 95]		61% [42 - 95]	
No	85% [52 - 103]		83% [43 - 97]	
Satisfaction, NASS		<0.001		<0.001
Satisfied	88% [62 - 106]		81% [53 - 100]	
Unsatisfied	26% [11 - 38]		28% [7 - 58]	
Preoperative Patient Reported Measures (Spearman's Correlation Coefficient)				
Axial Pain, NRS	-0.18	<0.001	-0.11	<0.001
Extremity Pain, NRS	-0.16	<0.001	-0.10	<0.001
Disability, ODI/NDI	-0.27	<0.001	-0.25	<0.001
Pain Interference, PROMIS	-0.22	<0.001	-0.20	<0.001
Physical Function, PROMIS	0.21	<0.001	0.28	<0.001
Depression, PROMIS	-0.15	<0.001	-0.21	<0.001
3 Month Patient Reported Measures (Spearman's Correlation Coefficient)				
Axial Pain, NRS	-0.59	<0.001	-0.33	<0.001
Extremity Pain, NRS	-0.49	<0.001	-0.34	<0.001
Disability, ODI/NDI	-0.70	<0.001	-0.51	<0.001
Pain Interference, PROMIS	-0.66	<0.001	-0.45	<0.001
Physical Function, PROMIS	0.68	<0.001	0.48	<0.001
Depression, PROMIS	-0.35	<0.001	-0.32	<0.001

Multivariable Linear Regression

Cross-Sectional Analysis at 3 months

Within the lumbar cohort, higher physical function (β: 1.0, 95% CI: 0.45 – 1.55) at 3 months was associated with a higher proportion of expectations fulfilled at 3 months, while higher pain interference (β: -0.6, 95% CI: -1.09 – 0.10), and satisfaction (β: -24.65, 95% CI: -32.92 – -16.39) at 3 months were associated with a lower proportion of expectations fulfilled (**Table 5.7)**. After adding the demographic, clinical, and surgical covariates, higher physical function at 3 months (β: 1.04, 95% CI: 0.45 – 1.63) and satisfaction at 3 months (β: -24.33, 95% CI: -32.96 – -15.70) remained significantly associated with a higher proportion fulfilled, while higher pain interference (β: -0.64, 95% CI: -1.15 – 0.12) remained significantly associated with a lower proportion fulfilled.

Table 5.3 Results of multivariable linear regression assessing the relationship between demographic, clinical, and 3 month patient reported variables and the proportion of fulfilled expectations at 3 months postoperatively in patients undergoing lumbar spine surgery

Variables	Coefficient	CI	p	Coefficient	CI	p
3 Month Patient Reported Measures						
Back Pain, NRS	-0.31	-1.94 – 1.33	0.71	-0.08	-1.80 – 1.64	0.93
Leg Pain, NRS	-0.58	-1.78 – 0.62	0.34	-0.59	-1.83 – 0.64	0.35
Disability, ODI	-0.44	-0.94 – 0.06	0.08	-0.47	-0.99 – 0.04	0.07
ODI'	0.02	-0.39 – 0.44	0.92	0.04	-0.39 – 0.48	0.85
Pain Interference, PROMIS	-0.6	-1.09 – -0.10	**0.02**	-0.64	-1.15 – -0.12	**0.02**
Physical Function, PROMIS	1	0.45 – 1.55	**<0.001**	1.04	0.45 – 1.63	**<0.01**
Depression, PROMIS	0.11	-0.16 – 0.38	0.44	0.14	-0.15 – 0.43	0.34
Satisfaction	24.65	16.39 – 32.92	**<0.001**	24.33	15.70 – 32.96	**<0.001**
Demographic						
Age				0.28	-0.12 – 0.67	0.17
Age'				-0.16	-0.62 – 0.31	0.50
BMI value				0.2	-0.28 – 0.68	0.41
Male Gender (vs. Female)				2.29	-2.97 – 7.56	0.39
Liability Claim (vs. No Claim				2.93	-6.74 – 12.59	0.55
Public Insurance (vs. Private)				1.7	-4.27 – 7.67	0.58
Non-white (vs. White)				-2.91	-10.94 – 5.13	0.48
Some College Education or Greater (vs. High School or Less)				1.28	-3.93 – 6.49	0.63
Not Currently Working (vs. Currently Working)				0.8	-5.39 – 6.99	0.80
Current Smoker (vs. non-Smoker)				1.62	-5.97 – 9.20	0.68
Ambulation (Require Assistance vs. Independently)				-1.02	-7.67 – 5.64	0.76
Clinical & Surgical						
Revision Surgery (vs. Primary)				0.19	-6.12 – 6.50	0.95
No preoperative opioid use				4.78	-1.22 – 10.78	0.11
Neurogenic Claudication				-3.91	-9.67 – 1.84	0.18
Posterior Decompression				2.54	-9.78 – 14.86	0.69
Posterior Fusion				-1.19	-13.73 – 11.35	0.85
Elixhauser Comorbidity Index				-0.14	-0.73 – 0.45	0.65

For the cross-sectional analysis with the proportion of cervical expectations fulfilled, higher 3 month physical function (β: 0.74, 95% CI: 0.12 – 1.36) and being satisfied with the surgical outcome (β: 24.61, 95% CI: 14.6 – 34.6) were associated with a higher proportion of fulfilled expectations, while higher levels of disability at 3-months (β: -0.55, 95% CI: -0.92 – -0.18) was associated with a lower proportion of fulfilled expectations when accounting for only the patient reported measures (**Table 5.8**). Upon adding the other covariates, physical function was no longer statistically significant, but higher levels of disability at 3-months (β: -0.58, 95% CI: -

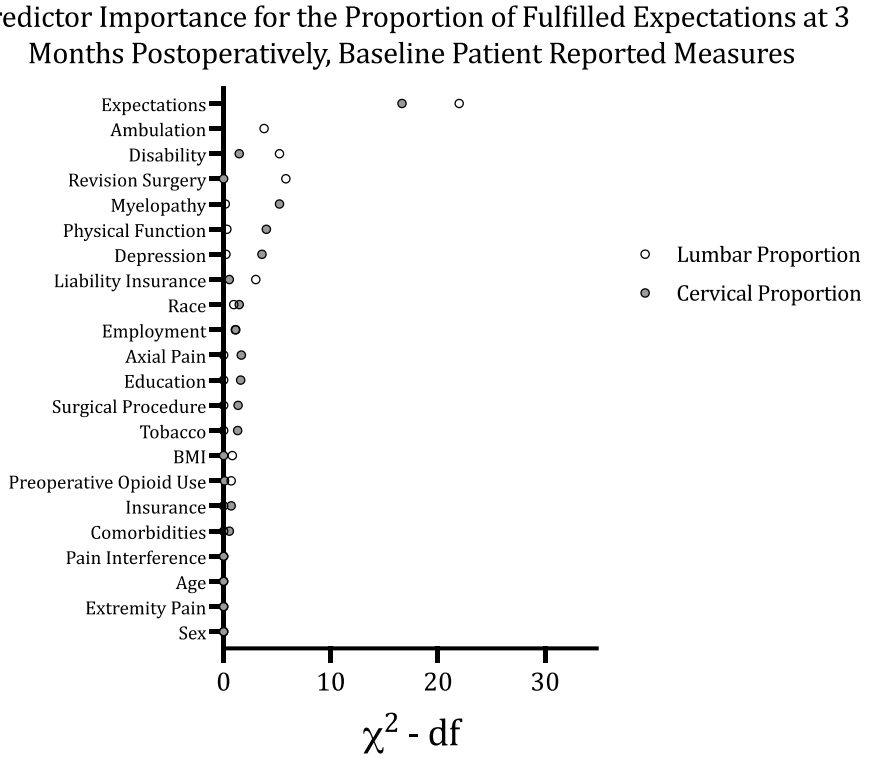
0.96 – -0.20) and satisfaction (β: 23.12, 95% CI: 12.83 – 33.41) remained associated with a lower and higher proportion of fulfilled expectations, respectively.

The importance of each variable based on its contribution to the chi-square statistic is shown in Figure 5.4 for both the lumbar and cervical cohorts. These results demonstrate that satisfaction with your surgical procedure is consistently the most important variable among the variables associated with the proportion of expectations fulfilled after adjusting for other covariates.

Table 5.4 Results of multivariable linear regression assessing the relationship between demographic, clinical, and 3-month patient reported variables and the proportion of fulfilled expectations at 3 months postoperatively in patients undergoing cervical spine surgery

Variables	Estimates	CI	p	Estimates	CI	p
3 Month Patient Reported Measures						
Neck Pain, NRS	1.09	-0.90 – 3.08	0.28	0.95	-1.09 – 2.98	0.36
Arm Pain, NRS	-1.27	-2.82 – 0.29	0.11	-1.14	-2.73 – 0.45	0.16
Disability, NDI	-0.55	-0.92 – -0.18	**<0.01**	-0.58	-0.96 – -0.20	**<0.01**
Pain Interference, PROMIS	-0.21	-0.81 – 0.39	0.49	-0.21	-0.83 – 0.41	0.50
Physical Function, PROMIS	0.74	0.12 – 1.36	**0.02**	0.6	-0.12 – 1.31	0.10
Depression, PROMIS	0.04	-0.40 – 0.47	0.87	0.02	-0.42 – 0.47	0.91
Satisfaction	24.61	14.61 – 34.60	**<0.001**	23.12	12.83 – 33.41	**<0.001**
Demographic						
Age				0.09	-0.62 – 0.80	0.81
Age'				-0.42	-1.30 – 0.45	0.34
BMI value				-0.03	-0.64 – 0.58	0.92
Male Gender (vs. Female)				0.75	-6.47 – 7.97	0.84
Liability Claim (vs. No Claim				0.43	-9.66 – 10.52	0.93
Public Insurance (vs. Private)				7.23	-1.81 – 16.27	0.12
Non-white (vs. White)				-9.16	-20.35 – 2.04	0.11
Some College Education or Greater (vs. High School or Less)				3.53	-3.89 – 10.94	0.35
Not Currently Working (vs. Currently Working)				1.46	-7.43 – 10.34	0.75
Current Smoker (vs. non-Smoker)				-6.43	-15.89 – 3.04	0.18
Clinical & Surgical						
Revision Surgery (vs. Primary)				5.27	-3.78 – 14.32	0.25
No preoperative opioid use				1.02	-7.59 – 9.62	0.82
Myelopathy				-5.81	-13.88 – 2.27	0.16
Posterior Decompression				-0.6	-9.48 – 8.28	0.89
Posterior Fusion				0.17	-14.23 – 14.57	0.98
Elixhauser Comorbidity Index				-0.22	-0.98 – 0.54	0.57

Figure 5.4. Variable importance plot depicting the strength of cross-sectional association for demographic, clinical, and patient reported variables and proportion of fulfilled expectations at 3 months postoperatively.



Abbreviations: Numeric Pain Rating Scale (NRS), Oswestry Disability Index (ODI), Neck Disability Index (NDI), Patient Reported Outcome Measurement Information System (PROMIS), Body Mass Index (BMI). Reference Groups (denoted with *): race (white* vs. non-white), working status (currently working* vs. not currently working), anticipated procedure (anterior fusion* vs. posterior fusion vs. posterior decompression), insurance type (public* vs. private), education (high school or less* vs. some college or more).

Prospective Analysis

When assessing the relationship between preoperative patient-reported measures and the proportion of lumbar expectations fulfilled at 3-months, preoperative patient reported disability had a significant non-linear relationship with the proportion of expectations fulfilled (Table 5.5, Figure 5.5). Patients with the lowest levels of preoperative disability generally had a lower proportion of their expectations fulfilled until baseline disability approached 50, at which point there was a generally flat relationship between preoperative disability and the proportion of expectations fulfilled. This relationship remained upon adding demographic, clinical, and surgical

variables, including preoperative expectations. Additionally, requiring assistance to ambulate preoperatively (β: -10.13, 95% CI: -19.23 – -1.04) and revision surgery (β: -10.89, 95% CI: -19.07 – -2.70) were associated with lower proportion of expectations fulfilled. There was a non-linear relationship between preoperative expectations and the proportion of expectations fulfilled at 3 months, as patients with lower preoperative expectations have a higher proportion of their expectations fulfilled at 3 months until preoperative expectations approach 70, at which point higher preoperative expectations were associated with a lower proportion of expectations fulfilled.

Table 5.5 Results of multivariable linear regression assessing the relationship between preoperative demographic, clinical, and patient reported variables and the proportion of fulfilled expectations at 3 months postoperatively in patients undergoing lumbar spine surgery

Variables	Coefficient	CI	p	Coefficient	CI	p
Preoperative Patient Reported Measures						
Back Pain, NRS	-0.51	-2.38 – 1.36	0.59	-0.88	-2.75 – 1.00	0.36
Leg Pain, NRS	0.09	-1.86 – 2.04	0.93	0.74	-1.21 – 2.70	0.46
Disability, ODI	-1.13	-1.76 – -0.50	**<0.001**	-0.86	-1.49 – -0.23	**<0.01**
ODI'	0.77	0.18 – 1.36	**0.01**	0.65	0.06 – 1.24	**0.03**
Pain Interference, PROMIS	-0.21	-1.05 – 0.63	0.63	0.04	-0.79 – 0.88	0.92
Physical Function, PROMIS	-0.39	-1.37 – 0.60	0.44	-0.58	-1.58 – 0.42	0.25
Depression, PROMIS	-0.15	-0.55 – 0.25	0.47	-0.22	-0.62 – 0.17	0.27
Baseline Expectations Score				-0.06	-0.47 – 0.35	0.78
Baseline Expectations Score'				-0.57	-1.11 – -0.02	**0.04**
Demographic						
Age				-0.15	-0.68 – 0.37	0.56
Age'				0.03	-0.59 – 0.64	0.94
BMI value				-0.44	-1.07 – 0.20	0.18
Male Gender (vs. Female)				-0.40	-7.56 – 6.77	0.91
Liability Claim (vs. No Claim				13.07	-0.24 – 25.89	0.05
Public Insurance (vs. Private)				-2.06	-9.96 – 5.85	0.61
Non-white (vs. White)				-7.75	-18.61 – 3.12	0.16
Some College Education or Greater (vs. High School or Less)				1.57	-5.46 – 8.60	0.66
Not Currently Working (vs. Currently Working)				-6.06	-14.26 – 2.14	0.15
Current Smoker (vs. non-Smoker)				-3.58	-13.63 – 6.47	0.48
Require Assistance to ambulate (vs. Independent)				-10.13	-19.23 – -1.04	**0.03**
Clinical & Surgical						
Revision Surgery (vs. Primary)				-10.89	-19.07 – -2.70	**<0.01**
No preoperative opioid use				5.32	-2.65 – 13.29	0.19
Neurogenic Claudication				-4.19	-11.83 – 3.46	0.28
Posterior Fusion				-1.6	-18.21 – 15.01	0.85
Posterior Decompression				-6.52	-23.57 – 10.52	0.45
Elixhauser Comorbidity Index				-0.27	-1.05 – 0.52	0.51

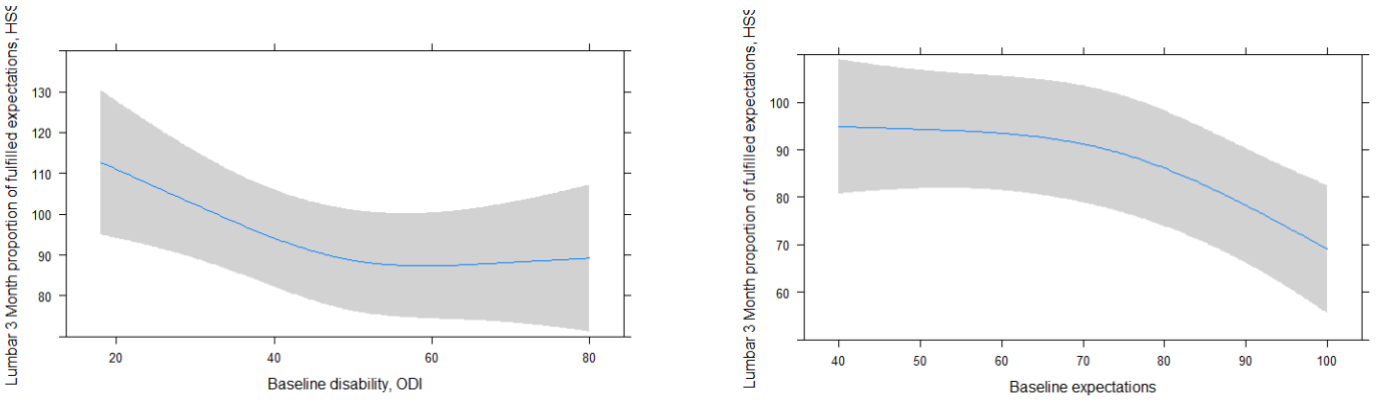


Figure 5.5 Graphs showing the relationship between (a) preoperative disability score and (b) preoperative expectations and the proportion of fulfilled expectations at 3 months when fit with restricted cubic spline with 3 knots.

Cervical

For the proportion of cervical expectations fulfilled, higher preoperative physical function (β: 1.4, 95% CI: 0.62 – 2.19) was associated with a higher proportion of fulfilled expectations at 3-months, while higher levels of depression (β: -0.49, 95% CI: -0.94 – -0.04) were associated with a lower proportion of fulfilled expectations when accounting for only the preoperative patient reported measures (**Table 5.6**). Upon adding the other covariates, the patient reported outcome measures remained, while patients presenting with myelopathy (β: -11.17, 95% CI: -19.97 – -2.37) and those with higher preoperative expectations (β: -0.41, 95% CI: -0.69 – -0.13) had a lower proportion of their expectations fulfilled.

The importance of each variable based on its contribution to the chi-square statistic is shown in Figure 5.6 for both cohorts. These results demonstrate that preoperative expectations is the most important predictor of proportion of expectations fulfilled after adjusting for other covariates.

Table 5.6 Results of multivariable linear regression assessing the relationship between preoperative demographic, clinical, and patient reported variables and the proportion of fulfilled expectations at 3 months postoperatively in patients undergoing cervical spine surgery

Variables	Coefficient	CI	p	Coefficient	CI	p
Preoperative Patient Reported Measures						
Neck Pain, NRS	1.48	-0.66 – 3.62	0.18	1.78	-0.37 – 3.92	0.10
Arm Pain, NRS	-0.53	-2.34 – 1.28	0.56	-0.09	-1.93 – 1.74	0.92
Disability, NDI	-0.63	-1.27 – 0.02	0.06	-0.57	-1.21 – 0.08	0.09
NDI'	0.49	-0.17 – 1.15	0.14	0.31	-0.35 – 0.97	0.35
Pain Interference, PROMIS	0.22	-0.55 – 0.99	0.57	0.33	-0.45 – 1.11	0.40
Physical Function, PROMIS	1.4	0.62 – 2.19	**<0.001**	0.99	0.12 – 1.86	**0.03**
Depression, PROMIS	-0.49	-0.94 – -0.04	**0.03**	-0.5	-0.95 – -0.04	**0.03**
Baseline Expectations Score				-0.41	-0.69 – -0.13	**<0.01**
Baseline Expectations Score'				-0.05	-0.56 – 0.47	0.86
Demographic						
Age				0.07	-0.70 – 0.84	0.87
Age'				-0.29	-1.24 – 0.66	0.55
BMI value				-0.33	-1.00 – 0.34	0.34
Male Gender (vs. Female)				0.69	-7.21 – 8.59	0.86
Liability Claim (vs. No Claim				6.85	-4.00 – 17.70	0.22
Public Insurance (vs. Private)				6.57	-3.29 – 16.43	0.19
Non-white (vs. White)				-9.78	-22.05 – 2.49	0.12
Some College Education or Greater (vs. High School or Less)				6.65	-1.47 – 14.76	0.11
Not Currently Working (vs. Currently Working)				-7.17	-16.78 – 2.44	0.14
Current Smoker (vs. non-Smoker)				-8.02	-18.39 – 2.35	0.13
Clinical & Surgical						
Revision Surgery (vs. Primary)				-2.75	-12.98 – 7.48	0.60
No preoperative opioid use				5.06	-4.47 – 14.59	0.30
Myelopathy				-11.17	-19.97 – -2.37	**0.01**
Posterior Decompression				-8.93	-18.70 – 0.83	0.07
Posterior Fusion				-5.88	-21.66 – 9.89	0.46
Elixhauser Comorbidity Index				-0.53	-1.36 – 0.31	0.22

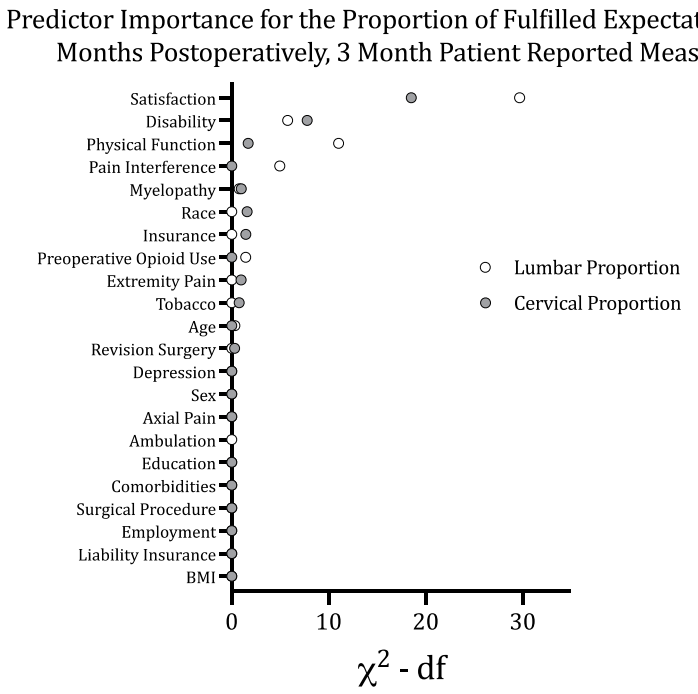


Figure 5.6. Variable importance plot depicting the strength of association for preoperative demographic, clinical, and patient reported variables and the proportion of fulfilled expectations at 3 months postoperatively.

Abbreviations: Numeric Pain Rating Scale (NRS), Oswestry Disability Index (ODI), Neck Disability Index (NDI), Patient Reported Outcome Measurement Information System (PROMIS), Body Mass Index (BMI). Reference Groups (denoted with *): race (white* vs. non-white), working status (currently working* vs. not currently working), anticipated procedure (anterior fusion* vs. posterior fusion vs. posterior decompression), insurance type (public* vs. private), education (high school or less* vs. some college or more).

DISCUSSION

This analysis of registry data of patients undergoing elective lumbar and cervical spine surgery at a single academic medical center evaluated the fulfillment of individual items of the HSS Lumbar and Cervical Spine Surgery Expectations Surveys and assessed the relationship between these surveys and patient reported measures and demographic, clinical, and surgical variables. The results demonstrated poor distribution for the fulfillment of preoperative expectations for items related to sexual function and work status for patients undergoing lumbar spine surgery, and sexual function, work status, and return to sports among patients undergoing cervical spine surgery. In both the 3-month lumbar and cervical multivariable models, satisfaction was

consistently associated with the proportion of fulfilled expectations, while the preoperative models demonstrated the importance of preoperative expectations to fulfilled expectations at 3-months. However, the models varied in their associations with other patient reported measures; in the three-month models, pain interference and physical function were associated with the proportion of fulfilled expectations among patients undergoing lumbar spine surgery, while disability was associated with the proportion of fulfilled expectations among patients undergoing cervical spine surgery. In the preoperative models, disability was a significant predictor of fulfilled expectations in the lumbar cohort, while physical function and depression were significant predictors of fulfilled expectations in the cervical cohort. Additional significant covariates at the preoperative time point included ambulation and revision surgery for the lumbar cohort and myelopathy for the cervical cohort.

The distribution of item scores for the proportion of fulfilled expectations was found to be similar to the distribution of the preoperative expectations item scores within this dissertation project (Chapter 4, pg. 88). The lowest proportion of fulfilled expectations was found for work status and sexual activity in patients undergoing both lumbar and cervical spine surgery, while return to sports was an unresolved issue for the cervical cohort only. Prior work using the Expectations Surveys also found that return to work was fulfilled least often; however, our sexual activity and return to sports findings were not consistent with work by Mancuso et al (73). This discrepancy may be due to the timeframe used in the prior study, which included fulfilled expectations at 2 years post-operatively rather than 3-months as used in our study. Separate studies by Mannion et al. and Licina and colleagues measured the fulfillment of expectations as an expectation-actuality discrepancy using the expectations component of the North America Spine Society Lumbar Spine Questionnaire and expected change in symptoms measured through visual analog scales and ODI , respectively.(5, 12) These authors found that the greatest discrepancies in

expectations versus actual results were related to general physical capacity, the ability to play sports, disability, and back and leg pain in patients undergoing lumbar spine surgery. Future research may benefit from creating subscores for the proportion of fulfilled expectations related to components such as expected pain relief and expected disability, as some studies have shown that fulfillment of individual domains are significant predictors of fulfilled expectations.(5, 6, 9)

Satisfaction with surgical outcome was associated with a higher proportion of fulfilled expectations at 3 months postoperatively for patients undergoing both lumbar and cervical procedures and consistently the most important variable in the model based on Chi-square minus degree of freedom plots. This relationship is frequently shown in the literature both within spine surgery populations and general orthopaedics.(5, 8, 9, 20-25) This may be due, in part, to the expectancy-discrepancy theory.(26) This theory postulates that expectations create a point of reference for an individual to evaluate an event; when an outcome meets or exceeds expectations, an individual is satisfied. Additionally, Munn and colleagues found that met expectations moderates the relationship between disability and satisfaction in patients undergoing total knee arthroplasty.(27) As such, it may be of value to address the moderating effect of fulfilled expectations in the early post-operative period in future research for this patient population.

In the preoperative multivariable regression models, preoperative expectations were the most important predictor for proportion of fulfilled expectations at 3-months. This finding is similar to work by Mancuso et al. that found greater preoperative expectations to be significantly associated with less fulfillment of expectations at 2 years post-operatively.(14) It is important to note that we found a non-linear relationship between preoperative expectations and the proportion of fulfilled expectations for the lumbar cohort. This may represent overly optimistic expectations which are not attainable; thus, the salient issue is whether such high expectations are realistic for most patients undergoing elective spine procedures.

An additional non-linear relationship was found between preoperative disability and the proportion of fulfilled expectations among patients undergoing lumbar spine surgery. In our sample, lower preoperative disability is associated with a higher proportion of fulfilled expectations until the score approaches 50, at which point the proportion fulfilled score had no relationship with disability. Rather than predicting fulfilled expectations from preoperative patient reported measures, most other studies have investigated the relationship between fulfilled expectations and changes in pre- to postoperative disability, and found that less improvement in disability is associated with a lower proportion of fulfilled expectations.(13, 14) In our study, 3-month disability was also associated with the proportion of fulfilled expectations among patients undergoing cervical spine surgery. Although prior work has not strictly characterized the relationship between postoperative disability and postoperative expectation fulfillment, both Mancuso et al. and Mannion et al. found an association between clinically significant changes in disability and fulfilled expectations among patients undergoing spine procedures.(5, 14) Additional preoperative and 3-month variables that were significantly associated with fulfilled expectations at 3-months included ambulation, revision, and 3-month pain interference and physical function for the lumbar cohort and preoperative physical function and depression for the cervical cohort. While previous studies have not examined the ambulation variable in relation to fulfilled expectations, analysis presented in chapter 4 showed that the patients who could ambulate independently also had higher preoperative expectations, which would also make them more difficult to fulfill. Further, the relationship between pain interference and physical function and fulfilled expectations has not been investigated in a degenerative spine population. However, Henry et al. found that higher preoperative physical function and lower pain interference scores were associated with higher fulfilled expectations among patients undergoing extremity orthopaedic surgery.(28) Similar to our findings, Mancuso et al. noted that patients with a positive

screen for depression had a lower proportion of their expectations fulfilled based on bivariate analysis at 2 years postoperatively; however, they did not include depression in multivariable analysis.(13)

In conclusion, results demonstrated that preoperative expectations and satisfaction at 3-months are the most important contributors to fulfilled expectations at 3-months after spine surgery. Additional patient-reported measures of disability, physical function, pain interference, and depression at either the preoperative or 3-month time-point also contributed to fulfilled expectations. Specific expectations that were least likely to be met at 3-months appeared to be return to work and sexual activity for patients undergoing lumbar and cervical surgery as well as return to sports for the cervical cohort. Findings have important implications for both the assessment and management of this patient population. Health care providers may want to consider comprehensively assessing expectations prior to surgery and at an early postoperative time-point to inform preoperative counseling and education efforts as well as referral to rehabilitation after surgery. Unresolved expectations around specific activities, such as return to work, may warrant referral for targeted postoperative care. While findings suggest that addressing patient expectations will improve satisfaction with surgery and other important patient-reported outcomes such as disability and physical function, additional research is needed to better understand the importance of preoperative expectations and their fulfillment on longer-term outcomes in patients undergoing spine surgery.

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CHAPTER 6

PREDICTIVE VALUE OF EXPECTATIONS & FULFILLED EXPECTATIONS FOR SPINE SURGERY OUTCOMES AT 12-MONTHS

Introduction

Expectations of elective spine procedures can be major determinants in the decision to undergo surgery, where prediction of their future condition may affect their treatment choices and perceptions of postoperative outcomes.(1-4) Prior research reveals that patients undergoing spine surgery generally have high expectations for the results of their surgical procedure; this includes an expected reduction in pain and disability as a result of surgery.(47, 50) There is no consensus on the relationship between preoperative expectations and fulfilled expectations on postoperative outcomes such as satisfaction. Some studies concluded that higher expectations were associated with higher levels of post-operative satisfaction or postoperative functional outcomes (1, 5, 6), while others noted that "unrealistically high" expectations lead to less satisfaction with their operative outcome.(1, 7, 8) Still other researchers have argued that fulfilled expectations, rather than the preoperative expectations themselves, have an impact on postoperative satisfaction.(1, 2, 5, 9)

Ultimately, the lack of agreement among studies could be due to the variety of measurement tools that have been used to assess patient expectations and fulfilled expectations. Most existing work utilized ad-hoc, physician derived surveys, or non-validated subscores within measures to assess patient expectations.(1, 2, 5-7, 9-11) Additionally, prior studies have quantified fulfilled expectations across a number of domains, including fulfilled improvements in disability, pain, and social roles, and compared preoperative expectations with the patients' perceived outcomes across the same domains.(2, 5, 12-14) Mancuso and colleagues have developed a series of validated expectations surveys specific to patients undergoing lumbar and cervical spine surgery, as well as a novel proportion of fulfilled expectations for use

postoperatively.(15-17) These tools have been validated at a single academic center, but additional work has not been done to examine the external validity of these expectations surveys. Additionally, there has been limited use of these tools to assess the relationship between preoperative expectations and fulfilled expectations at early postoperative time periods on functional outcomes.(14, 18) The goal of this study is to determine the association between preoperative expectations and fulfilled expectations at 3 months on disability, physical function, pain and satisfaction at 12-months postoperatively.

Methods

Patient Population

At the preoperative timepoint, 693 and 578 patients were enrolled in the prospective Vanderbilt Spine Registry. In order to be eligible for inclusion in the present study, patients needed to have completed the 1) HSS preoperative expectations survey, 2) HSS 3-month expectations fulfilled survey, and 3) at least one of the patient-reported outcome measures at 12 months, including the Oswestry/disability indices, NRS pain scales, or PROMIS pain interference or Physical Function questionnaire. When comparing the cohorts of patients who completed preoperative questionnaires alone to those eligible for inclusion, negligible (<0.2) effect sizes (Cohen's D) were present for all cervical patients, while small cohen's d values were present for age (D = 0.28) among lumbar participants.(19) All differences were negligible for preoperative expectations for both patients undergoing both lumbar (non-responders cohort: 71.8, responders cohort: 74.8), or cervical (non-responders cohort: 64.7, responders cohort: 68.5) spine surgery.

Patient Expectations

Patient expectations are measured using the HSS Lumbar and Cervical Spine Surgery Expectations Surveys, which have been previously described in chapters 4 and 5 of this

manuscript. Preoperative expectations were used as a continuous measurement, while fulfilled expectations were defined the aforementioned proportion of fulfilled expectations.

Outcomes

Outcomes data were collected 12-months postoperatively. Outcomes included back- and neck-related disability (ODI and NDI), physical function (PROMIS), back/neck pain (NRS), leg/arm pain (NRS), pain interference (PROMIS), and satisfaction (NASS).

Statistical Analysis

Descriptive statistics were used to characterize the demographic, clinical, and surgical characteristics for the lumbar and cervical cohorts at baseline, three months, and 12 months, including frequency and proportion for categorical variables or mean and standard deviation for continuous variables. A series of multivariable models with block entry of predictors were developed for each 12-month outcome. In the first model, preoperative patient expectations and the relevant preoperative outcome were assessed in block one to establish the relationship between preoperative expectations and the outcomes when controlling for preoperative level of pain, disability, etc. (e.g. in the back pain model, 12-month Back Pain = β_1 (Preoperative Expectations) + β_2 (preoperative back pain). In the second block, additional covariates, including relevant demographic, clinical, and surgical variables were added in conjunction with the other preoperative patient reported measures. The second model followed a similar process, with the proportion of fulfilled expectations and the relevant 3-month patient reported outcome predicting the 12-month patient reported outcome (e.g. in the back pain model, 12-month back pain = β_1 (Proportion of Fulfilled Expectations) + β_2 (3-month back pain). In the second block, additional covariates, including relevant demographic, clinical, and surgical variables were added in conjunction with the other 3-month patient reported measures. The third model assessed the interaction of preoperative expectations and the proportion of fulfilled expectations on 12-month

patient reported outcomes. Block one followed a similar structure, with the interaction of preoperative expectations and the proportion of fulfilled expectations entered at the same time as the 3-month patient reported outcome (e.g. in the back pain model, 12-month Back Pain = β_1 (Preoperative Expectations) + β_2 (Proportion of Fulfilled Expectations) + β_3 (Preoperative Expectations * Proportion of Fulfilled Expectations) + β_4 (3-month back pain). In the second block, additional covariates, including relevant demographic, clinical, and surgical variables were added in conjunction with the other 3-month patient reported measures. Multiple linear regression models were used for the continuous outcomes, and multiple logistic regression was used for 12-month satisfaction.

All regression models were initially fit with restricted cubic splines on continuous variables to allow for potential non-linear relationships between the variables and outcomes. Age, preoperative expectations, the proportion of fulfilled expectations, and all patient reported measures were initially fit with 3 knots at the 10^{th}, 50^{th}, and 90^{th} percentiles as automatically selected in the RMS package. (20) Reduction of the models proceeded by comparing reduced, nested models with a likelihood ratio test to assess model fit between models including linear and non-linear terms. Non-linear terms were removed if they did not improve the fit of the model. Variable importance to the final multivariable models were assessed using Chi-square statistics minus degrees of freedom.

Less than 5% of data were missing for all variables. Missing values were multiply imputed using a flexible additive imputation model with predictive mean matching (aregImpute from the Hmisc package in R). A p-value of 0.05 was considered statistically significant, and all confidence intervals are set to 95%. Analyses were conducted using R 4.1.0 with the rms and Hmisc packages.(20-22)

Results

Our total sample consisted of 394 and 321 patients undergoing elective spine surgery for lumbar and cervical conditions, respectively. The mean age (standard deviation [SD]) of the lumbar cohort was 59.8 [13.2], compared to 56.9 [11.4] for the cervical cohort (**Table 6.1**). In both populations, 11% of participants identified as non-white, and slightly more males participated than females (51% lumbar, 54% cervical). At 12-months postoperatively, satisfaction (79% lumbar and cervical), and disability were similar between the cohorts (**Table 6.2**)

Table 6.1: Patient demographic, clinical and surgical characteristics and patient-reported outcome measures for patients with complete 12-month data

	Lumbar Cohort (n=394) N (%) or Mean [SD]	Cervical Cohort (N=321) N (%) or Mean [SD]
Patient Demographics		
Age	59.8 [13.2]	56.9 [11.4]
Body Mass Index	31.1 [6.3]	30.5 [6.5]
Gender		
Female	192 (49%)	148 (46%)
Male	200 (51%)	172 (54%)
Missing	2 (1%)	1 (0%)
Race		
White	337 (86%)	275 (86%)
Non-White	44 (11%)	36 (11%)
Missing	13 (3%)	10 (3%)
Ambulation		
Independently	285 (72%)	-
Require Assistance	102 (26%)	-
Missing	7 (2%)	-
Insurance		
Private	203 (52%)	185 (58%)
Public	190 (48%)	135 (42%)
Missing	1 (0%)	1 (0%)
Education		
High School or Less	167 (42%)	134 (42%)
Some College or More	219 (56%)	180 (56%)
Missing	8 (2%)	7 (2%)
Employment		
Working	140 (36%)	130 (40%)
Not Currently Working	251 (64%)	191 (60%)
Missing	3 (1%)	
Smoker		
Non-Smoker	344 (87%)	266 (83%)
Current Smoker	47 (12%)	55 (17%)
Missing	3 (1%)	
Clinical and Surgical Characteristics		
Comorbidity Index, Elixhauser [IQR]	-2.7 [-16 - 19]	-2.44 [-14 - 21]
Preoperative Opioid Use	97 (25%)	72 (22%)
Revision Surgery	93 (24%)	67 (21%)
Radiculopathy	310 (79%)	198 (62%)
Neurogenic Claudication or Myelopathy	126 (32%)	119 (37%)

Procedure		
Anterior Fusion	17 (4%)	198 (62%)
Posterior Fusion	224 (57%)	101 (32%)
Posterior Decompression	153 (39%)	22 (7%)
Patient Reported Measures		
Preoperative		
Expectations Score	74.9 [18.5]	68.1 [23]
Disability, ODI and NDI	48.5 [15.3]	43.6 [16.6]
Back/Neck Pain Intensity, NRS	6.5 [2.4]	5.9 [2.8]
Leg/ Arm Pain Intensity, NRS	6.9 [2.2]	5.5 [3]
PROMIS		
Pain Interference	67.8 [6.5]	64.8 [8.1]
Physical Function	33.6 [5.5]	38.1 [6.4]
Depression	51.6 [9.6]	51.9 [9.5]
3 Months		
Proportion of Fulfilled Expectations	81.5 [48.3]	79.3 [50.3]
Disability, ODI and NDI	29.2 [19.5]	29.5 [18.7]
Back/Neck Pain Intensity, NRS	3.4 [2.7]	3.3 [2.6]
Leg/Arm Pain Intensity, NRS	2.6 [2.9]	2.4 [2.7]
PROMIS		
Pain Interference	57.2 [10]	57.3 [9.6]
Physical Function	41.2 [8.7]	42.2 [8.7]
Patient Satisfaction		
Satisfied	332 (84%)	274 (85%)
Unsatisfied	56 (14%)	45 (14%)
Missing	6 (2%)	2 (1%)

Abbreviations: Body Mass Index (BMI), Patient-Reported Outcomes Measurement Information System (PROMIS), Numeric Rating Scale (NRS), Oswestry Disability Index (ODI), Neck Disability Index (NDI)
Note: PROMIS measures are reported as t-scores; the standardized t-scores have a population mean of 50, and a standard deviation of 10.

Table 6.2: Patient-reported outcome measures at 12-months postoperatively		
	Lumbar Cohort (n=394)	Cervical Cohort (N=321)
Disability, ODI and NDI	28.5 [19.9]	28.8 [19.2]
Back/Neck Pain Intensity, NRS	3.7 [2.9]	3.6 [2.9]
Leg/Arm Pain Intensity, NRS	3.2 [3]	2.9 [2.9]
PROMIS		
Pain Interference	57.5 [10.3]	57 [10.6]
Physical Function	42.6 [9.4]	43.1 [9.4]
Patient Satisfaction		
Satisfied	313 (79%)	253 (79%)
Unsatisfied	78 (20%)	62 (19%)
Missing	3 (1%)	6 (2%)

Lumbar

Higher preoperative expectations of lumbar surgery was associated with lower levels of back pain (Coefficient [95% Confidence Interval]: -0.31 [-0.45 – -0.17]), leg pain (-0.3 [-0.45 – -0.14]), disability, (-2.37 [-3.32 – -1.43]), and pain interference (-1.11 [-1.64 – -0.58]), as well as higher physical function (0.92 [0.45 – 1.39]) at 12 months postoperatively when controlling for the preoperative value (**Table 6.3**). Once additional covariates were added in the second block, higher preoperative expectations remain associated with lower levels of back pain (Coefficient [95% Confidence Interval]: - -0.28 [-0.43 – -0.14]), leg pain (-0.21 [-0.36 – -0.05]), disability, (-1.96 [-2.91 – -1.01]), and pain interference (-0.74 [-1.27 – -0.21]). Additionally, higher preoperative expectations remained associated with higher levels of physical function at 12 months postoperatively (0.61 [0.17 – 1.06]). Preoperative expectations were not found to be statistically associated with 12 months satisfaction based on logistic regression.

In the second model assessing the relationship between the proportion of fulfilled expectations and 12 month patient reported outcomes, a higher proportion of fulfilled expectations was associated with lower levels of leg pain (-0.01 [-0.01 – -0.00]) and pain interference (-0.02 [-0.04 – -0.00]), when controlling for the 3 month outcome, as well as higher odds of satisfaction at 12 months postoperatively (Odds Ratio (OR) [95% CI]: 1.03 [1.02-1.04] **(Table 6.4)**. Upon adding the second block of covariates, a higher proportion of fulfilled

expectations remained associated with higher odds of satisfaction (OR 1.02 [1.01-1.03]. However, there was no statistical relationship between the proportion of fulfilled expectations and 12-month patient reported outcomes of leg pain and pain interference.

A significant interaction term was observed between preoperative expectations and the proportion of fulfilled expectations (OR 1.01 [1.00 – 1.01] on 12-month satisfaction among patients undergoing lumbar spine surgery. When the preoperative expectation score is greater than 41.7, the slope of the proportion of expectations fulfilled is $p< 0.05$, indicating that the proportion of fulfilled expectations mattered more when patient expectations were higher preoperatively. No other significant interaction terms were noted.

Cervical

Higher preoperative expectations of lumbar surgery were associated with lower levels of neck pain (Coefficient [95% Confidence Interval]: -0.23 [-0.36 – -0.11]), arm pain (-0.27 [-0.40 – -0.14]), disability, (-1.58 [-2.32 – -0.84]), and pain interference (-1.01 [-1.45 – -0.57]), as well as higher physical function (0.83 [0.48 – 1.18]) at 12 months postoperatively when controlling for the preoperative value (**Table 6.5**). Higher preoperative expectations were also found to be associated with higher odds of 12-month satisfaction in simple logistic regression (OR 1.19 [1.08 – 1.28]. Once additional covariates were added in the second block, higher preoperative expectations remained associated with lower levels of disability, (-.80 [-1.60- – -0.01]) and pain interference (-0.58 [-1.05 – -0.10]). Additionally, higher preoperative expectations remained associated with higher levels of physical function at 12 months postoperatively (0.45 [0.07 – 0.83]) and higher odds of satisfaction at 12-months postoperatively (OR 1.15 [1.01 -1.28])

In the second model assessing the relationship between the proportion of fulfilled expectations and 12 month patient reported outcomes, a higher proportion of fulfilled

expectations was associated with lower levels of arm pain (-0.01 [-0.01 – -0.00]) when controlling for the 3 month outcome, as well as higher odds of satisfaction at 12 months postoperatively (Odds Ratio (OR) [95% CI]: 1.02 [1.01-1.03] **(Table 6.6)**. Upon adding the second block of covariates, a higher proportion of fulfilled expectations remained associated with higher odds of satisfaction (OR 1.01 [1.00-1.02]. Additionally, a higher proportion of fulfilled expectations was associated with higher pain interference (0.03 [0.01 – 0.05] at 12 months despite not being associated in univariate analysis. No other statistical relationships between the proportion of fulfilled expectations and 12-month patient reported outcomes of back pain, leg pain, disability, or physical function were observed. There were no significant findings from model 3, which evaluated the effect of the interaction between preoperative expectations and the proportion of fulfilled expectations on 12 month outcomes for patients undergoing cervical spine surgery.

Table 6.3 Results of multiple regression analysis with block entry of predictors showing the association between preoperative expectations and patient reported measures on 12 month back pain, leg pain, disability, pain interference, physical function, and satisfaction for patients undergoing elective lumbar spine surgery.

		12 Mo. Back Pain	12 Mo. Leg Pain	12 Mo. Disability	12 Mo. Pain Interference	12 Mo. Physical Function	12 Mo. Satisfaction
		Coefficient [95% CI]	Coefficient [95% CI]	Coefficient [95% CI]	Coefficient [95% CI]	Coefficient [95% CI]	Odds Ratio [95% CI]
Block 1*	Preoperative Expectations, HSS	-0.31 [-0.45 – -0.17]	-0.3 [-0.45 – -0.14]	-2.37 [-3.32 – -1.43]	-1.11 [-1.64 – -0.58]	0.92 [0.45 – 1.39]	1.08 [0.95 – 1.20]
	Preoperative PRO	0.50 [0.39 – 0.60]	0.42 [0.30 – 0.55]	0.57 [0.45 – 0.68]	0.53 [0.38 – 0.68]	0.60 [0.45 – 0.76]	-
Block 2#	Preoperative Expectations, HSS	-0.28 [-0.43 – -0.14]	-0.21 [-0.36 – -0.05]	-1.96 [-2.91 – -1.01]	-0.74 [-1.27 – -0.21]	0.61 [0.17 – 1.06]	1.04 [0.88 – 1.17]
	Preoperative Back Pain, NRS	0.34 [0.20 – 0.48]	0.28 [0.13 – 0.43]	1.38 [0.46 – 2.31]	0.91 [0.40 – 1.43]	-0.8 [-1.23 – -0.37]	0.93 [0.75 – 1.08]
	Preoperative Leg Pain, NRS	0.11 [-0.04 – 0.26]	0.21 [0.05 – 0.37]	0.34 [-0.64 – 1.32]	0.02 [-0.52 – 0.57]	0.11 [-0.35 – 0.57]	0.96 [0.77 – 1.12]
	Preoperative Disability, ODI	0.01 [-0.01 – 0.04]	0.02 [-0.01 – 0.05]	0.28 [0.10 – 0.47]	0.06 [-0.04 – 0.17]	-0.06 [-0.15 – 0.03]	0.98 [0.95 – 1.01]
	Preoperative Pain Interference, PROMIS	0.03 [-0.03 – 0.09]	-0.01 [-0.08 – 0.05]	0.18 [-0.22 – 0.58]	0.2 [-0.02 – 0.43]	-0.04 [-0.22 – 0.15]	0.99 [0.92 – 1.05]
	Preoperative Physical Function, PROMIS	0.11 [0.04 – 0.18]	0.07 [-0.00 – 0.15]	0.42 [-0.05 – 0.90]	0.28 [0.01 – 0.54]	0.02 [-0.20 – 0.24]	0.91 [0.83 – 0.99]

Abbreviations: Hospital for Special Surgery (HSS), Numeric Rating Scale (NRS), Oswestry Disability Index (ODI), Patient Reported Outcome Measurement Information System (PROMIS); *Block one for all models included preoperative expectations and the preoperative measure of the outcome (e.g., 12 month back pain = β_1 preoperative expectations + β_2 preoperative back pain); # Additional unlisted block 2 covariates included depression (PROMIS), age, body mass index, elixhauser comorbidity index, race (white* vs. non-white), working status (currently working* vs. not currently working), anticipated procedure (anterior fusion* vs. posterior fusion vs. posterior decompression), insurance type (public* vs. private), education (high school or less* vs. some college or more) (reference groups denoted with *).

Table 6.4 Results of multiple regression analysis with block entry of predictors showing the association between the proportion of fulfilled expectations and patient reported measures at 3 months on 12 month back pain, leg pain, disability, pain interference, physical function, and satisfaction for patients undergoing elective lumbar spine surgery.

		12 Mo. Back Pain	12 Mo. Leg Pain	12 Mo. Disability	12 Mo. Pain Interference	12 Mo. Physical Function	12 Mo. Satisfaction
		Coefficient [95% CI]	Coefficient [95% CI]	Coefficient [95% CI]	Coefficient [95% CI]	Coefficient [95% CI]	Odds Ratio [95% CI]
Block 1*	Proportion of Fulfilled Expectations, HSS	0 [-0.01 – 0.00]	-0.01 [-0.01 – -0.00]	-0.02 [-0.05 – 0.02]	-0.02 [-0.04 – -0.00]	0.01 [-0.01 – 0.03]	1.03 [1.02 – 1.04]
	3 Month PRO	0.54 [0.40 – 0.69]	0.28 [0.16 – 0.40]	0.36 [0.19 – 0.53]	0.24 [0.09 – 0.39]	0.71 [0.61 – 0.81]	-
Block 2#	Proportion of Fulfilled Expectations, HSS	0 [-0.01 – 0.01]	0 [-0.00 – 0.01]	0 [-0.03 – 0.04]	0 [-0.02 – 0.02]	0 [-0.02 – 0.02]	0.98 [0.97 – 0.99]
	3 Mo. Back Pain, NRS	0.54 [0.40 – 0.69]	0.17 [-0.00 – 0.33]	1.34 [0.43 – 2.25]	0.74 [0.22 – 1.26]	-0.43 [-0.87 – 0.01]	0.76 [0.47 – 0.99]
	3 Mo. Leg Pain, NRS	0.06 [-0.04 – 0.16]	0.28 [0.16 – 0.40]	0.12 [-0.51 – 0.76]	0.09 [-0.27 – 0.46]	-0.01 [-0.32 – 0.30]	0.97 [0.83 – 1.10]
	3 Mo. Disability, ODI	0.01 [-0.02 – 0.04]	0.02 [-0.01 – 0.05]	0.36 [0.19 – 0.53]	0.06 [-0.04 – 0.16]	-0.06 [-0.15 – 0.02]	0.98 [0.94 – 1.02]
	3 Mo. Pain Interference, PROMIS	0.01 [-0.03 – 0.05]	0 [-0.04 – 0.05]	0.11 [-0.15 – 0.37]	0.24 [0.09 – 0.39]	-0.09 [-0.22 – 0.03]	0.96 [0.89 – 1.02]
	3 Mo. Physical Function, PROMIS	-0.01 [-0.06 – 0.04]	-0.01 [-0.06 – 0.05]	-0.29 [-0.60 – 0.02]	-0.13 [-0.30 – 0.05]	0.33 [0.18 – 0.48]	0.94 [0.76 – 1.02]

Abbreviations: Hospital for Special Surgery (HSS), Numeric Rating Scale (NRS), Oswestry Disability Index (ODI), Patient Reported Outcome Measurement Information System (PROMIS); *Block one for all models included the proportion of fulfilled expectations and the 3 month measure of the outcome (e.g., 12 month back pain = β_1 proportion of fulfilled expectations + β_2 3 month back pain); # Additional unlisted block 2 covariates included depression (PROMIS), age, body mass index, elixhauser comorbidity index, race (white* vs. non-white), working status (currently working* vs. not currently working), anticipated procedure (anterior fusion* vs. posterior fusion vs. posterior decompression), insurance type (public* vs. private), education (high school or less* vs. some college or more) (reference groups denoted with *).

Table 6.5 Results of multiple regression analysis with block entry of predictors showing the association between preoperative expectations and patient reported measures on 12 month neck pain, arm pain, disability, pain interference, physical function, and satisfaction for patients undergoing elective cervical spine surgery.

		12 Mo. Neck Pain	12 Mo. Arm Pain	12 Mo. Disability	12 Mo. Pain Interference	12 Mo. Physical Function	12 Mo. Satisfaction
		Coefficient [95% CI]	Coefficient [95% CI]	Coefficient [95% CI]	Coefficient [95% CI]	Coefficient [95% CI]	Odds Ratio [95% CI]
Block 1*	Preoperative Expectations, HSS	-0.23 [-0.36 – -0.11]	-0.27 [-0.40 – -0.14]	-1.58 [-2.32 – -0.84]	-1.01 [-1.45 – -0.57]	0.83 [0.48 – 1.18]	1.19 [1.08 – 1.28]
	Preoperative PRO	0.53 [0.43 – 0.63]	0.39 [0.29 – 0.50]	0.67 [0.57 – 0.77]	0.65 [0.52 – 0.77]	0.85 [0.73 – 0.98]	-
Block 2#	Preoperative Expectations, HSS	-0.09 [-0.22 – 0.04]	-0.13 [-0.27 – 0.00]	-0.8 [-1.60 – -0.01]	-0.58 [-1.05 – -0.10]	0.45 [0.07 – 0.83]	1.15 [1.00– 1.28]
	Preoperative Neck Pain, NRS	0.26 [0.12 – 0.41]	0.07 [-0.09 – 0.22]	1.09 [0.20 – 1.98]	0.52 [-0.01 – 1.06]	-0.29 [-0.72 – 0.13]	0.81 [0.57 – 1.02]
	Preoperative Arm Pain, NRS	0.05 [-0.07 – 0.17]	0.2 [0.06 – 0.33]	-0.12 [-0.87 – 0.64]	-0.02 [-0.47 – 0.44]	0.42 [0.05 – 0.78]	1.05 [0.90 – 1.18]
	Preoperative Disability, ODI	0.01 [-0.02 – 0.04]	0.01 [-0.02 – 0.04]	0.33 [0.17 – 0.49]	0.04 [-0.05 – 0.14]	-0.03 [-0.11 – 0.04]	1 [0.97 – 1.03]
	Preoperative Pain Interference, PROMIS	0.05 [0.00 – 0.10]	0.03 [-0.03 – 0.08]	0.13 [-0.19 – 0.44]	0.32 [0.13 – 0.51]	-0.02 [-0.17 – 0.13]	1.01 [0.94 – 1.07]
	Preoperative Physical Function, PROMIS	-0.01 [-0.06 – 0.05]	-0.03 [-0.09 – 0.03]	-0.25 [-0.61 – 0.11]	-0.14 [-0.36 – 0.08]	0.58 [0.40 – 0.75]	1.02 [0.94 – 1.09]

Abbreviations: Hospital for Special Surgery (HSS), Numeric Rating Scale (NRS), Oswestry Disability Index (ODI), Patient Reported Outcome Measurement Information System (PROMIS); *Block one for all models included preoperative expectations and the preoperative measure of the outcome (e.g., 12 month neck pain = β_1 preoperative expectations + β_2 preoperative neck pain); # Additional unlisted block 2 covariates included depression (PROMIS), age, body mass index, elixhauser comorbidity index, race (white* vs. non-white), working status (currently working* vs. not currently working), anticipated procedure (anterior fusion* vs. posterior fusion vs. posterior decompression), insurance type (public* vs. private), education (high school or less* vs. some college or more) (reference groups denoted with *).

Table 6.6 Results of multiple regression analysis with block entry of predictors showing the association between the proportion of fulfilled expectations and patient reported measures at 3 months on 12 month neck pain, arm pain, disability, pain interference, physical function, and satisfaction for patients undergoing elective cervical spine surgery.

		12 Mo. Neck Pain	12 Mo. Arm Pain	12 Mo. Disability	12 Mo. Pain Interference	12 Mo. Physical Function	12 Mo. Satisfaction
		Coefficient [95% CI]	Coefficient [95% CI]	Coefficient [95% CI]	Coefficient [95% CI]	Coefficient [95% CI]	Odds Ratio [95% CI]
Block 1*	Proportion of Fulfilled Expectations	0 [-0.01 – 0.00]	-0.01 [-0.01 – -0.00]	-0.02 [-0.05 – 0.01]	0.01 [-0.01 – 0.02]	0.01 [-0.01 – 0.02]	1.02 [1.01 – 1.03]
	3 Month PRO	0.74 [0.64 – 0.83]	0.58 [0.48 – 0.68]	0.79 [0.71 – 0.87]	0.75 [0.65 – 0.84]	0.78 [0.69 – 0.78]	-
Block 2#	Proportion of Fulfilled Expectations, HSS	0 [-0.00 – 0.01]	0 [-0.01 – 0.01]	-0.02 [-0.05 – 0.01]	0.03 [0.01 – 0.05]	0 [-0.02 – 0.01]	1.01 [1.00 – 1.02]
	3 Mo. Neck Pain, NRS	0.41 [0.28 – 0.54]	0.04 [-0.10 – 0.19]	0.76 [0.02 – 1.50]	0.55 [0.07 – 1.02]	0.04 [-0.35 – 0.44]	0.75 [0.48 – 0.97]
	3 Mo. Arm Pain, NRS	-0.01 [-0.11 – 0.10]	0.38 [0.26 – 0.49]	-0.04 [-0.63 – 0.55]	0.04 [-0.34 – 0.42]	0.12 [-0.20 – 0.43]	1 [0.85 – 1.14]
	3 Mo. Disability, ODI	0.04 [0.01 – 0.06]	0.01 [-0.02 – 0.04]	0.61 [0.47 – 0.75]	0.15 [0.06 – 0.24]	-0.1 [-0.18 – -0.02]	0.99 [0.95 – 1.03]
	3 Mo. Pain Interference, PROMIS	0.05 [0.01 – 0.09]	0.05 [0.00 – 0.09]	-0.06 [-0.29 – 0.17]	0.35 [0.20 – 0.50]	-0.02 [-0.15 – 0.10]	1.01 [0.95 – 1.07]
	3 Mo. Physical Function, PROMIS	0.04 [-0.00 – 0.09]	0 [-0.05 – 0.05]	-0.06 [-0.32 – 0.19]	-0.06 [-0.23 – 0.10]	0.52 [0.38 – 0.65]	1.04 [0.97 – 1.11]

Abbreviations: Hospital for Special Surgery (HSS), Numeric Rating Scale (NRS), Oswestry Disability Index (ODI), Patient Reported Outcome Measurement Information System (PROMIS); *Block one for all models included the proportion of fulfilled expectations and the 3 month measure of the outcome (e.g., 12 month neck pain = β_1 proportion of fulfilled expectations + β_2 3 month neck pain); # Additional unlisted block 2 covariates included depression (PROMIS), age, body mass index, elixhauser comorbidity index, race (white* vs. non-white), working status (currently working* vs. not currently working), anticipated procedure (anterior fusion* vs. posterior fusion vs. posterior decompression), insurance type (public* vs. private), education (high school or less* vs. some college or more) (reference groups denoted with *).

Discussion

This study aimed to determine the association between preoperative expectations and early postoperative fulfilled expectations and patient-reported outcomes at 12-months postoperatively. Based on multivariable analysis, we found that higher preoperative expectations were associated with lower levels disability and pain interference, as well as higher levels of physical function among patients undergoing both lumbar and cervical spine surgery. Higher preoperative expectations were also associated with lower levels of back and leg pain among patients undergoing lumbar spine surgery and with increased odds of satisfaction among patients undergoing cervical spine surgery. Additionally, a higher proportion of fulfilled expectations at 3-months was associated with increased odds of satisfaction a 12-months among patients undergoing both lumbar and cervical spine surgery. Finally, a positive interaction effect was observed for patients undergoing lumbar spine surgery, with patients who had higher preoperative expectations and a higher proportion of fulfilled expectations more likely to be satisfied at 12-months

The significant association between preoperative expectations and disability at the 12-month postoperative timepoint is in agreement with work by Cobo Soriano et al, who found that general expectations significant correlated with decreased postoperative ODI at 12 months.(23) However, other studies have failed to identify a relationship between preoperative expectations and disability using either the ODI (9) or the Roland Morris disability scale at time points ranging from 6 to 12 months postoperatively. (11, 24) Soroceanu et al evaluated specific expectations for a wide range of disability constructs (increased activity, sleep comfort, return to work, ability to exercise, and prevention of future disability) and the only significant relationships were for sleep and ability to exercise.(1) Ultimately, these discrepancies may be due to other studies utilizing

expectations for specific functional improvements rather than a composite expectations score. Future research using the HSS Expectations Survey may want to consider developing valid subscores to evaluate their utility in predicting disability outcomes.

This study found that the higher preoperative expectations were associated with lower 12 month back and leg pain, as well as lower arm pain among patients undergoing lumbar or cervical spine surgery, respectively. There is no consensus on the relationship between preoperative expectations and postoperative back pain among patients undergoing lumbar surgery. McGregor et al identified a relationship between higher expectations and lower back pain at 6 weeks postoperatively (8); while others have found a relationship between higher expectations and higher postoperative back pain (7) or no relationship between preoperative expectations and postoperative back pain.(10, 23, 25) There are fewer disparities surrounding the relationship between preoperative expectations and leg pain, however, as higher preoperative expectations are generally correlated with lower leg pain at timepoints ranging from 6 weeks to 24 months postoperatively.(8, 10, 23) However, these studies have exclusively evaluated patients undergoing lumbar discectomy. Although there is limited work evaluating the relationship between patient expectations and postoperative outcomes among patients undergoing cervical spine surgery, Carr et al noted a relationship between expecting no pain and reporting lower postoperative arm pain scores among patients undergoing 1-to-3 level anterior cervical discectomy and fusion surgery.(26)

Though the predictive relationship between preoperative expectations and 12-month pain interference and physical function, has not been evaluated in the spine surgery population, Henry et al indicated that patients with lower preoperative expectations tended to be less active at 2 weeks after surgery compared to before surgery among patients undergoing extremity surgeries.(27) Additionally, they found that higher preoperative expectations were correlated

with lower early postoperative pain. Additionally, Dyck et al found that greater preoperative expectations were consistently associated with better disease-specific and general health outcomes at various time points among patients undergoing joint arthroplasty.(28) Henn et al noted that higher preoperative expectations were predictors of better performance at one year and greater improvement on shoulder outcomes measuring shoulder pain and function among patients undergoing rotator cuff repair surgery.(29)

We identified an association between higher preoperative expectations and greater satisfaction among patients undergoing cervical spine surgery. Although Soroceanu identified no relationship between preoperative expectations and satisfaction among patients undergoing either lumbar or cervical spine surgery, others have found a relationship between preoperative expectations and satisfaction among a mixed lumbar cohort.(5, 6, 25, 30) Ellis et al noted in their systematic review of patients undergoing lumbar surgery that, in general, the expectations for symptomatology, general health, activity, and recovery positively correlated with satisfaction.(31) Additionally, they found that the expectations for activity and recovery positively correlated with satisfaction at 6 months and beyond, as well as a trend where the expectations correlate positively with satisfaction at earlier (<6 months) and later (>24 months) time points, but are insignificant at the midterm (6 to 24 months).(31)

Our study also found an association between fulfilled expectations and satisfaction among patients undergoing both lumbar and cervical spine surgery. Several studies have demonstrated an association between met expectations and satisfaction in procedure or joint specific cohorts.(32-35)These findings are similar to those of Mannion et al, McGregor et al, and Soroceanu et al, who found that fulfilled expectations are associated with satisfaction.(1, 2, 8) However, these studies not only use different expectations measures, including the Musculoskeletal Outcomes Data Evaluation and Management System's (MODEMS)(1) and the expectations component of the

North American Spine Society's Lumbar Spine Questionnaire (24), they also used fulfilled expectations for individual items (i.e., fulfilled expectation for leg pain) rather than a composite score.(8) Our results are also similar to other orthopaedic populations, including foot and ankle (27) and joint arthroplasty.(28)

Mannion et al. note that the expectation-actuality discrepancy (EA-D) (the difference between the expected outcome and the actual outcome) is the most important predictor when assessing the global treatment effectiveness at 12-months among patients undergoing lumbar decompression surgery.(2) Additionally, a systematic review by Witiw et al. noted that fulfilled expectations (described as an EA-D) predicted satisfaction more effectively than the effects of change in pain, function, and preoperative expectations among patients undergoing lumbar spine surgery.(36) This is largely in line with the "expectancy disconfirmation theory"(37, 38) which posits that satisfaction is a function of the degree of discrepancy between patients' prior expectations and their outcomes, such that if expectations exceed the outcomes, the resulting expectation discrepancy has a negative effect on satisfaction. This, interestingly, may be confirmed by our findings in the interaction model, where patients with higher preoperative expectations may have an effect on the relationship between the proportion of fulfilled expectations and satisfaction when patients have higher preoperative expectations scores.

This study expands on existing work by evaluating the relationship between preoperative expectations, the proportion of fulfilled expectations, and post operative outcomes using a validated expectations measurement tool for patients undergoing elective lumbar or cervical spine surgery. Our findings illustrate that generally fulfilled expectations are important components in patient satisfaction, while preoperative expectations may be important predictors of postoperative functional outcomes. Ultimately, improving the patients' fulfillment of expectations may help improve global measurements, such as satisfaction, at later term follow-up.

Because prior research in other populations has shown that expectations are modifiable through patient education and targeted interventions, (39, 40) future research should assess if addressing patients' fulfilled expectations at early time points helps improve satisfaction among patients undergoing lumbar and cervical surgeries.

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CHAPTER 7

SUMMARY AND FUTURE DIRECTIONS

Our study demonstrated that patients' expectations varied depending on demographic, clinical, and patient reported measures. These findings have implications for both patients, who can now acknowledge the extent of their expectations, and surgeons, who can choose topics for educating their patients based on the patients' expectations. Ultimately, although this study cannot determine "realistic expectations" for patients or how they should be established, these results may give surgeons a better understanding of what patients expect as a result of their surgery, as well as some of the discrepancies in preoperative expectations that exist based on patient factors such as leg/arm pain or disability. Future research should focus on developing interventions or education programs to effectively modify patients' expectations based on realistic outcomes for their surgical procedure.

Additionally, we demonstrated that the proportion of fulfilled expectations at 3 months after surgery is primarily influenced by both preoperative expectations and patient satisfaction at 3 months. Together, these findings may inform the importance of measuring expectations across the continuum of care. By measuring specific expectation fulfillment, there is a possibility that future care, particularly within the context of referral to physical therapy, may benefit from addressing specific areas where patients have not had their expectations fulfilled, or, said another way, are not satisfied with their outcome. This increases the communication between patient and provider, thus allowing for more effective shared decision making.

Finally, we found that higher preoperative expectations is a significant predictor of lower 12-month disability, pain intensity, pain interference, and higher physical function, particularly among patients undergoing lumbar spine surgery. We also found that a higher proportion of fulfilled expectations at 3 months is associated with higher odds of the patient being satisfied with

their surgical outcome in patients undergoing both lumbar and cervical spine surgery. As such, measuring both preoperative expectations and their fulfillment in the early postoperative time period (i.e., 3 months) may allow surgeons to identify patients at risk of worse outcomes at 12 months after spine surgery. Future clinical work could consider including preoperative expectations as a part of an informed consent process in order to ensure that patient preferences are well understood prior to surgical intervention. This, in turn, could increase communication and potentially increase satisfaction, particularly if the patient feels that more of their expectations have been fulfilled as a result of this open communication.

Alternative Approaches

Our study utilized both cross sectional analysis and longitudinal modelling strategies to address the aims in this study, rather than a time-varying approach. The use of Generalized Estimating Equations (GEE) may have been another appropriate methodological approach for estimating the effects of expectations on post-operative outcomes. The goal of GEE is to make inferences about the population when accounting for the within-subject correlations. This method would have allowed for improved precision and efficiency of the model; however, we also would have relied more heavily on multiple imputation (or suffered from a decreased sample size) as the number of patients who completed all 3 time points was less than those who completed the baseline, 3-month, and 12-month independently. An alternative opportunity is the use of mediation analysis to assess demographic factors such as gender assigned at birth or race as potential mediators of expectations or fulfilled expectations. This may be a valuable modeling strategy when evaluating health equity, particularly as social determinants of health have been shown to affect outcomes in spine surgery patients.[1]

Future Directions

Moving forward, it is important for patients and provides to consider expectations and their fulfillment when deciding on the course of care. First, because prior research in other populations has shown that expectations are modifiable through patient education and targeted interventions, future research should assess if addressing patients' fulfilled expectations at early time points helps improve satisfaction among patients undergoing lumbar and cervical surgery.[2]

Future work to reduce this scale could improve its clinical utilization. As currently structured, 20 items is a cumbersome, time consuming scale that would be difficult to implement in routine clinical care. However, removing items that have consistently low expectations for that particular item (such as work or sexual activity) may create an easier expectations scale for clinical use without leading to losses in important clinical information . As shown in other spine-related research, questions related to expectations for returning to work or sexual function may be more appropriate as stand-alone items.[3,4] Another future opportunity relates to the use of cut-points to identify red flags for patients with expectations that are too high or too low. This could be driven through the assessment of non-linear effects to inform a cut-point, but would require a considerably larger sample size and the inclusion of patients from multiple geographic areas.

Lastly, developing subscales from this work to focus on specific areas, such as pain relief, activities of daily living, symptom relief, regaining function, and emotional improvement could help identify if these targeted areas are better predictors of outcomes than a generalized scale. Work using individual items from non-validated spine surgery expectations measures has shown this to be true in populations, including single-level decompression and fusion; it may be beneficial to test the utility of individual items or subscales in a general spine surgery cohort using a validated instrument.[4,5]

Conclusion

In summary, we found that higher preoperative expectations was associated with better postoperative outcomes, while a higher proportion of fulfilled expectations in the early postoperative time-period was associated with greater odds of satisfaction at one year postoperatively in patients undergoing both lumbar and cervical spine surgery. Together, the preoperative expectations and the proportion of fulfilled expectations may facilitate dialogue between the patient and provider, particularly as it relates to ways the patient believes surgery did and did not meet their goals. Additional research should work to reduce this measurement tool in order to improve its clinical utility

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Appendices

Appendix 3.1: Hospital for Special Surgery Lumbar Spine Surgery Expectations Survey

Hospital For Special Surgery Lumbar Spine Surgery Expectations Survey

Please circle the number that best describes your response to each question.

How much improvement do you expect in the following areas as a result of your spine surgery?

	Back to normal or complete improvement	**Not back to normal, but…**			I do not have this expectation, or this expectation does not apply to me
		A lot of improvement	A moderate amount of improvement	A little improvement	
Relieve Pain	4	3	2	1	0
Relieve symptoms that interfere with sleep	4	3	2	1	0
Improve ability to walk more than several blocks	4	3	2	1	0
Improve ability to site more than half an hour	4	3	2	1	0
Improve ability to stand more than half an hour	4	3	2	1	0
Regain strength in legs	4	3	2	1	0
Improve balance	4	3	2	1	0
Improve ability to go up and down stairs	4	3	2	1	0
Improve ability to manage personal care (such as, dress, bathe)	4	3	2	1	0
Improve ability to drive	4	3	2	1	0
Remove need for pain medications	4	3	2	1	0
Improve ability to interact with others (such as, social and family activities)	4	3	2	1	0
Improve sexual activity	4	3	2	1	0
Improve ability to perform daily activities (such as, chores, shopping, errands)	4	3	2	1	0
Improve ability to exercise for general health	4	3	2	1	0
Remove restrictions in activities (such as, be more mobile, not have to rest every few minutes)	4	3	2	1	0
If currently employed: Fulfill job responsibilities (such as, work required hours, complete expected tasks)	4	3	2	1	0
If currently work-disabled or unemployed due to spine: Go back to work for salaried employment	4	3	2	1	0
Reduce emotional stress or sad feelings	4	3	2	1	0
Stop my spine condition from getting worse	4	3	2	1	0
Remove the control the spine condition has on my life	4	3	2	1	0

Appendix 3.2: Hospital for Special Surgery Cervical Spine Surgery Expectations Survey

Hospital For Special Surgery Lumbar Spine Surgery Expectations Survey

Please circle the number that best describes your response to each question.

How much improvement do you expect in the following areas as a result of your spine surgery?

	Back to normal or complete improvement	**Not back to normal, but…**			I do not have this expectation, or this expectation does not apply to me
		A lot of improvement	A moderate amount of improvement	A little improvement	
Relieve neck pain	4	3	2	1	0
Relieve shoulder, arm or hand pain	4	3	2	1	0
Relieve symptoms that interfere with sleep	4	3	2	1	0
Improve strength in arms and hands	4	3	2	1	0
Relieve numbness in arms and hands	4	3	2	1	0
Improve ability to use hands for fine activities (such as, button a shirt, write)	4	3	2	1	0
Improve balance	4	3	2	1	0
Improve ability to position head to read	4	3	2	1	0
Improve ability to manage personal care (such as, comb hair, brush teeth, shave)	4	3	2	1	0
Improve ability to drive	4	3	2	1	0
Remove need for pain medications	4	3	2	1	0
Improve ability to interact with others (such as, social and family activities)	4	3	2	1	0
Improve sexual activity	4	3	2	1	0
Improve ability to perform daily activities (such as, chores, shopping, errands)	4	3	2	1	0
Improve ability to exercise for general health	4	3	2	1	0
Improve ability to participate in sports	4	3	2	1	0
If currently employed: Fulfill job responsibilities (such as, work required hours, complete expected tasks)	4	3	2	1	0
If currently work-disabled or unemployed due to spine: Go back to work for salaried employment	4	3	2	1	0
Reduce emotional stress or sad feelings	4	3	2	1	0
Stop my spine condition from getting worse	4	3	2	1	0
Remove the control the spine condition has on my life	4	3	2	1	0

Appendix 3.3: Oswestry Low Back Pain Disability Questionnaire

Oswestry Low Back Pain Disability Questionnaire

Instructions

This questionnaire has been designed to give us information as to how your back or leg pain is affecting your ability to manage in everyday life. Please answer by checking ONE box in each section for the statement which best applies to you. We realise you may consider that two or more statements in any one section apply but please just shade out the spot that indicates the statement which most clearly describes your problem.

Section 1 – Pain Intensity

- I have no pain at the moment
- The pain is very mild at the moment
- The pain is moderate at the moment
- The pain is fairly severe at the moment
- The pain is very severe at the moment
- The pain is the worst imaginable at the moment

Section 2 – Personal Care

- I can look after myself normally without causing extra pain
- I can look after myself normally, but it causes extra pain
- It is painful to look after myself and I am slow and careful
- I need some help but manage most of my personal care
- I need help every day in most aspects of self-care
- I do not get dressed, I wash with difficulty, and stay in bed

Section 3 – Lifting

- I can lift heavy weights without extra pain
- I can lift heavy weights but it gives extra pain
- Pain prevents me from lifting heavy weights off the floor, but I can manage if they are conveniently place, eg. on a table
- Pain prevents me from lifting heavy weights off the floor, but I can manage light to medium weights if they are conveniently positioned
- I can lift very light weights
- I cannot lift or carry anything at all

Section 4 – Walking

- Pain does not prevent me walking any distance
- Pain prevents me walking more than 1 mile
- Pain prevents me walking more than ½ mile
- Pain prevents me walking more than 100 yards
- I can only walk using a stick or crutches
- I am in bed most of the time

Section 5 – Sitting

- I can sit in any chair as long as I like
- I can only sit in my favorite chair as long as I like
- Pain prevents me sitting more than one hour
- Pain prevents me sitting more than 30 minutes
- Pain prevents me sitting more than 10 minutes
- Pain prevents me from sitting at all

Section 6 – Standing

- I can stand as long as I want without extra pain
- I can stand as long as I want, but it give me extra pain
- Pain prevents me from standing for more than 1 hour
- Pain prevents me from standing for more than 30 minutes
- Pain prevents me from standing for more than 10 minutes
- Pain prevents me from standing at all

Section 7 – Sleeping

- My sleep is never disturbed by pain
- My sleep is occasionally disturbed by pain
- Because of pain, I have less than 6 hours sleep
- Because of pain, I have less than 4 hours sleep
- Because of pain, I have less than 2 hours sleep
- Pain prevents me from sleeping at all

Section 8 – Sex life (if applicable)

- My sex life is normal and causes no extra pain
- My sex life is normal but causes some extra pain
- My sex life is nearly normal but is very painful
- My sex life is severely restricted by pain
- My sex life is nearly absent because of pain
- Pain prevents any sex life at all

Section 9 – Social Life

- My social life is normal and gives me no extra pain
- My social life is normal but increases the degree of pain
- Pain has no significant effect on my social life apart from limiting my more energetic interests eg, sport
- Pain has restricted my social life and I do not go out as often
- Pain has restricted my social life to my home
- I have no social life because of pain

Section 10 – Travelling

- I can travel anywhere without pain
- I can travel anywhere but it gives me extra pain
- Pain is bad but I manage journeys over two hours
- Pain restricts me to journeys of less than one hour
- Pain restricts me to short, necessary journeys under 30 minutes
- Pain prevents me from travelling except to receive treatment

Appendix 1.4: Neck Disability Index

Neck Disability Index

Instructions

This questionnaire has been designed to give us information as to how your neck pain has affected your ability to manage in everyday life. Please answer every section and mark in each section only the one box that applies to you. We realise you may consider that two or more statements in any one section relate to you, but please just mark the box that most closely describes your problem.

Section 1 – Pain Intensity

- □ I have no pain at the moment
- □ The pain is very mild at the moment
- □ The pain is moderate at the moment
- □ The pain is fairly severe at the moment
- □ The pain is very severe at the moment
- □ The pain is the worst imaginable at the moment

Section 2 – Personal Care

- □ I can look after myself normally without causing extra pain
- □ I can look after myself normally, but it causes extra pain
- □ It is painful to look after myself and I am slow and careful
- □ I need some help but manage most of my personal care
- □ I need help every day in most aspects of self-care
- □ I do not get dressed, I wash with difficulty, and stay in bed

Section 3 – Lifting

- □ I can lift heavy weights without extra pain
- □ I can lift heavy weights but it gives extra pain
- □ Pain prevents me from lifting heavy weights off the floor, but I can manage if they are conveniently place, eg. on a table
- □ Pain prevents me from lifting heavy weights off the floor, but I can manage light to medium weights if they are conveniently positioned
- □ I can lift very light weights
- □ I cannot lift or carry anything at all

Section 4 – Reading

- □ I can read as much as I want to with no pain in my neck
- □ I can read as much as I want to with slight pain in my neck
- □ I can read as much as I want with moderate pain in my neck
- □ I can't read as much as I want because of moderate pain in my neck
- □ I can hardly read at all because of severe pain in my neck
- □ I cannot read at all

Section 5 – Headaches

- □ I have no headaches at all
- □ I have slight headaches, which come infrequently
- □ I have moderate headaches, which come infrequently
- □ I have moderate headaches, which come frequently
- □ I have severe headaches, which come frequently
- □ I have headaches almost all the time

Section 6 – Concentration

- □ I can concentrate fully when I want to with no difficulty
- □ I can concentrate fully when I want to with slight difficulty
- □ I have a fair degree of difficulty in concentrating when I want to
- □ I have a lot of difficulty in concentrating when I want to
- □ I have a great deal of difficulty in concentrating when I want to
- □ I cannot concentrate at all

Section 7 – Work

- □ I can do as much work as I want to
- □ I can only do my usual work, but no more
- □ I can do most of my usual work, but no more
- □ I cannot do my usual work
- □ I can hardly do any work at all
- □ I can't do any work at all

Section 8 – Driving

- □ I can drive my car without any neck pain
- □ I can drive my car as long as I want with slight pain in my neck
- □ I can drive my car as long as I want with moderate pain in my neck
- □ I can't drive my car as long as I want because of moderate pain in my neck
- □ I can hardly drive at all because of severe pain in my neck
- □ I can't drive my car at all

Section 9 – Sleeping

- □ I have no trouble sleeping
- □ My sleep is slightly disturbed (less than 1 hr sleepless)
- □ My sleep is mildly disturbed (1-2 hrs sleepless)
- □ My sleep is moderately disturbed (2-3 hrs sleepless)
- □ My sleep is greatly disturbed (3-5 hrs sleepless)
- □ My sleep is completely disturbed (5-7 hrs sleepless)

Section 10 – Recreation

- □ I am able to engage in all my recreation activities with no neck pain at all
- □ I am able to engage in all my recreation activities, with some pain in my neck
- □ I am able to engage in most, but not all of my usual recreation activities because of pain in my neck
- □ I am able to engage in a few of my usual recreation activities because of pain in my neck
- □ I can hardly do any recreation activities because of pain in my neck
- □ I can't do any recreation activities at all

Appendix 1.5: PROMIS Physical Function and Pain Intensity 4-Item Short Forms

Physical Function – Short Form 4a

Please respond to each question or statement by marking one box per row.

	Without any difficulty (5)	With a little difficulty (4)	With some difficulty (3)	With much difficulty (2)	Unable to do (1)
Are you able to do chores such as vacuuming or yard work?	☐	☐	☐	☐	☐
Are you able to go up and down stairs at a normal pace?	☐	☐	☐	☐	☐
Are you able to go for a walk of at least 15 minutes?	☐	☐	☐	☐	☐
Are you able to run errands and shop?	☐	☐	☐	☐	☐

Pain Interference – Short Form 4a

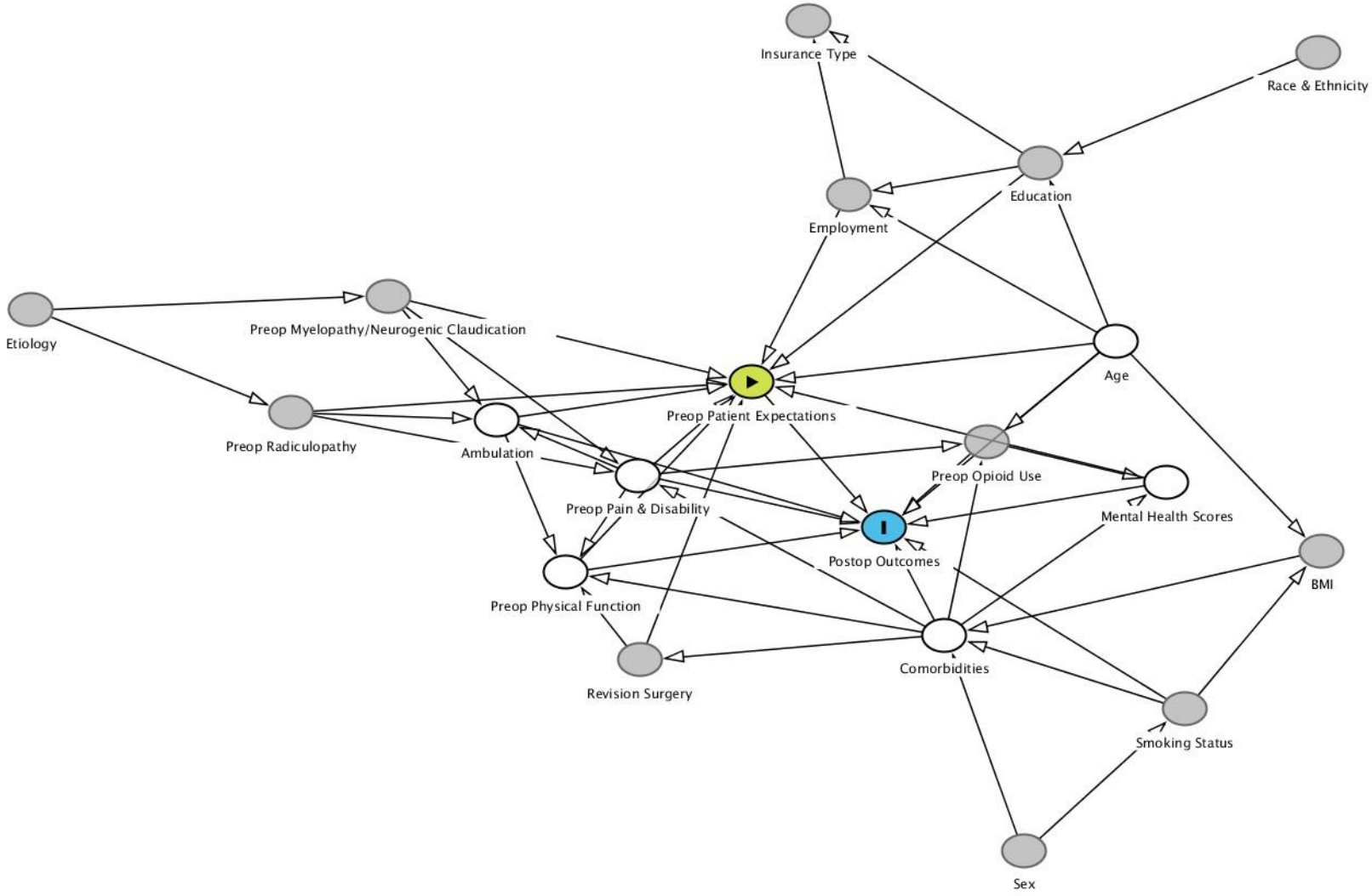
Please respond to each question or statement by marking one box per row.

In the past 7 days…	Not at all (1)	A little bit (2)	Somewhat (3)	Quite a bit (4)	Very Much (5)
How much did pain interfere with your day-to-day activities?	☐	☐	☐	☐	☐
How much did pain interfere with your work around the home?	☐	☐	☐	☐	☐
How much did pain interfere with your ability to participate in social activities?	☐	☐	☐	☐	☐
How much did pain interfere with your household chores	☐	☐	☐	☐	☐

Appendix 1.6: North America Spine Society (NASS) Satisfaction Scale

Score	NASS Satisfaction Measure
1	The treatment met my expectations
2	I did not improve as much as I hoped, but I would undergo the same treatment for the same outcome
3	I did not improve as much as I had hoped, and I would not undergo the same treatment for the same outcome
4	I am the same or worse than before treatment

Appendix 3.7: Directed Acyclic Graph Depicting the Relationship between Preoperative Expectations and Postoperative Outcomes in Elective Spine Surgery



Appendix 4.1. Univariate correlations among expectations, patient reported measures, and continuous demographic factors

A. Lumbar Corr. Matrix	Expectations Score	ODI	Back Pain	Leg Pain	Physical Function	Pain Interference	Age	BMI	Depression	Elixhauser Comorbidity
Expectations Score	-	0.07	0.07	0.16	-0.04	0.13	-0.15	-0.01	-0.06	-0.05
Disability, ODI		-	0.54	0.49	-0.75	0.70	0.00	0.13	0.40	-0.03
Back Pain			-	0.57	-0.44	0.52	0.02	0.10	0.26	-0.06
Leg Pain				-	-0.47	0.46	0.02	0.10	0.20	-0.09
Physical Function					-	-0.68	-0.14	-0.17	-0.34	0.04
Pain Interference						-	-0.04	0.14	0.37	-0.05
Age							-	-0.16	-0.04	0.06
BMI								-	0.12	-0.59
Depression									-	-0.09
Elixhauser Comorbidity										-

B. Cervical Corr. Matrix	Expectations Score	NDI	Neck Pain	Arm Pain	Physical Function	Pain Interference	Age	BMI	Depression	Elixhauser Comorbidity
Expectations Score	-	0.04	0.09	0.18	0.14	0.05	-0.25	-0.04	-0.12	0.04
Disability, NDI		-	0.63	0.53	-0.62	0.73	-0.17	0.14	0.38	-0.15
Neck Pain			-	0.69	-0.38	0.60	-0.17	0.09	0.30	-0.08
Arm Pain				-	-0.35	0.52	-0.12	0.11	0.23	-0.06
Physical Function					-	-0.61	-0.15	-0.20	-0.39	0.15
Pain Interference					-	-	-0.18	0.12	0.35	-0.12
Age							-	-0.08	-0.06	0.06
BMI								-	0.10	-0.54
Depression									-	-0.15
Elixhauser Comorbidity										-

Abbreviations: Oswestry Disability Index (ODI), Body Mass Index (BMI), Neck Disability Index (NDI)

Appendix 5.1: Overview of 3-month cohort characteristics, including patient demographics, clinical and surgical characteristics, and 3-month patient reported measures

	Lumbar Cohort (n=483)	Cervical Cohort (N=393)
Patient Demographics	Mean [SD] or N(%)	Mean [SD] or N(%)
Age	59.1 [13.5]	56.8 [11.5]
Body Mass Index	31.3 [6.4]	30.2 [6.6]
Gender		
Female	231 (49%)	185 (47%)
Male	242 (51%)	206 (52%)
Missing	2 (0%)	2 (1%)
Race		
White	403 (85%)	338 (86%)
Non-White	55 (12%)	44 (11%)
Missing	17 (4%)	11 (3%)
Ambulation		
Independently	344 (72%)	-
Require Assistance	124 (26%)	-
Missing	7 (1%)	-
Insurance		
Private	246 (52%)	230 (59%)
Public	226 (48%)	162 (41%)
Missing	3 (1%)	1 (0%)
Education		
High School or Less	213 (45%)	167 (42%)
Some College or More	254 (53%)	218 (55%)
Missing	8 (2%)	8 (2%)
Employment		

Working	167 (35%)	154 (39%)
Not Currently Working	305 (64%)	239 (61%)
Missing	3 (1%)	0 (0%)
Tobacco		
Non-Smoker	408 (86%)	319 (81%)
Current Smoker	64 (13%)	74 (19%)
Missing	3 (1%)	0 (0%)
Clinical and Surgical Characteristics		
Comorbidity Index, Elixhauser	-2.9 [4.9]	-2.5 [5.2]
Preoperative Opioid Use	120 (25%)	94 (24%)
Revision Surgery	118 (25%)	91 (23%)
Radiculopathy	369 (78%)	246 (63%)
Neurogenic Claudication or Myelopathy	147 (31%)	141 (36%)
Procedure		
Anterior Fusion	22 (5%)	240 (61%)
Posterior Fusion	267 (56%)	28 (7%)
Posterior Decompression	186 (39%)	125 (32%)
3 Month Patient Reported Measures		
Disability, ODI and NDI	29.9 [19.1]	30.6 [19.1]
Axial Pain Intensity, NRS	3.5 [2.7]	3.4 [2.7]
Extremity Pain Intensity, NRS	2.8 [3]	2.5 [2.8]
PROMIS		
Pain Interference	57.6 [9.9]	57.6 [9.8]
Physical Function	41 [8.6]	41.9 [8.7]
Depression	48.8 [8.6]	49.8 [9.6]

Patient Satisfaction		
Satisfied	395 (83%)	328 (83%)
Unsatisfied	72 (15%)	63 (16%)
Missing	8 (2%)	2 (1%)
Preoperative Patient Reported Measures		
Disability, ODI and NDI	29.9 [19.1]	30.6 [19.1]
Axial Pain Intensity, NRS	3.5 [2.7]	3.4 [2.7]
Extremity Pain Intensity, NRS	2.8 [3]	2.5 [2.8]
PROMIS		
Pain Interference	57.6 [9.9]	57.6 [9.8]
Physical Function	41 [8.6]	41.9 [8.7]
Depression	48.8 [8.6]	49.8 [9.6]
Preoperative Expectations		

Appendix 5.2 – Inter item correlations and correlations with scale and individual items (will need cleaning)

3 Month, Ordinal	Pain	Sleep	Walking	Sitting	Standing	Leg Strength	Balance	Stairs	Personal Care	Driving	Pain Meds	Social Expectations	Sexual Activity	Exercise	Improve ability to exercise	Improve Daily Activities	Work	Stress/Sadness	Stop Spine Condition from Worsening	Remove the Control	lum_ex
Pain	1	0.63	0.73	0.66	0.72	0.68	0.53	0.66	0.5	0.46	0.61	0.55	0.39	0.65	0.65	0.69	0.39	0.38	0.71	0.75	
Sleep		1	0.62	0.63	0.64	0.57	0.55	0.61	0.59	0.58	0.6	0.66	0.43	0.6	0.66	0.62	0.41	0.46	0.58	0.62	
Walking			1	0.67	0.85	0.71	0.6	0.79	0.54	0.55	0.62	0.64	0.49	0.68	0.76	0.76	0.52	0.42	0.68	0.74	
Sitting				1	0.73	0.64	0.63	0.68	0.66	0.59	0.63	0.67	0.41	0.64	0.72	0.68	0.36	0.52	0.64	0.66	
Standing					1	0.7	0.61	0.77	0.55	0.54	0.63	0.63	0.48	0.69	0.76	0.78	0.5	0.42	0.72	0.74	
Leg Strength						1	0.66	0.72	0.56	0.56	0.59	0.57	0.42	0.69	0.66	0.71	0.44	0.44	0.62	0.69	
Balance							1	0.65	0.62	0.58	0.58	0.66	0.41	0.58	0.63	0.62	0.4	0.53	0.54	0.6	
Stairs								1	0.58	0.58	0.62	0.66	0.48	0.73	0.77	0.76	0.49	0.45	0.64	0.72	
Personal Care									1	0.7	0.56	0.67	0.44	0.58	0.63	0.59	0.35	0.55	0.52	0.55	
Driving										1	0.55	0.65	0.49	0.59	0.64	0.6	0.42	0.54	0.53	0.57	
Pain Meds											1	0.67	0.48	0.65	0.68	0.68	0.41	0.49	0.57	0.63	
Social Expectations												1	0.49	0.66	0.77	0.68	0.43	0.56	0.58	0.66	
Sexual Activity													1	0.52	0.54	0.52	0.52	0.42	0.41	0.45	
Improve Ability to Exercise														1	0.74	0.78	0.44	0.47	0.63	0.7	
Improve Daily Activities															1	0.82	0.54	0.51	0.65	0.74	
Remove Restrictions in Activities																1	0.5	0.5	0.68	0.76	
Work																	1	0.34	0.39	0.43	
Stress/Sad																		1	0.47	0.47	
Stop Spine Condition from Worsening																			1	0.81	
Remove the Control																				1	
Expectations Score																					

3 Month, Fulfilled	Pain	Sleep	Walking	Sitting	Standing	Leg Strength	Balance	Stairs	Personal Care	Driving	Pain Meds	Social Expectations	Sexual Activity	Exercise	Improve ability to exercise	Improve Daily Activities	Work	Stress/Sadness	Stop Spine Condition from Worsening	Remove the Control	lum_ex
Pain	1	0.66	0.66	0.59	0.59	0.68	0.64	0.7	0.47	0.49	0.61	0.5	0.42	0.6	0.61	0.63	0.45	0.44	0.65	0.66	

Sleep	1	0.57	0.61	0.61	0.43	0.53	0.58	0.6	0.63	0.54	0.54	0.5	0.54	0.65	0.6	0.55	0.55	0.56	0.56
Walking		1	0.7	0.7	0.63	0.69	0.71	0.59	0.54	0.58	0.62	0.39	0.61	0.74	0.7	0.55	0.54	0.62	0.7
Sitting			1	1	0.53	0.55	0.6	0.59	0.57	0.59	0.59	0.51	0.59	0.68	0.61	0.48	0.51	0.64	0.65
Standing				1	0.53	0.55	0.6	0.59	0.57	0.59	0.59	0.51	0.59	0.68	0.61	0.48	0.51	0.64	0.65
Leg Strength					1	0.73	0.72	0.53	0.54	0.53	0.47	0.39	0.63	0.57	0.58	0.59	0.44	0.66	0.67
Balance						1	0.73	0.58	0.57	0.66	0.53	0.4	0.56	0.68	0.62	0.56	0.48	0.59	0.64
Stairs							1	0.6	0.59	0.62	0.63	0.48	0.65	0.74	0.71	0.63	0.51	0.66	0.7
Personal Care								1	0.76	0.53	0.64	0.49	0.61	0.68	0.61	0.63	0.63	0.53	0.6
Driving									1	0.5	0.53	0.54	0.6	0.69	0.61	0.63	0.56	0.59	0.61
Pain Meds										1	0.67	0.47	0.58	0.7	0.61	0.54	0.53	0.57	0.61
Social Expectations											1	0.55	0.57	0.72	0.61	0.59	0.66	0.54	0.67
Sexual Activity												1	0.49	0.61	0.5	0.49	0.49	0.44	0.52
Improve Ability to Exercise													1	0.71	0.68	0.6	0.58	0.57	0.69
Improve Daily Activities														1	0.73	0.64	0.56	0.66	0.77
Remove Restrictions in Activities															1	0.58	0.51	0.68	0.77
Work																1	0.54	0.53	0.61
Stress/Sad																	1	0.47	0.55
Stop Spine Condition from Worsening																		1	0.8
Remove the Control																			1
Expectations Score																			

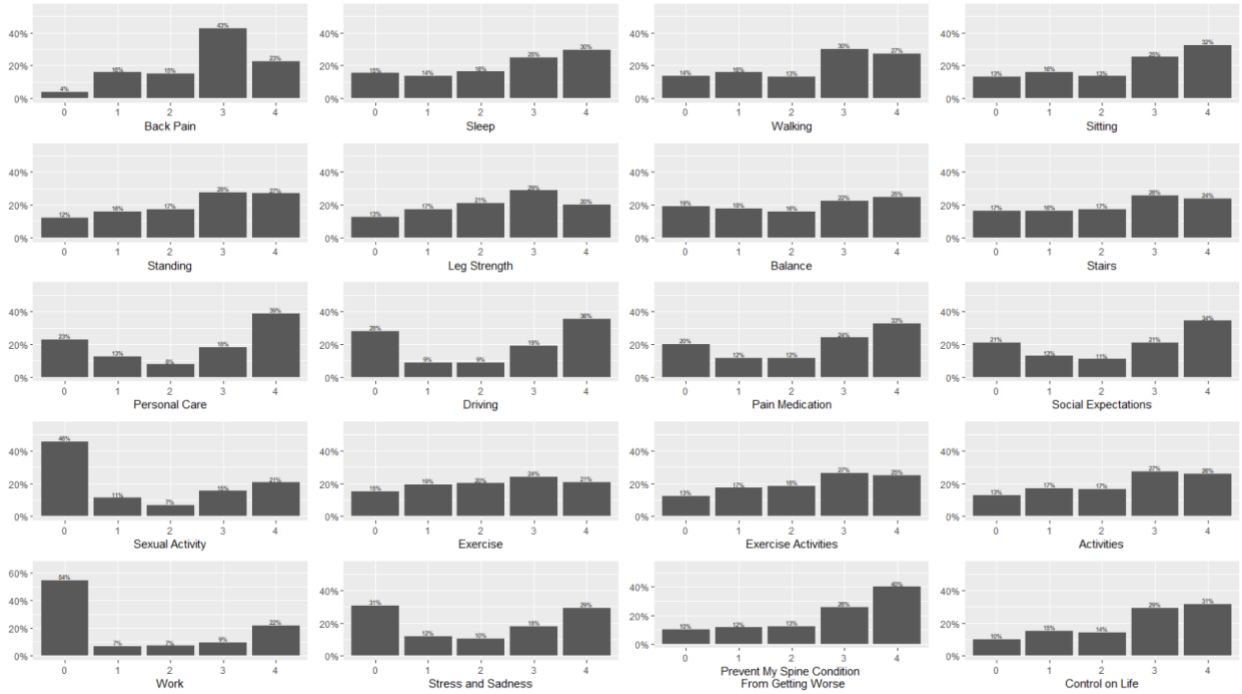
Appendix 5.3

	Neck Pain	Arm Pain	Sleep	Arm Strength	Arm Numbness	Push/Pull	Activities	Head Position	Personal Care	Drive	Pain Meds	Social Expectations	Sexual Activity	Exercise	Activites	Sports	Work	Stress/ Sadness	Worsening Condition	Remove Control	Composite Score
Neck Pain	1	0.59	0.53	0.46	0.42	0.48	0.45	0.61	0.52	0.58	0.48	0.5	0.36	0.52	0.59	0.39	0.38	0.4	0.47	0.54	0.68
Arm Pain		1	0.6	0.64	0.68	0.62	0.62	0.53	0.57	0.56	0.53	0.54	0.43	0.53	0.62	0.48	0.49	0.42	0.55	0.57	0.76
Sleep			1	0.55	0.56	0.57	0.59	0.6	0.6	0.57	0.51	0.56	0.48	0.52	0.64	0.45	0.43	0.49	0.46	0.54	0.74
Arm Strength				1	0.61	0.72	0.62	0.58	0.6	0.56	0.45	0.56	0.52	0.58	0.66	0.47	0.46	0.45	0.47	0.56	0.76

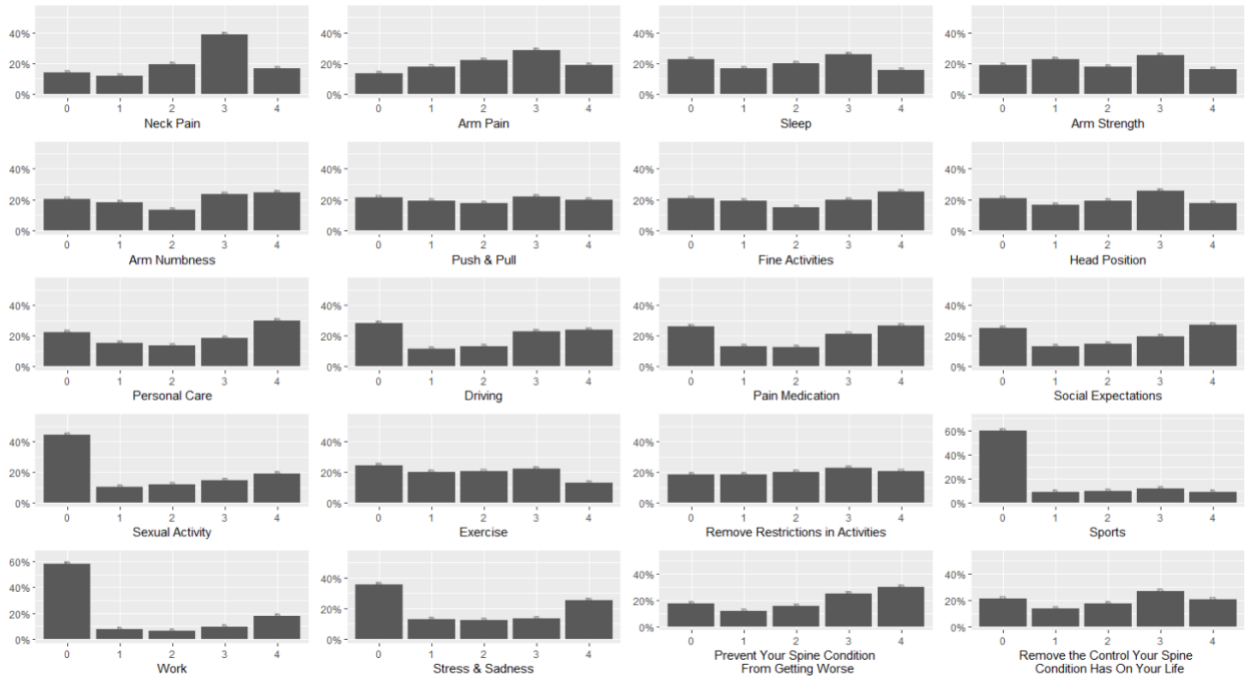
Arm Numbness	1	0.6	0.7	0.54	0.56	0.51	0.5	0.5	0.52	0.51	0.64	0.47	0.45	0.43	0.5	0.55	0.74		
Push/Pull		1	0.7	0.65	0.63	0.63	0.57	0.62	0.48	0.66	0.67	0.5	0.52	0.5	0.55	0.62	0.82		
Fine Activities			1	0.56	0.61	0.59	0.56	0.59	0.48	0.57	0.66	0.47	0.49	0.49	0.5	0.55	0.78		
Head Position				1	0.72	0.69	0.54	0.6	0.49	0.59	0.71	0.51	0.49	0.51	0.54	0.58	0.79		
Personal Care					1	0.72	0.57	0.68	0.47	0.6	0.73	0.51	0.46	0.51	0.48	0.58	0.8		
Drive						1	0.62	0.68	0.55	0.6	0.75	0.55	0.52	0.51	0.49	0.59	0.82		
Pain Meds							1	0.61	0.48	0.56	0.63	0.52	0.46	0.48	0.5	0.59	0.74		
Social Expectations								1	0.58	0.58	0.72	0.49	0.47	0.59	0.47	0.6	0.79		
Sexual Activity									1	0.58	0.6	0.59	0.48	0.48	0.38	0.47	0.68		
Exercise										1	0.69	0.62	0.49	0.48	0.51	0.66	0.78		
Activities											1	0.6	0.56	0.58	0.56	0.69	0.88		
Sports												1	0.51	0.46	0.44	0.5	0.67		
Work													1	0.39	0.47	0.54	0.65		
Stress/Sadness														1	0.4	0.5	0.67		
Worsening Condition															1	0.72	0.69		
Remove Control																1	0.79		
Expectations Score																	1		

	Neck Pain	Arm Pain	Sleep	Arm Strength	Arm Numbness	Push/Pull	Activities	Head Position	Personal Care	Drive	Pain Meds	Social Expectations	Sexual Activity	Exercise	Activites	Sports	Work	Stress/Sadness	Worsening Condition	Remove Control	Composite Score
Neck Pain	1	0.45	0.62	0.42	0.51	0.44	0.43	0.58	0.55	0.48	0.52	0.53	0.48	0.54	0.66	0.26	0.36	0.43	0.32	0.54	0.62
Arm Pain		1	0.54	0.73	0.66	0.58	0.62	0.41	0.54	0.48	0.42	0.53	0.42	0.48	0.56	0.44	0.56	0.3	0.46	0.48	0.69
Sleep			1	0.52	0.62	0.56	0.56	0.59	0.66	0.52	0.41	0.6	0.5	0.53	0.63	0.4	0.48	0.41	0.36	0.51	0.72
Arm Strength				1	0.61	0.72	0.62	0.54	0.58	0.52	0.42	0.51	0.44	0.55	0.64	0.45	0.52	0.4	0.47	0.5	0.73
Arm Numbness					1	0.65	0.71	0.58	0.6	0.61	0.61	0.6	0.58	0.59	0.65	0.53	0.58	0.46	0.44	0.46	0.79
Push/Pull						1	0.69	0.53	0.63	0.61	0.47	0.56	0.42	0.62	0.68	0.5	0.5	0.47	0.52	0.5	0.75
Fine Activities							1	0.58	0.65	0.66	0.54	0.6	0.54	0.6	0.66	0.6	0.61	0.43	0.46	0.54	0.78

Head Position	1	0.64	0.69	0.54	0.56	0.67	0.61	0.65	0.58	0.51	0.49	0.43	0.53	0.73
Personal Care		1	0.67	0.54	0.73	0.57	0.55	0.66	0.48	0.52	0.5	0.5	0.54	0.8
Drive			1	0.53	0.64	0.65	0.61	0.61	0.6	0.62	0.56	0.48	0.53	0.79
Pain Meds				1	0.63	0.5	0.57	0.6	0.44	0.5	0.46	0.54	0.61	0.7
Social Expectations					1	0.6	0.57	0.65	0.52	0.57	0.53	0.58	0.62	0.8
Sexual Activity						1	0.56	0.65	0.64	0.6	0.56	0.52	0.56	0.75
Exercise							1	0.65	0.58	0.56	0.53	0.58	0.69	0.76
Activities								1	0.54	0.62	0.59	0.54	0.65	0.85
Sports									1	0.59	0.51	0.55	0.53	0.72
Work										1	0.46	0.51	0.59	0.77
Stress/Sadness											1	0.52	0.55	0.65
Worsening Condition												1	0.64	0.67
Remove Control													1	0.73
Expectations Score														1

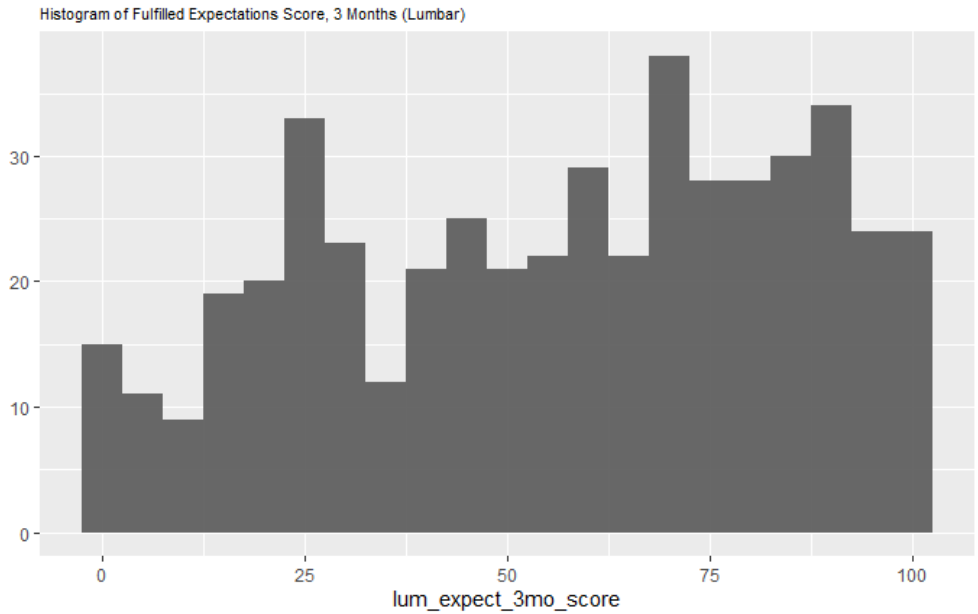


Appendix 5.4. Histograms of Individual Items of HSS Lumbar Expectations Survey, where 0 represents no expectation for improvement from baseline and 4 represents complete improvement from baseline

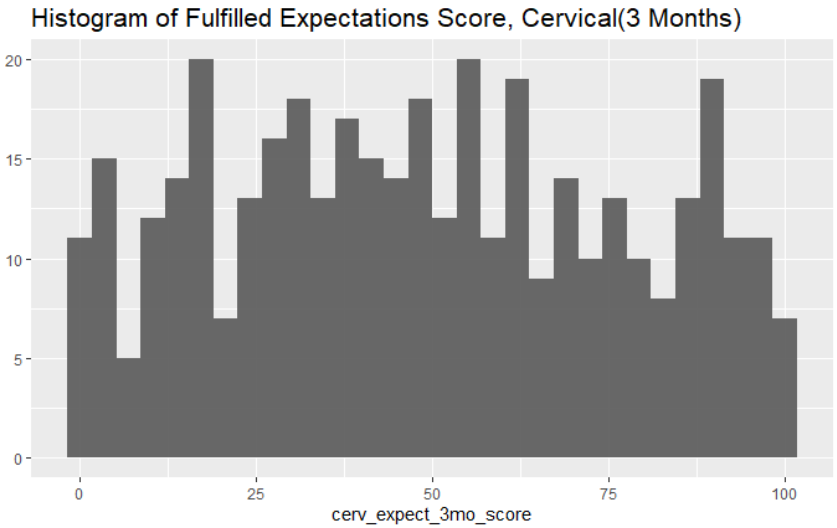


Appendix 5.5. Histograms of Individual Items of HSS Cervical Expectations Survey, where 0 represents no expectation for improvement from baseline and 4 represents complete improvement from baseline

Appendix 5.6: Distribution of 3 Month HSS Lumbar Spine Surgery Expectations Survey Composite Score



Appendix 5.7: Distribution of 3 Month HSS Lumbar Spine Surgery Expectations Survey Composite Score



Appendix 5.8 Univariate analysis comparing fulfilled expectations scores by demographic, clinical and surgical characteristics, and patient reported measures

	Lumbar		Cervical	
	Mean Fulfilled Expect Score	*p*	Mean Fulfilled Expect Score	*p*
Gender		0.78		0.82
Male	56.7		48.9	
Female	57.4		49.5	
Liability or Disability Claim		0.16		0.08
Yes	49.8		43.2	
No	57.5		50.1	
Insurance type		0.03		0.009
Public	53.7		44.7	
Private	59.4		52.2	
Race		0.04		0.04
White	58.4		49.9	
Non-White	50		40.6	
Education		0.02		0.003
High School or Less	53.4		44	
Some College or Greater	59.7		52.7	
Employment		<0.001		<0.001
Currently Working	64.6		60.4	
Not Currently Working	52.5		41.7	
Tobacco		0.14		0.04
Current Smoker	51.5		42.9	
Non-Smoker	57.7		50.4	
Ambulation		<0.001		
Independently	61		-	
With Assistance	46.4		-	
Lumbar Procedure		0.13		<0.001
Anterior Fusion	59.2		54.3	
Posterior Fusion	54.5		44.9	
Posterior Decompression	59.8		39.7	
Primary or Revision		<0.001		<0.001
Primary	59.5		51.8	
Revision	48.7		39.9	
Radiculopathy		<0.01		<0.001
Yes	58.5		55	
No	50.9		38.9	
Neurogenic Claudication / Myelopathy		0.1		<0.001
Yes	53.7		38.3	
No	58.2		55	
Pre-operative Opioids		0.03		0.03

Yes	51.9		43.7	
No	58.5		50.7	
Satisfaction		<0.001		<0.001
Satisfied	63.2		54.2	
Unsatisfied	21.2		21.7	

When assessing the relationship between preoperative measures of back pain, leg pain, disability, pain interference, physical function, and depression and fulfilled expectations at 3 months in multivariable linear regression, higher levels of both disability (Beta Coefficient (β): -0.65, 95% Confidence Interval (95% CI): -1.11 – -0.19) and depression (β: -0.75, 95% CI: -1.44 – -0.05) are associated with lower fulfilled expectations. Once demographic, clinical and surgical, and preoperative expectations are added to the model, higher levels of disability (β: -0.55, 95% CI: -0.99 – -0.11) and depression (β: -0.74, 95% CI: -1.39 – -0.09) remain associated with lower fulfilled expectations at 3 months. Additionally, both requiring assistance to ambulate (β: -7.16, 95% CI: -13.51 – -0.18) and revision surgeries (β: -8.39, 95% CI: -14.09 – -2.70) are associated with lower fulfillment of 3 month expectations, while higher preoperative expectations (β: 0.44, 95% CI: 0.30 – 0.57) are associated with higher fulfillment of 3 month expectations.

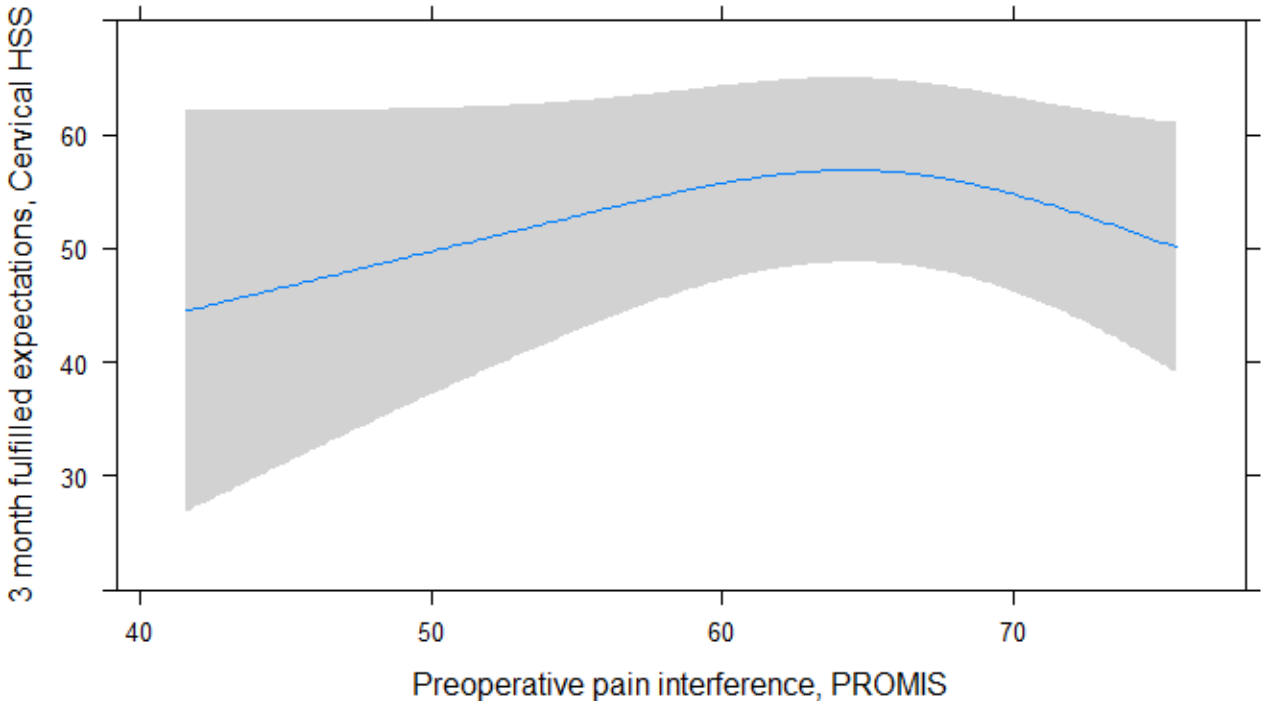
Appendix 5.9: Results of multivariable linear regression assessing the relationship between preoperative demographic, clinical, and patient reported variables and the continuous fulfilled expectations score at 3 months postoperative in patients undergoing lumbar spine surgery

Variables	Coefficient	CI	p	Coefficient	CI	p
Demographic						
Age				-0.18	-0.54 – 0.18	0.33
Age'				0.05	-0.38 – 0.48	0.83
BMI value				-0.42	-0.86 – 0.03	0.07
Male Gender (vs. Female)				-2.93	-7.86 – 1.99	0.24
Liability Claim (vs. No Claim				8.99	-0.08 – 17.91	0.05
Public Insurance (vs. Private)				-0.38	-5.88 – 5.11	0.89
Non-white (vs. White)				-6.76	-14.62 – 1.10	0.09
Some College Education or Greater (vs. High School or Less)				0.63	-4.27 – 5.53	0.80
Not Currently Working (vs. Currently Working)				-3.17	-8.88 – 2.55	0.28
Current Smoker (vs. non-Smoker)				-3.22	-10.22 – 3.77	0.37
Require Assistance to ambulate (vs. Independent)				-7.16	-13.51 – -0.81	**0.03**
Clinical & Surgical						
Revision Surgery (vs. Primary)				-8.39	-14.09 – -2.70	**<0.01**
No preoperative opioid use				1.9	-3.64 – 7.45	0.50
Neurogenic Claudication				-2.44	-7.76 – 2.88	0.37
Posterior Fusion				0.08	-11.53 – 11.68	0.99
Posterior Decompression				-3.21	-15.09 – 8.67	0.60
Elixhauser Comorbidity Index				-0.23	-0.78 – 0.31	0.40
Patient Reported Measures						
Baseline Expectations Score				0.44	0.30 – 0.57	**<0.001**
Back Pain, NRS	-0.9	-2.25 – 0.46	0.20	-0.69	-2.00 – 0.61	0.230
Leg Pain, NRS	0.87	-0.54 – 2.29	0.23	0.63	-0.73 – 1.99	0.36
Disability, ODI	-0.65	-1.11 – -0.19	**<0.01**	-0.55	-0.99 – -0.11	**0.03**
ODI'	0.38	-0.05 – 0.82	0.09	0.37	-0.04 – 0.79	0.08
Pain Interference, PROMIS	0.33	-0.28 – 0.94	0.29	-0.05	-0.63 – 0.53	0.86
Physical Function, PROMIS	-0.01	-0.73 – 0.71	0.98	-0.45	-1.15 – 0.24	0.20
Depression, PROMIS	-0.75	-1.44 – -0.05	**0.04**	-0.74	-1.39 – -0.09	**0.03**

Appendix 5.10 Results of multivariable linear regression assessing the relationship between preoperative demographic, clinical, and patient reported variables and the continuous expectations fulfilled score at 3 months postoperatively in patients undergoing cervical spine surgery

Variables	Coefficient	CI	p	Coefficient	CI	p
Demographic						
Age				0.26	-0.20 – 0.72	0.27
Age'				-0.47	-1.04 – 0.10	0.11
BMI value				-0.06	-0.47 – 0.34	0.76
Male Gender (vs. Female)				-1.48	-6.23 – 3.27	0.54
Liability Claim (vs. No Claim				5.59	-0.97 – 12.15	0.10
Public Insurance (vs. Private)				4.45	-1.46 – 10.37	0.14
Non-white (vs. White)				-6.89	-14.30 – 0.51	0.07
Some College Education or Greater (vs. High School or Less)				3.34	-1.61 – 8.29	0.19
Not Currently Working (vs. Currently Working)				-7.18	-12.95 – -1.41	**0.02**
Current Smoker (vs. non-Smoker)				-6.4	-12.68 – 0.12	0.05
Clinical & Surgical						
Revision Surgery (vs. Primary)				-2.12	-8.28 – 4.03	0.50
No preoperative opioid use				1.91	-3.81 – 7.64	0.51
Myelopathy				-5.98	-11.32 – -0.64	**0.03**
Posterior Decompression				-5.12	-11.01 – 0.78	0.09
Posterior Fusion				-2.09	-11.57 – 7.40	0.67
Elixhauser Comorbidity Index				-0.2	-0.70 – 0.31	0.44
Patient Reported Measures						
Baseline Expectations Score				0.42	0.30 – 0.53	**<0.001**
Neck Pain, NRS	0.21	-1.22 – 1.64	0.77	0.55	-0.76 – 1.87	0.41
Arm Pain, NRS	1.39	0.21 – 2.58	**0.02**	0.7	-0.40 – 1.80	0.21
Disability, NDI	-0.4	-0.85 – 0.04	0.08	-0.42	-0.83 – -0.01	**0.04**
NDI'	0.33	-0.16 – 0.83	0.19	0.4	-0.05 – 0.86	0.08
Pain Interference, PROMIS	1.24	0.46 – 2.02	**0.00**	0.63	-0.10 – 1.35	0.09
PI'	-1.37	-2.38 – -0.35	**0.01**	-1.08	-2.01 – -0.15	**0.02**
Physical Function, PROMIS	2.05	0.89 – 3.20	**0.00**	1.04	-0.05 – 2.13	0.06
PF'	-0.79	-2.10 – 0.52	0.24	-0.44	-1.63 – 0.74	0.46
Depression, PROMIS	-0.52	-0.82 – -0.22	**0.00**	-0.3	-0.57 – -0.02	**0.04**

Among patients undergoing cervical spine surgery, patients with higher preoperative arm pain (β: 1.39, 95% CI: 0.21 – 2.58) and higher preoperative physical function (β: 2.05, 95% CI: 0.89 – 3.20) had higher fulfillment of their expectations, while patients with higher levels of depression (β: -0.52, 95% CI: -0.82 – -0.22) had lower fulfillment of their expectations at three months when evaluating only preoperative patient reported measures. Additionally, a non-linear relationship between pain interference and fulfillment of expectations at 3 months was observed, where fulfilled expectations increase as preoperative pain interference increases until the PROMIS score approaches 65, at which point the relationship changes and further increases in pain interference are associated with lower fulfillment of expectations at 3 months postoperatively. Once demographic, surgical, and clinical variables are added to the model, the relationship between both arm pain and physical function becomes insignificant, while patients with higher levels of preoperative disability (β: -0.42, 95% CI: -0.83 – -0.01) are associated with lower fulfillment of their expectations at 3 months. The relationship between both depression (β: -0.30, 95% CI: -0.57 – -0.02) and pain interference remain similar to the relationship found in the prior block. Additionally, not currently working (β: -7.18, 95% CI: -12.95 – -1.41) and patients presenting with myelopathy (β: -5.98, 95% CI: -11.32 – -0.64) show fewer fulfilled expectations, while patients with higher preoperative expectations (β: 0.42, 95% CI: 0.30 – 0.53) are associated with higher fulfillment of their expectations at 3 months.


3 month fulfilled expectations, Cervical HSS
60
50
40
30
40
50
60
70
Preoperative pain interference, PROMIS

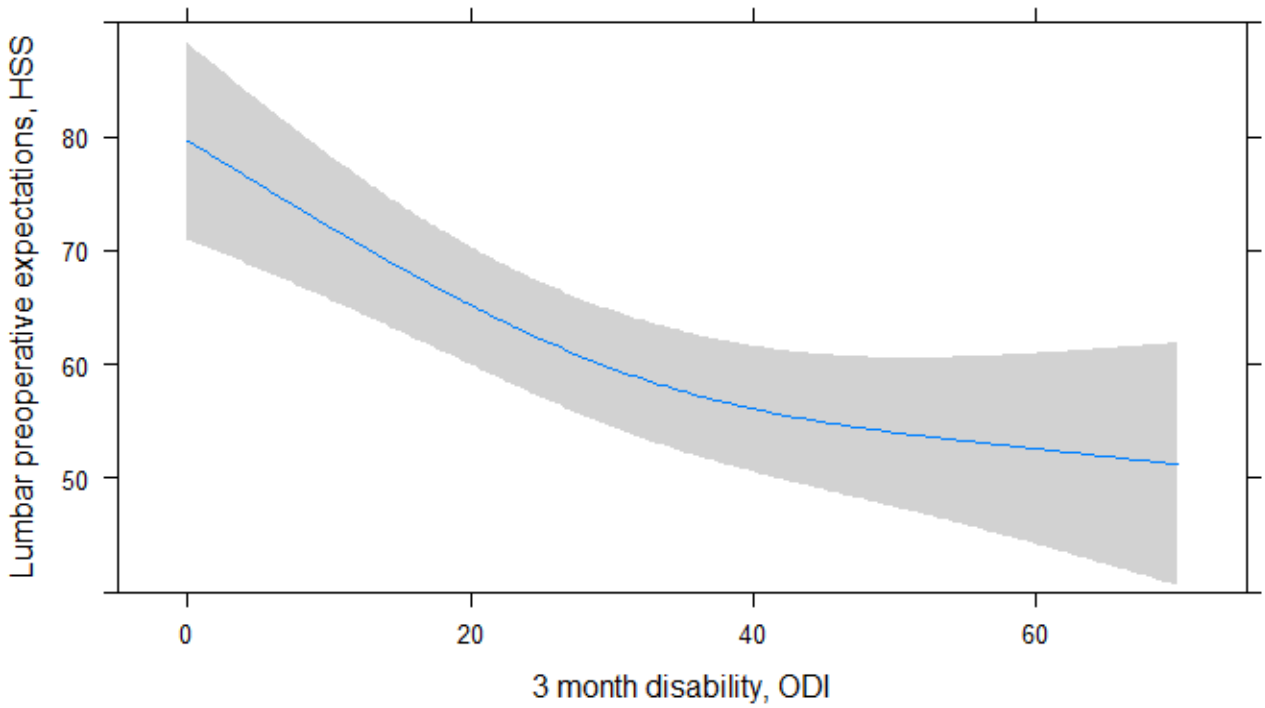
Appendix 5.11 Results of multivariable linear regression assessing the relationship between demographic, clinical, and 3 month patient reported variables and the continuous fulfilled expectations score at 3 months postoperatively in patients undergoing lumbar spine surgery

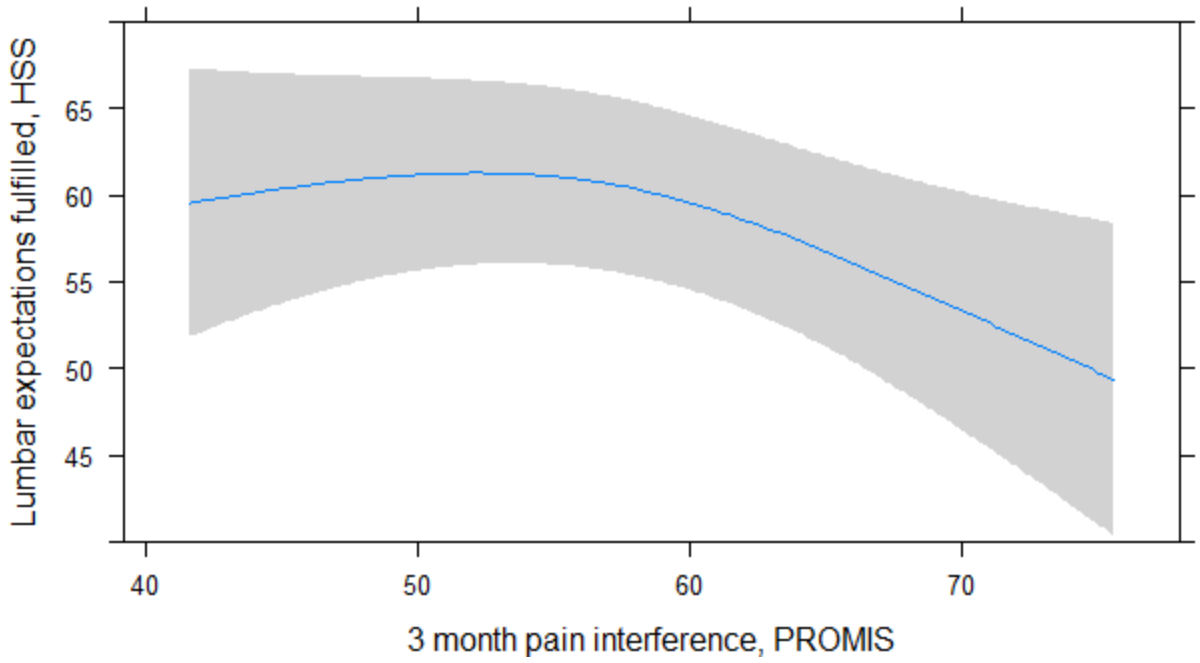
Variables	Coefficient	CI	p	Coefficient	CI	p
Demographic						
Age				0.1	-0.14 – 0.34	0.41
Age'				-0.13	-0.41 – 0.15	0.38
BMI value				0.02	-0.27 – 0.31	0.87
Male Gender (vs. Female)				-4.48	-7.63 – -1.33	**<0.01**
Liability Claim (vs. No Claim				1.13	-4.68 – 6.95	0.70
Public Insurance (vs. Private)				0.63	-2.95 – 4.21	0.73
Non-white (vs. White)				-2.51	-7.32 – 2.30	0.31
Some College Education or Greater (vs. High School or Less)				1.86	-1.29 – 5.02	0.25
Not Currently Working (vs. Currently Working)				0.76	-2.94 – 4.46	0.69
Current Smoker (vs. non-Smoker)				2.15	-2.41 – 6.72	0.35
Ambulation (Require Assistance vs. Independently)				2.78	-1.20 – 6.77	0.17
Clinical & Surgical						
Revision Surgery (vs. Primary)				1.39	-2.37 – 5.15	0.47
No preoperative opioid use				0.04	-3.57 – 3.66	0.98
Neurogenic Claudication				-1.04	-4.51 – 2.43	0.56
Posterior Decompression				-0.99	-8.38 – 6.39	0.79
Posterior Fusion				0.06	-7.44 – 7.57	0.99
Elixhauser Comorbidity Index				-0.12	-0.47 – 0.24	0.52
Patient Reported Measures						
Back Pain, NRS	-0.8	-1.78 – 0.19	0.11	-0.72	-1.75 – 0.31	0.17
Leg Pain, NRS	-0.16	-0.89 – 0.56	0.65	-0.17	-0.92 – 0.57	0.65
Disability, ODI	-0.85	-1.19 – -0.52	**<0.001**	-0.84	-1.18 – -0.49	**<0.001**
ODI'	0.46	0.14 – 0.78	**<0.01**	0.4	0.07 – 0.73	**0.02**
Pain Interference, PROMIS	0.42	-0.08 – 0.92	0.10	0.46	-0.05 – 0.97	0.08
PI'	-0.58	-1.05 – -0.12	**0.01**	-0.61	-1.08 – -0.13	**0.01**
Physical Function, PROMIS	1.26	0.66 – 1.86	**<0.001**	1.35	0.71 – 1.99	**<0.001**
PF'	-0.58	-1.46 – 0.29	0.19	-0.56	-1.46 – 0.35	0.23
Satisfaction, NASS	-16.02	-21.10 – -10.94	**<0.001**	-14.09	-19.40 – -8.77	**<0.001**
Depression, PROMIS	0.02	-0.18 – 0.22	0.85	-0.01	-0.22 – 0.19	0.90

Note:

When evaluating the cross-sectional relationship between patient reported measures and patient's fulfilled expectations, higher physical function at the 3-months is associated with more fulfilled expectations (β: 1.26, 95% CI: 0.66 – 1.86), while unsatisfied

patients have fewer fulfilled expectations (β: -16.02, 95% CI: -21.10 – -10.94). In this model, there is also a significant non-linear relationship between both disability and pain interference and fulfilled expectations among patients undergoing lumbar surgery (Figure 5.X). Once additional covariates are added to the final model, the aforementioned linear and non-linear relationships remain significant. For disability, the relationship is generally negative as higher levels of disability at the 3 month time points are associated with fewer fulfilled expectations, but relationship flattens some as it approaches 30. For pain interference, lower levels are associated with relatively stable levels of fulfillment of expectations until the PROMIS score approaches 55, at which point higher levels of pain interference at 3 months are associated with lower fulfillment of expectations. Additionally, males (β: -4.48, 95% CI: -7.63 – -1.33) have lower fulfillment of expectations at 3 months than females when controlling for all other variables in the model.


Lumbar preoperative expectations, HSS
80
70
60
50
0
20
40
60
3 month disability, ODI

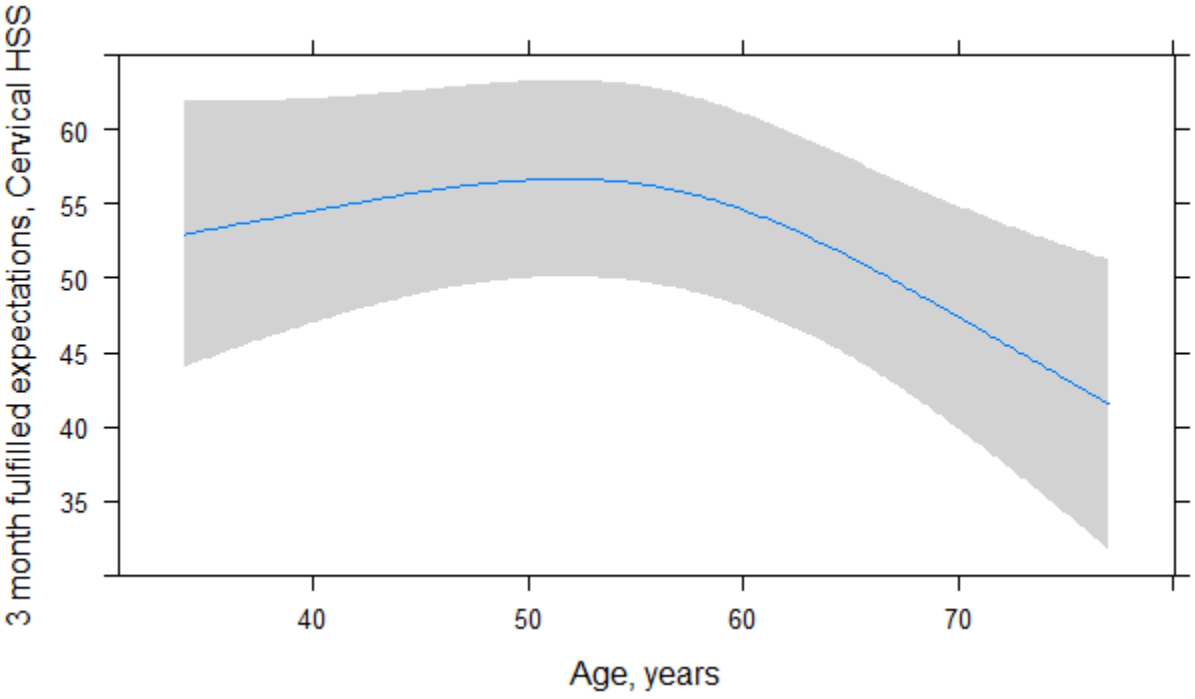

Lumbar expectations fulfilled, HSS
65
60
55
50
45
40
50
60
70
3 month pain interference, PROMIS

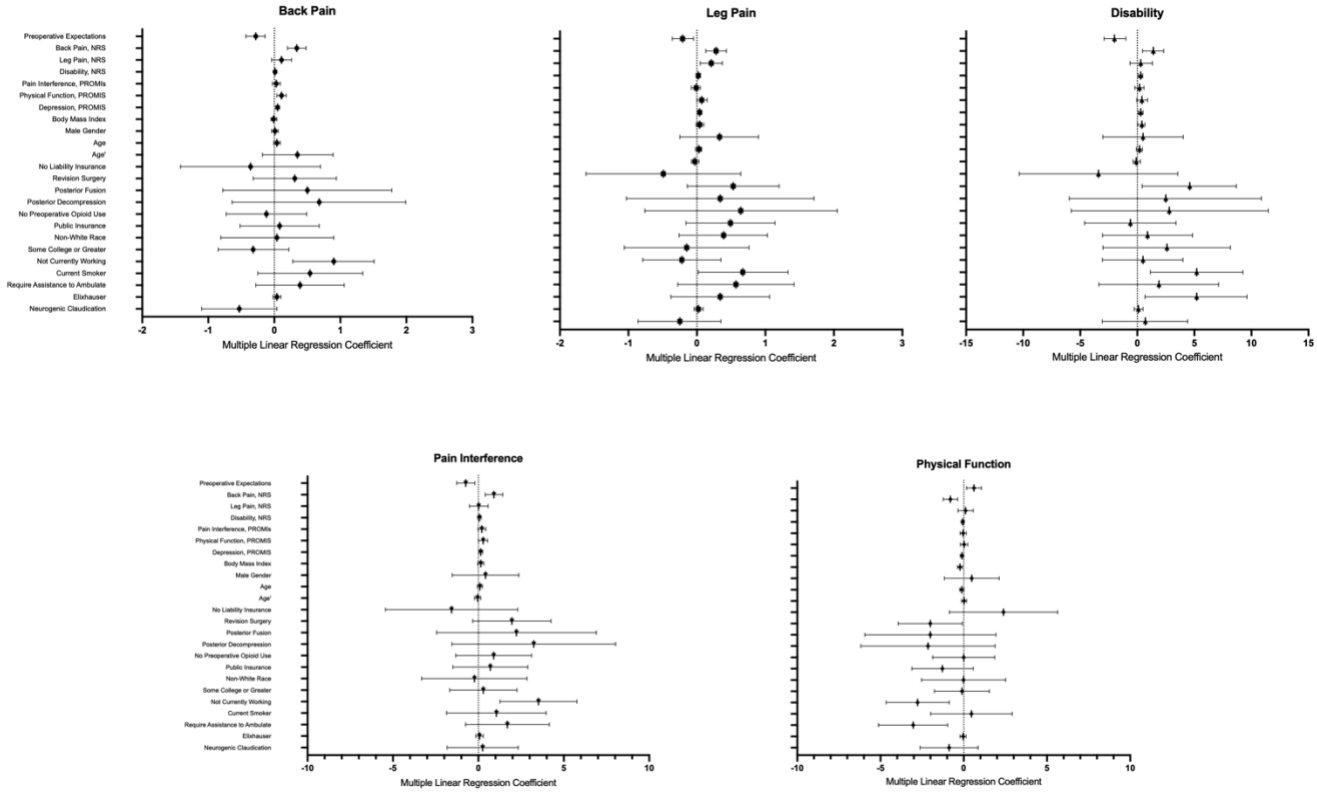
Appendix 5.1 Results of multivariable linear regression assessing the relationship between demographic, clinical, and 3 month patient reported variables and the continuous fulfilled expectations score at 3 months postoperatively in patients undergoing cervical spine surgery

Variables	Coefficient	CI	p	Coefficient	CI	p
Demographic						
Age				0.27	-0.13 – 0.68	0.18
Age'				-0.66	-1.16 – -0.16	**<0.01**
BMI value				0.13	-0.22 – 0.47	0.47
Male Gender (vs. Female)				-0.81	-4.89 – 3.28	0.70
Liability Claim (vs. No Claim				0.96	-4.75 – 6.68	0.74
Public Insurance (vs. Private)				3.04	-2.08 – 8.16	0.24
Non-white (vs. White)				-2.02	-8.48 – 4.45	0.54
Some College Education or Greater (vs. High School or Less)				3.13	-1.06 – 7.33	0.14
Not Currently Working (vs. Currently Working)				-2.22	-7.25 – 2.81	0.39
Current Smoker (vs. non-Smoker)				-3.94	-9.30 – 1.42	0.15
Clinical & Surgical						
Revision Surgery (vs. Primary)				-0.52	-5.64 – 4.61	0.84
No preoperative opioid use				-0.37	-5.25 – 4.50	0.88
Myelopathy				-4.68	-9.25 – 0.11	0.05
Posterior Decompression				-3.43	-8.46 – 1.59	0.18
Posterior Fusion				-2.81	-10.96 – 5.35	0.50
Elixhauser Comorbidity Index				-0.12	-0.55 – 0.31	0.58
Patient Reported Measures						
Neck Pain, NRS	1.06	-0.10 – 2.22	0.07	1.11	-0.05 – 2.26	0.06
Arm Pain, NRS	-0.53	-1.43 – 0.38	0.25	-0.47	-1.38 – 0.43	0.30
Disability, NDI	-0.36	-0.57 – -0.14	**<0.01**	-0.42	-0.64 – -0.20	**<0.001**
Pain Interference, PROMIS	-0.23	-0.58 – 0.12	0.19	-0.24	-0.59 – 0.11	0.18
Physical Function, PROMIS	1.14	0.78 – 1.50	**<0.001**	0.82	0.42 – 1.23	**<0.001**
Depression, PROMIS	-0.14	-0.39 – 0.11	0.28	-0.19	-0.45 – 0.06	0.13
Satisfaction	-16.9	-22.71 – -11.10	**<0.001**	-14.92	-20.74 – -9.10	**<0.001**

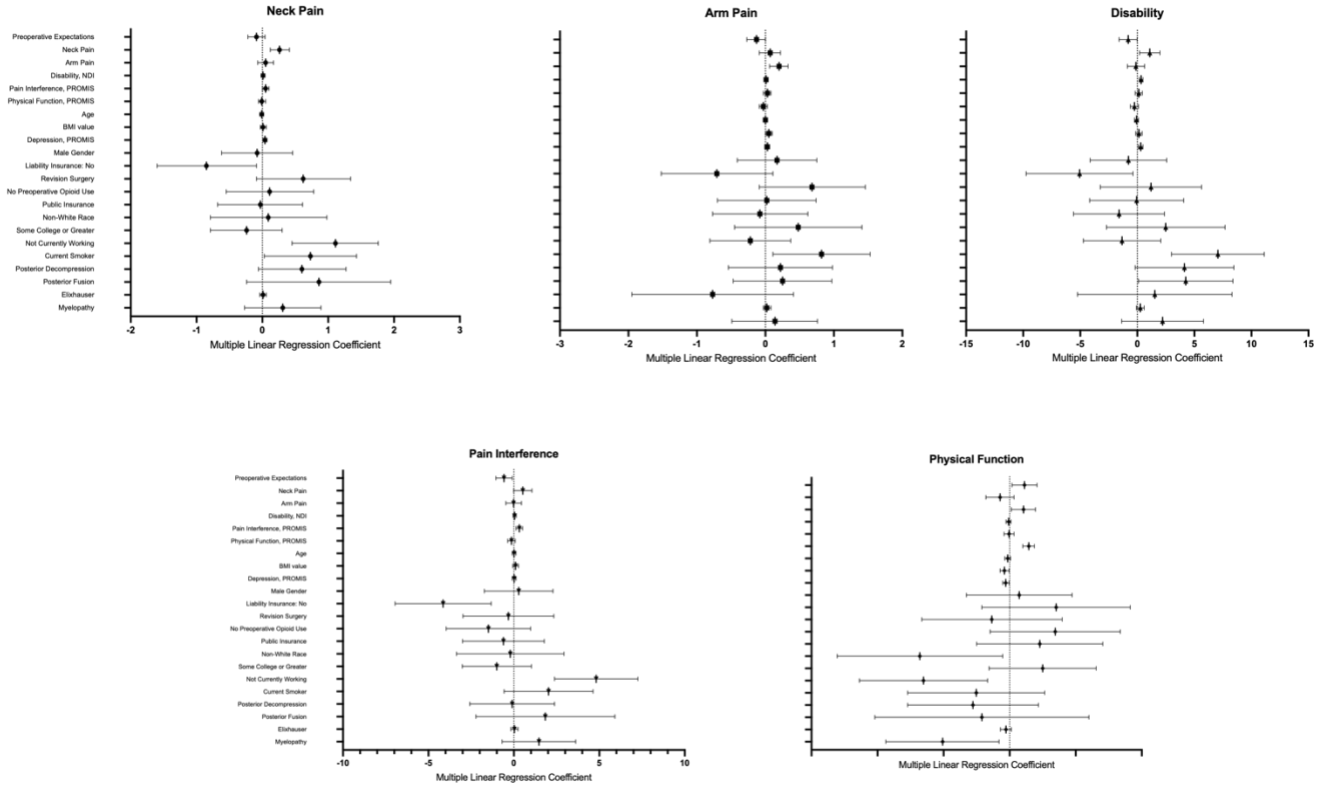
Within the cervical cohort, higher physical function (β: 1.14, 95% CI: 0.78 – 1.50) is associated with a higher level of fulfilled expectations, while higher disability (β: -0.36, 95% CI: -0.57 – -0.14), and being unsatisfied with your surgical outcome (β: -16.90, 95% CI: -22.71 – -11.10) were associated with a fewer fulfilled expectations in the first model evaluating 3 month patient reported measures. After adding the additional covariates for

the final block, a non-linear relationship between age and fulfilled expectations is observed . In this data, patients see a gradual increase in their fulfilled expectations as they age from younger than 40 to 55; then, there is a negative relationship between age and fulfilled expectations as patients age beyond the inflection point. Additionally, higher physical function (β: 0.82, 95% CI: 0.42 – 1.23) remains associated with a higher proportion fulfilled, and higher disability (β: -0.42, 95% CI: -0.64 – -0.20) and being unsatisfied with the outcome (β: -14.92, 95% CI: -20.74 – -9.10) remain associated with a lower proportion fulfilled.

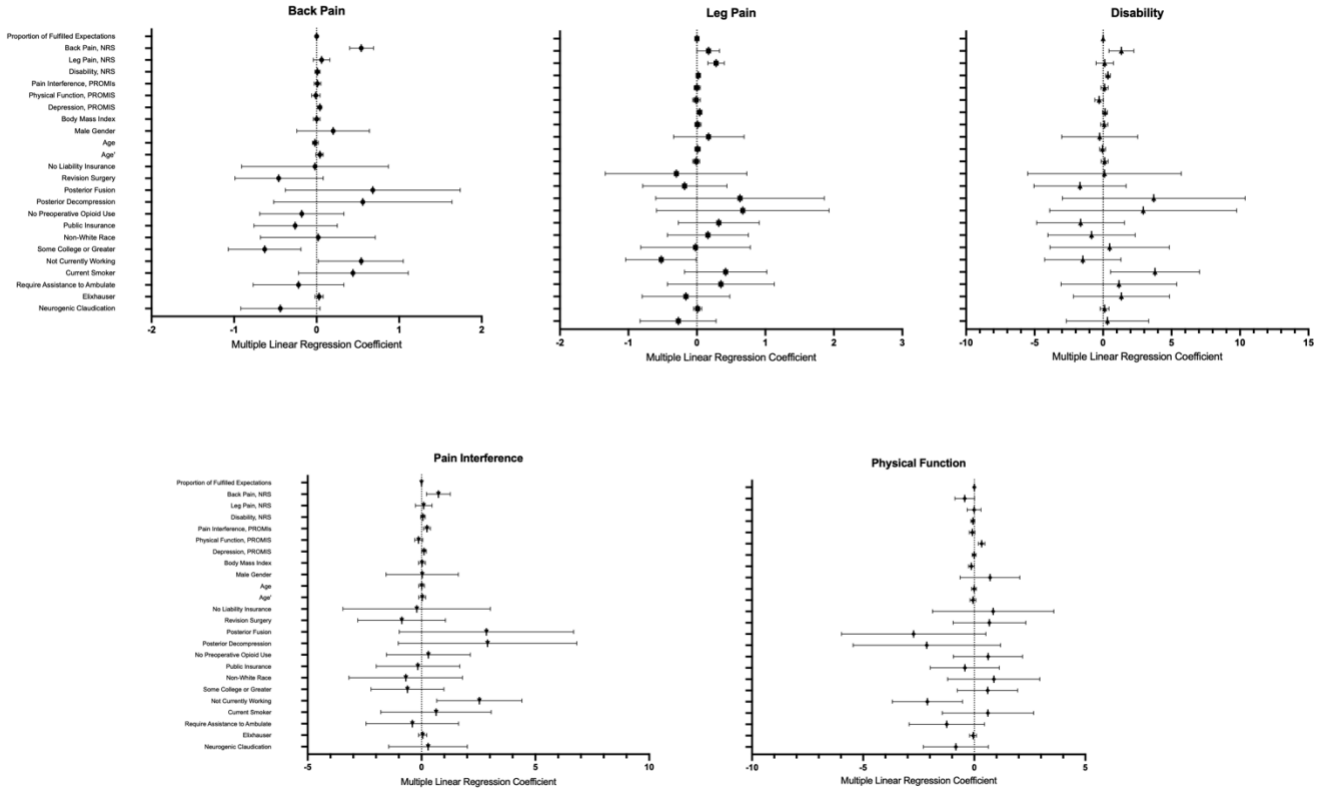




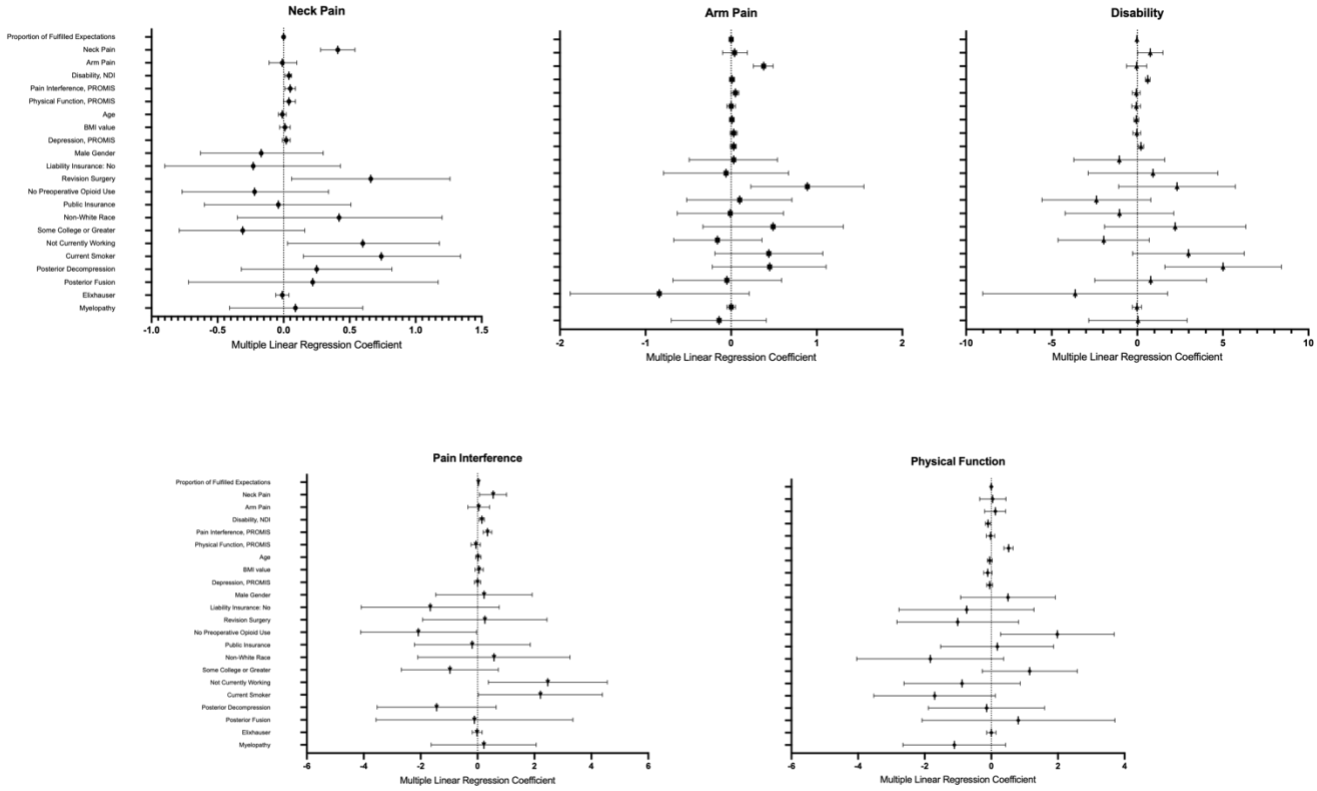
Appendix 6.1 Multivariable regression model results for predictors of 12-month back pain (NRS), leg pain (NRS), disability (ODI), pain interference (PROMIS), and physical function (PROMIS) among patients undergoing lumbar spine surgery



Appendix 6.2 Adjusted preoperative linear regression coefficients and 95% confidence intervals for predictors of 12-month neck pain (NRS), arm pain (NRS), disability (NDI), pain interference (PROMIS), and physical function (PROMIS) among patients undergoing cervical spine surgery



Appendix 6.3 Adjusted 3-month linear regression coefficients and 95% confidence intervals for predictors of 12-month back pain (NRS), leg pain (NRS), disability (ODI), pain interference (PROMIS), and physical function (PROMIS) among patients undergoing cervical spine surgery



Appendix 6.4 Adjusted 3-month linear regression coefficients and 95% confidence intervals for predictors of 12-month neck pain (NRS), arm pain (NRS), disability (NDI), pain interference (PROMIS), and physical function (PROMIS) among patients undergoing cervical spine surgery