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Pain Catastrophizing Throughout the Perioperative Period in Adolescents With Idiopathic Scoliosis

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Objectives: Pain catastrophizing in children and adolescents has been associated to unfavorable postsurgical outcomes. However, pain catastrophizing is rarely measured throughout the perioperative period. Using a prospective longitudinal approach, the present study aimed to identify how pain catastrophizing changes over the perioperative period in pediatric surgical patients with adolescent idiopathic scoliosis.

Materials and Methods: Adolescent patients undergoing spinal fusion surgery completed the Pain Catastrophizing Scale for Children and additional questionnaires to assess pain intensity, state and trait anxiety, and kinesiophobia before surgery, and 1, 2, 5 days, 6 weeks, and 6 months after surgery.

Results: Patients who had higher levels of pain catastrophizing before surgery were more likely to be anxious, avoid activity that may cause pain, report higher pain intensity before surgery and anticipate more pain after surgery. Low pain catastrophizers increased into a moderate level of pain catastrophizing before decreasing after discharge from the hospital. Meanwhile, moderate and high pain catastrophizers both decreased into lower and moderate levels of catastrophizing, respectively, after discharge from the hospital.

Discussion: These findings demonstrate that pain catastrophizing in adolescents changes over the perioperative period. Observing changes in pain catastrophizing throughout the perioperative period may help in recognizing when patients are most vulnerable during this time. Decreasing pain catastrophizing before surgery or in the acute postoperative period through therapies that target pain catastrophizing may help reduce the patient's likelihood of experiencing unfavorable postoperative outcomes.

Key Words: pain catastrophizing, perioperative pain, pediatric, adolescent idiopathic scoliosis

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For patients undergoing spinal surgery for adolescent idiopathic scoliosis (AIS), pain postsurgery is a prevalent and disabling issue.[1,2] Psychosocial factors such as maladaptive coping mechanisms have been shown to be important determinants and predictors of pain experience. One maladaptive behavior of interest is pain catastrophizing which is the tendency to overstate negative appraisals of nociceptive stimuli and is described through 3 main constructs: magnification, rumination, and helplessness.[3] In both healthy children[4] and pediatric patients undergoing surgery, pain catastrophizing has been associated with other psychological measures such as anxiety,[5,6] and is associated with greater functional disability[4,7–10] and greater pain intensity[1,4,8–12] up to 5 years after surgery. There are several other measures, in addition to pain catastrophizing, that are associated with outcomes after surgery. Pain intensity is one such measure that is considered as one of the core measures of the pain experience in clinical practice and in research.[13] Another key measure is anxiety, as pediatric patients experiencing greater anxiety before surgery are more likely to have greater pain and sleep problems following surgery.[14] In addition, kinesiophobia, a measure of fear of movement related to pain, has been shown to increase disability, pain interference, and pain intensity up to 6 months after spinal surgery.[15]

Pain catastrophizing is usually measured as a trait-like, rather than state-like, construct, meaning that it is expected to remain relatively stable in an individual over time.[16] Therefore, it is most typically only assessed at 1 timepoint, before surgery, as one of many psychological measures known to be associated with surgical outcomes and rarely measured longitudinally throughout the perioperative period. However, a previous study examining the relationship between parent and child pain catastrophizing before and following surgery observed that pain catastrophizing may not remain stable over time.[17] Furthermore, Giordano et al[18] assessed pain catastrophizing, using the trait version of the questionnaire, up to 6 months postoperatively in an adult patient sample and observed that pain catastrophizing changed over the perioperative period, and that initial catastrophizing levels did not necessarily inform the trajectory of pain catastrophizing or association to pain intensity throughout the perioperative period. Moreover, when an adapted state pain catastrophizing questionnaire reflecting thoughts about a specific pain was compared with a trait pain catastrophizing questionnaire, it was observed that state pain catastrophizing scores had stronger associations with acute pain intensity and state anxiety.[19] Together, these studies suggest that pain catastrophizing may not behave as a stable trait-like construct in the context of surgery and therefore warrants further investigation as a perioperative rather than preoperative measure.

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To our knowledge, there is limited data investigating pain catastrophizing over time in the context of surgery in children and adolescents due to their social-cognitive development. Eccleston et al[20] highlighted 4 features that result in youth having different pain-related cognition than adults, including reduced emotional control, magical thinking, egocentric distortion, and fragile coping. The latter feature was described by Feinstein and colleagues who showed that pain catastrophizing and emotional distress predicted poor physical and emotional functioning most strongly in children and adolescents compared with adults. They suggest that children and adolescents may catastrophize because they lack adult-like coping strategies.[21] Therefore, children's catastrophizing may manifest differently and may interact with other postoperative outcomes differently throughout the perioperative period, necessitating further investigation. If children and adolescents have a different experience with pain catastrophizing, it is important to investigate pain catastrophizing in pediatric patients to determine beneficial therapies and interventions that may be different from those used in adults.

The objective of this study was to identify how pain catastrophizing changes over the perioperative period in adolescents scheduled to undergo posterior spinal fusion surgery for AIS, and how pain catastrophizing relates to other measures such as pain intensity, anxiety, and kinesiophobia. We hypothesized that pain catastrophizing will not remain stable throughout the perioperative period in pediatric patients undergoing surgery. Moreover, we hypothesized that pain catastrophizing will correlate with pain intensity, anxiety, and kinesiophobia before surgery, and significant differences regarding these outcomes measures over time will be associated with pain catastrophizing before surgery.

MATERIALS AND METHODS

Study Procedures

Data used in this prospective longitudinal study were collected as part of a larger study approved by the Institutional Review Board of McGill University (A08-M71-17B). Participants' written informed consent or parental consent were obtained before the beginning of the study. Study variables were assessed at different timepoints throughout the perioperative period: baseline (7 to 10 d before surgery during the standard preoperative consultation at the hospital); postoperative day (POD) 1 (in the patient's room); POD2 (in the patient's room); POD5 (day of discharge, in the patient's room); and 6 weeks and 6 months after surgery (standard postoperative consultations at the hospital) (Fig. 1). The perioperative anesthesia and analgesia care for the participants was standardized for the study and have been previously described by our group.[2,22] Intraoperatively, patients received intravenous propofol, remifentanil/sufentanil/fentanyl, ketamine, and dexamethasone. After induction, patients received an intrathecal injection of morphine (5 μg/kg). Postoperatively, all patients received IV patient-controlled analgesia (PCA) (1:1) morphine/ketamine of 20 mcg/kg bolus on demand with a 6-minute lockout interval and a maximum dose per hour of 0.1 to 0.4 mg/kg/h available upon arrival at the postanesthesia care unit till the morning of POD3. Throughout the acute postoperative period, acetaminophen and ketorolac were available on a scheduled and pro re nata basis. Furthermore, opiates were available after PCA on a scheduled and pro re nata basis.

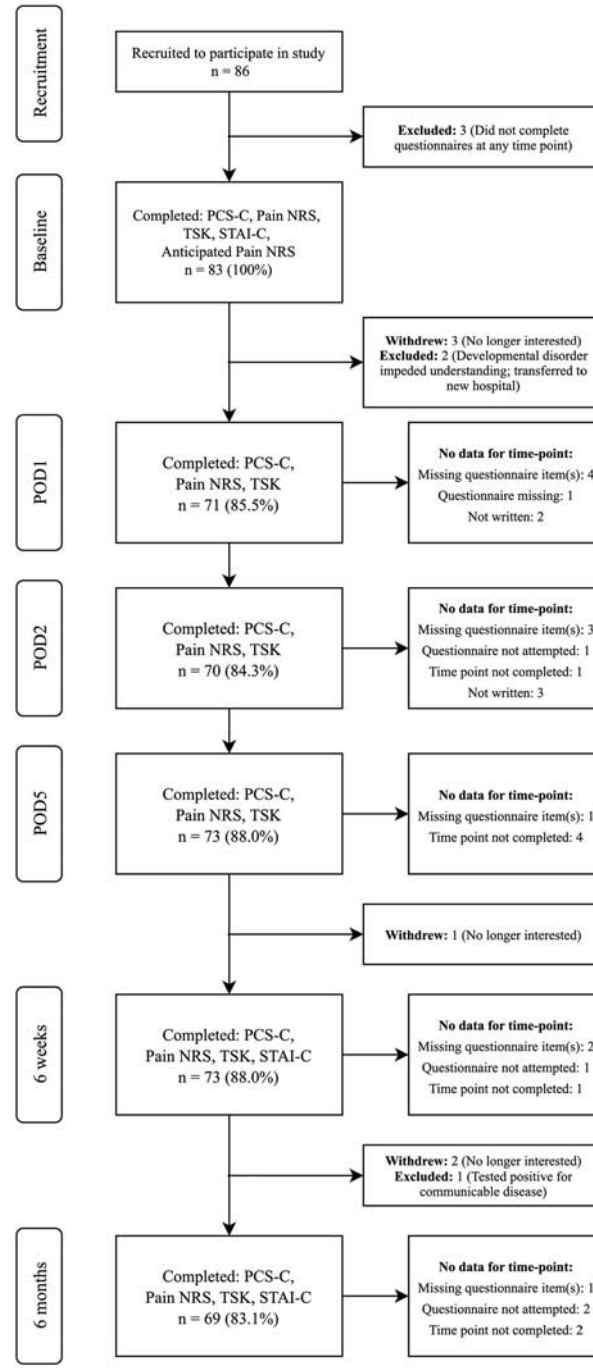

FIGURE 1. Time-course of study including measures collected at each timepoint. Sample size and justification for missing data, as well as reasons for withdrawal/exclusion, are included. NRS indicates Numeric Rating Scale; PCS-C, Pain Catastrophizing Scale for Children; POD, postoperative day; STAI-C, State-Trait Anxiety Inventory for Children; TSK, Tampa Scale for Kinesiophobia.

Participants

Adolescents between 10 and 19 years old with idiopathic scoliosis and scheduled to undergo posterior spinal fusion surgery with instrumentation were prospectively recruited and consented at the Shriners Hospitals for Children-Canada between 2015 and 2019. Other inclusion

criteria included the ability to adequately understand and respond to outcome measures, and to not have undergone a previous major orthopedic surgery. Patients were excluded if they were not proficient in at least one of the testing languages (English or French), were diagnosed with a developmental delay that would interfere with understanding of questions being asked (eg, autism spectrum disorder, intellectual disability) or had a major chronic medical condition (American Society of Anesthesiologists status III or higher).

Outcome Measures

Pain Catastrophizing

The Pain Catastrophizing Scale for Children (PCS-C) was administered at all timepoints to assess the degree to which patients experienced negative thoughts or feelings while experiencing pain.[23] The PCS-C is a 13-item scale and can be divided into 3 subscales: rumination, magnification and helplessness. One of the main adaptations of the child version of the pain catastrophizing scale is the repetition of the stem "When I have pain, …" at the beginning of each item. Responses for each statement are done using a Likert-type rating scale, ranging from 0 (not at all) to 4 (extremely). A total score for pain catastrophizing was calculated. A higher score on this scale would indicate a higher level of pain catastrophizing. This score has been shown to have good internal consistency[3] as well as sufficient test-retest stability,[24] and good construct and predictive validity.[23]

Anxiety

The State-Trait Anxiety Inventory for Children (STAI-C) was used to assess trait and state anxiety before surgery, 6 weeks after surgery, and 6 months after surgery. State-anxiety involves the feelings of nervousness, tension, arousal, and worry while trait-anxiety is the tendency and susceptibility to have those feelings.[25] The STAI-C is a 40-item self-report measure and is divided into the 2 portions mentioned above: state-anxiety and trait-anxiety. Ratings for each statement are done using a Likert-type rating scale ranging from 1 (not at all) to 3 (very much so). A total score was calculated, with higher scores suggesting higher state-anxiety and trait-anxiety. This measure demonstrates good internal consistency.[26]

Kinesiophobia

The Tampa Scale for Kinesiophobia (TSK) was used to assess the participants' fear of movement at all timepoints. The TSK is a 17-item questionnaire and is divided into 2 subscales: somatic focus and activity avoidance. Responses for each statement are done using a Likert-type rating scale, ranging from 1 (strongly disagree) to 4 (strongly agree). A higher score on this scale would indicate a higher level of kinesiophobia. This questionnaire has been demonstrated to have good internal consistency and test-retest reliability.[27] However, recent work has shown that for adolescents undergoing spinal fusion surgery, the activity avoidance subscale accurately describes kinesiophobia, while the somatic focus subscale does not.[28] Therefore, only the scores for activity avoidance were used in this study.

Pain Intensity

A Numerical Rating Scale (NRS) ranging from 0 (no pain) to 10 (worst possible pain) validated in pediatric clinical samples,[29] was used to assess participants' perceived intensity of pain in the past 24 hours at all timepoints. In addition, the NRS was used to assess participants' baseline self-reported anticipated intensity of pain 1 day, week, month, and year after surgery.

Statistical Analysis

Baseline Measures

All analyses were performed using PRISM software version 8.4.2. A χ^2 test was used to test for a main effect of sex, and a Kruskal-Wallis 1-way analysis of variance was conducted to test for main effects in all other baseline outcome measures. For all significant effects, Dunn multiple comparisons test was used to identify significant differences between groups. Spearman correlation was used to identify baseline characteristics associated with baseline pain catastrophizing.

Longitudinal Measures

Due to missing data at all timepoints (Fig. 1), a mixed-effects analysis was conducted to evaluate how the pain catastrophizing groups differ in terms of pain catastrophizing scores, pain intensity, state anxiety scores, and activity avoidance scores at each timepoint. Mixed-effect models were used to estimate the overall fit of the independent variable (ie, pain catastrophizing groups) in estimating repeated measure outcomes (pain catastrophizing score, pain intensity, state anxiety, and activity avoidance) with the assumption that missing data is random at the individual level. The total pain catastrophizing pain scale scores were used to divide the sample into 3 groups at baseline: low pain catastrophizers (0 to 14), moderate pain catastrophizers (15 to 25), and high pain catastrophizers (26 to 52).[30] These 3 clinical reference points have been established to identify significant differences in child functioning across catastrophizing levels in children and adolescents with chronic pain.[30] As all patients received IV PCA after surgery, the 5-day postoperative cumulative opioid consumption was included in the mixed-effects models as a covariate. G*Power 3.1 was used a priori to determine the necessary sample size. The calculation was done for a within-between repeated measures analysis of variance, as an equivalent measure to the mixed-effects analysis. It was found that, to detect a medium effect size ($f = 0.25$) with a power of 95% and $\alpha = 0.05$, we would require a sample size of 36 patients. As the current study was part of a larger research study, data were included for all the participants tested to date. Following the mixed-effects analysis, uncorrected Fisher LSD multiple comparisons were used to compare outcome measures between each timepoint for each group.

RESULTS

Demographic and Psychosocial Characteristics of the Pain Catastrophizing Subgroups

A total of 86 participants were recruited for this study, only the data from 83 participants were included in the analyses. Three participants were excluded as they did not complete the study questionnaires for any of the timepoints. The mean age of the sample was 15.66 (range: 10.9 to 19.5) and the majority were female (68.7%). Among the cohort, 22 were identified as low pain catastrophizers, 35 as moderate and 26 as high pain catastrophizers. No significant differences were found across groups in sex or age (Table 1). All groups had significantly different baseline trait anxiety

TABLE 1. Baseline Characteristics of Sample

Variables	Total Sample (n = 83)	Low Pain Catastrophizers (n = 22)	Moderate Pain Catastrophizers (n = 35)	High Pain Catastrophizers (n = 26)	Test Statistic	*P*
Age, mean (range)	15.66 (10.9-19.5)	16.09 (12.6-19.3)	15.50 (10.9-19.5)	15.53 (12.2-19.3)	1.16*	0.561
Sex, n (%)					4.56†	0.103
Female	57 (68.7)	14 (63.6)	21 (60.0)	22 (84.6)		
Male	26 (31.3)	8 (36.3)	14 (40.0)	4 (15.4)		
Baseline Pain Catastrophizing, mean (range)						
PCS-C total score	21.37 (0-43)	10.09 (0-14)[bc]	20.31 (15-25)[ac]	32.35, (26-43)[ab]	71.94*	**< 0.001**
Baseline anxiety, mean (range)						
STAI-C trait anxiety score	35.73 (22-56)	29.95 (22-41)[bc]	35.49 (23-48)[ac]	40.95 (29-56)[ab]	20.79*	**< 0.001**
STAI-C state anxiety score	33.77 (20-54)	31.62 (21-51)	32.86 (20-49)	36.75 (27-54)	5.43*	0.066
Baseline kinesiophobia, mean (range)						
TSK activity avoidance	17.99 (9-32)	16.86 (10-22)	17.22 (9-27)	19.88 (11-32)	4.36*	0.113
Baseline pain, mean (range)						
NRS average—past 24 h	2.78 (0-8)	1.73 (0-6)[c]	2.26 (0-8)[c]	4.39 (2-8)[ab]	20.99*	**< 0.001**
NRS anticipated (d)	7.89 (0-10)	7.17 (0-10)[c]	7.94 (4-10)	8.40 (0-10)[a]	7.33*	**0.026**
NRS anticipated (wk)	5.40 (0-10)	4.95 (1-10)	5.17 (2-8)[c]	6.06 (0-9)[b]	7.63*	**0.022**
NRS anticipated (mo)	3.02 (0-8)	2.60 (0-6)	2.77 (1-5)	3.69 (0-8)	5.63*	0.060
NRS anticipated (y)	0.62 (0-5)	0.36 (0-2.5)	0.47 (0-2)	1.02 (0-5)	2.82*	0.244

Superscript alphabets indicate significant Dunn multiple comparisons with [a]low, [b]moderate or [c]high pain catastrophizers.

Pain catastrophizing groups were defined based on PCS-C scores: low pain catastrophizers (0 to 14), moderate pain catastrophizers (15 to 25), and high pain catastrophizers (26 to 52).

$P \leq 0.05$ are bolded.

*Kruskal-Wallis 1-way analysis of variance.

†χ^2 Test.

NRS indicates Numeric Rating Scale; PCS-C, Pain Catastrophizing Scale for Children; STAI-C, State-Trait Anxiety Inventory for Children; TSK, Tampa Scale for Kinesiophobia.

scores ($P < 0.001$), presenting higher trait anxiety in moderate versus low catastrophizers ($z = 2.55$, $P \leq 0.001$), high versus moderate catastrophizers ($z = 2.42$, $P \leq 0.001$), and high versus low catastrophizers ($z = 4.56$, $P < 0.001$). Different pain intensity scores were also reported across groups before surgery ($P < 0.001$). Higher pain intensity scores were observed in high pain catastrophizers in comparison to low catastrophizers ($z = = 4.17$, $P < 0.001$) and to moderate catastrophizers ($z = 3.77$, $P < 0.001$). In addition, low pain catastrophizers also anticipated significantly less pain 1 day after surgery than high pain catastrophizers ($z = 2.62$, $P = 0.027$). Moreover, moderate pain catastrophizers also anticipated significantly less pain 1 week after surgery than high pain catastrophizers ($z = 2.40$, $P = 0.049$). No significant differences in state anxiety ($P = 0.066$) and activity avoidance ($P = 0.113$) was observed between groups.

As hypothesized, before surgery, pain catastrophizing was significantly associated with the other psychosocial characteristics assessed at baseline such as a higher pain catastrophizing score was associated with higher scores for state ($r = 0.236$, $P = 0.033$) and trait anxiety ($r = 0.497$, $P < 0.001$), and activity avoidance ($r = 0.279$, $P = 0.012$) (Figs. 2A−C). Higher pain catastrophizing scores were also significantly associated with higher pain intensity reported for the past 24 hours ($r = 0.482$, $P < 0.001$) (Fig. 2D), and higher anticipated pain intensity 1 week ($r = 0.268$, $P = 0.015$), 1 month ($r = 0.269$, $P = 0.027$), and 1 year after surgery ($r = 0.316$, $P = 0.031$).

Pain Catastrophizing Over the Perioperative Period

As hypothesized, a significant interaction between time and pain catastrophizing level was found for the total sample ($F = 2.19$, $P = 0.018$), as well as a significant effect of time on pain catastrophizing ($F = 39.67$, $P < 0.001$) and a significant effect of time for each of the pain catastrophizing groups ($F = 23.97$, $P < 0.001$) (Table 2). A significant difference in PCS-C scores was observed between all groups at all timepoints ($P < 0.05$), except 5 days after the surgery, in which a significant difference in PCS-C scores was observed only in the high pain catastrophizing group in comparison to the moderate and low pain catastrophizing groups ($P < 0.05$) (Fig. 3A).

Significant differences in pain catastrophizing scores over time were also observed among each pain catastrophizing group (Table 2). For the low pain catastrophizing group, a significant increase in PCS-C scores to a moderate level ($P < 0.05$) was observed in the low catastrophizer group during the acute postoperative period (POD1, POD2, POD5) when compared with baseline PCS-C scores. Furthermore, a significant decrease in PCS-C scores was observed in the low catastrophizing group between the acute postoperative period and the 6-week and 6-month follow-up ($P < 0.05$). No significant differences in PCS-C scores was observed between baseline and the follow-up assessments. For the moderate pain catastrophizing group, there was no significant change observed in PCS-C scores during the acute postoperative period when compared with baseline.

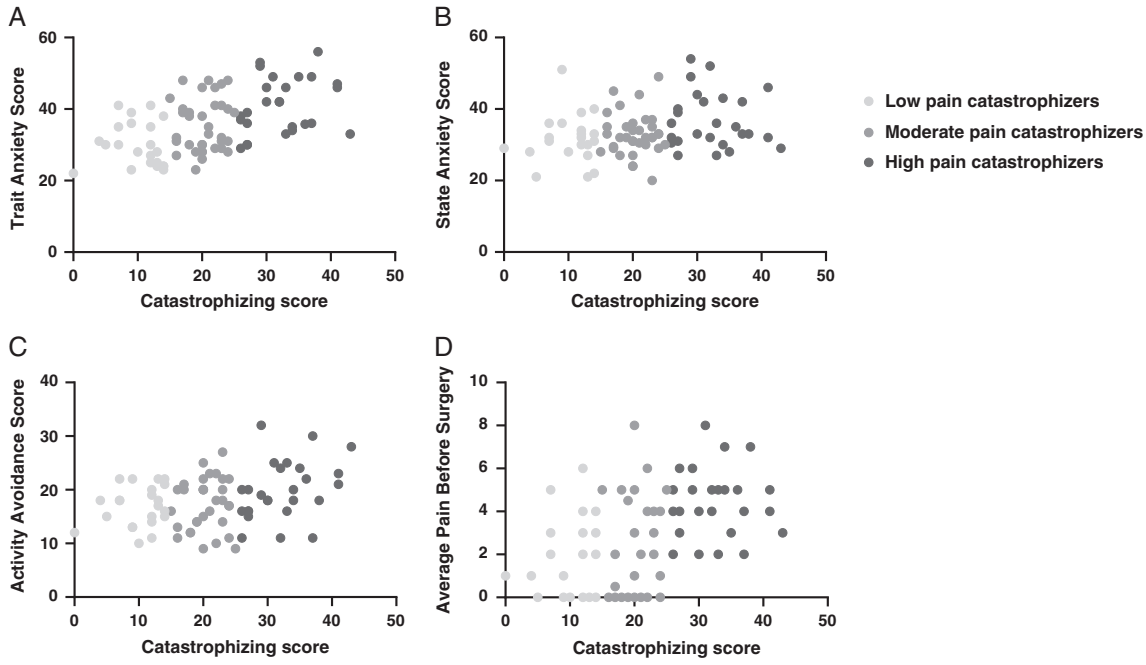

FIGURE 2. Scatterplot showing the correlations between baseline pain catastrophizing and trait anxiety, state anxiety, activity avoidance, and average pain before surgery. A, Correlation between pain catastrophizing and trait anxiety before surgery ($r = 0.497$, $P < 0.001$). B, Correlation between pain catastrophizing and state anxiety before surgery ($r = 0.236$, $P = 0.033$). C, Correlation between pain catastrophizing and activity avoidance before surgery ($r = 0.279$, $P = 0.012$). D, Correlation between pain catastrophizing and average pain before surgery ($r = 0.482$, $P < 0.001$).

However, a significant decrease in PCS-C scores was observed 6 weeks and 6 months after surgery in comparison to before surgery or during the acute postoperative period ($P < 0.05$). For high pain catastrophizing group, a significant decrease in PCS-C scores was observed during the 6 weeks and 6 months follow-up assessment after surgery when compared with PCS-C scores at baseline and during the acute postoperative period ($P < 0.05$).

Pain Intensity Over the Perioperative Period

As hypothesized, significant interaction between time and pain catastrophizing level was found for the change in pain intensity for the total sample ($F = 1.83$, $P = 0.041$), as well as a significant effect of time ($F = 88.84$, $P < 0.001$) and a significant effect of time for each of the groups ($F = 10.66$, $P < 0.001$) (Table 2). A significant difference in NRS scores was observed between the low and high pain catastrophizing groups at baseline, POD1, and POD2 ($P < 0.05$) and between the moderate and high pain catastrophizing groups at baseline, POD1, POD2, POD5, and 6 months ($P < 0.05$) (Fig. 3B).

Multiple comparisons across timepoints revealed similar patterns of difference in pain intensity throughout the perioperative period among each pain catastrophizing group (Table 2). A significant increase in pain intensity was observed during the acute postoperative period for all pain catastrophizing groups when compared with pain intensity at baseline ($P < 0.05$). Furthermore, a significant decrease in pain intensity was observed during the 6-week and 6-month follow assessments when compared with the acute postoperative period ($P < 0.05$). Moreover, for the moderate and high pain catastrophizing groups, the pain intensity reported at the follow-up assessments were significantly lower than before surgery ($P < 0.05$).

State Anxiety Over the Perioperative Period

Only a significant effect of time on state anxiety for the total sample ($F = 26.63$, $P < 0.001$) was observed. Contrary as hypothesized, no significant effect of pain catastrophizing level ($F = 1.93$, $P = 0.153$) and no significant interaction between time and pain catastrophizing level was observed ($F = 1.07$, $P = 0.374$) (Table 2). There were significant differences in STAI-C state anxiety scores between high pain catastrophizers and the other groups only at baseline ($P < 0.05$) (Fig. 4A). For each pain catastrophizing group, multiple comparisons revealed a significant decrease in state anxiety scores when comparing baseline to 6 weeks and 6 months after surgery ($P < 0.05$) (Table 2).

Activity Avoidance Over the Perioperative Period

As hypothesized, significant effect of time on activity avoidance for the total sample ($F = 16.17$, $P < 0.001$) and a significant effect of time for each of the groups ($F = 16.17$, $P < 0.001$) was observed, but there was no significant interaction between time and activity avoidance for the total sample ($F = 1.26$, $P = 0.247$) (Table 2). A significant difference in TSK activity avoidance scores was observed between the low and moderate pain catastrophizing groups at 6 months ($P = 0.021$) and between the low and high pain catastrophizing groups at baseline, POD5 and 6 months ($P = 0.031$; $P = 0.017$; $P < 0.001$). A significant difference in TSK activity avoidance was also observed between the moderate and high pain catastrophizers at POD1 ($P = 0.025$) (Fig. 4B). The multiple comparisons across timepoints revealed different patterns of change in TSK activity avoidance scores among each pain catastrophizing group (Table 2). For the low pain catastrophizing group, a significant increase in activity avoidance scores was observed during the acute postoperative period and 6 weeks

TABLE 2. Mixed-effects Analysis of Outcome Measures Across the Perioperative Period

	Baseline[a]	POD1[b]	POD2[c]	POD5[d]	6 Weeks[e]	6 Months[f]
PCS-C score, mean (range)						
Low Pain Catastrophizers	10.09 (0-14)[bcd]	16.00 (0-43)[adf]	17.58 (4-44)[aef]	20.44 (5-48)[abef]	12.35 (0-20)[cd]	8.88 (0-22)[bcd]
Moderate Pain Catastrophizers	20.31 (15-25)[ef]	21.71 (9-47)[ef]	22.52 (9-43)[ef]	23.29 (10-39)[ef]	16.79 (1-38)[abcd]	14.14 (0-30)[abcd]
High Pain Catastrophizers	32.35 (26-43)[bef]	27.92 (6-51)[acdef]	31.77 (13-52)[bef]	32.54 (18-52)[bef]	23.77 (2-41)[abcd]	22.45 (2-34)[abcd]
Pain NRS score, mean (range)						
Low Pain Catastrophizers	1.73 (0-6)[bcd]	4.00 (1-7)[aef]	4.55 (2-6)[aef]	4.19 (1-7)[aef]	1.29 (0-4)[bcd]	1.16 (0-7)[bcd]
Moderate Pain Catastrophizers	2.26 (0-8)[bcdef]	4.06 (0-7)[aef]	4.59 (2-8)[aef]	3.88 (0-7.5)[aef]	0.86 (0-4)[abcd]	0.47 (0-3)[abcd]
High Pain Catastrophizers	4.39 (2-8)[bcdef]	5.38 (0-8)[aef]	5.71 (2-8)[aef]	5.33 (0-10)[aef]	1.83 (0-5)[abcd]	1.86 (0-8)[abcd]
STAI-C State score, mean (range)						
Low Pain Catastrophizers	31.62 (21-51)[ef]	—	—	—	28.06 (23-37)[a]	27.33 (20-40)[a]
Moderate Pain Catastrophizers	32.86 (20-49)[ef]	—	—	—	28.61 (21-42)[a]	29.81 (20-39)[a]
High Pain Catastrophizers	36.75 (27-54)[ef]	—	—	—	29.96 (22-38)[a]	30.07 (22-41.5)[a]
TSK Activity Avoidance score, mean (range)						
Low Pain Catastrophizers	16.86 (10-22)[bcde]	21.35 (12-29)[af]	21.00 (13-29)[af]	20.28 (14-28)[af]	21.00 (17-31)[af]	17.11 (11-22)[bcde]
Moderate Pain Catastrophizers	17.22 (9-27)[bcdef]	20.85 (12-32)[ae]	21.44 (13-32)[a]	22.09 (13-29)[af]	22.32 (12-30)[abf]	20.04 (12-29)[ade]
High Pain Catastrophizers	19.88 (11-32)[bcdef]	23.23 (14-30)[a]	22.76 (13-32)[a]	23.29 (11-32)[a]	22.80 (14-30)[a]	22.05 (14-30)[a]

Superscript alphabets indicate significant Fisher LSD multiple comparisons with each respective timepoint.
Pain catastrophizing groups were defined based on PCS-C scores: low pain catastrophizers (0 to 14), moderate pain catastrophizers (15 to 25) and high pain catastrophizers (26 to 52).
NRS indicates Numeric Rating Scale; PCS-C, Pain Catastrophizing Scale for Children; POD, postoperative day; STAI-C, State-Trait Anxiety Inventory for Children; TSK, Tampa Scale for Kinesiophobia.

after the surgery ($P<0.05$). However, a significant decrease in their scores to baseline levels was observed at the 6-month follow-up assessment of this group ($P<0.05$). Similar to the low pain catastrophizing group, the moderate group displayed a significant increase in their activity avoidance scores during the acute postoperative period and 6 weeks after surgery. Furthermore, a significant decrease in their scores was also observed at 6 months after surgery, but still significantly higher when compared with their baseline scores ($P<0.05$). For the high pain catastrophizing group, a significant increase in their activity avoidance scores was observed at all postoperative timepoints when compared with baseline ($P<0.05$).

DISCUSSION

To our knowledge, this study is one of the few aimed to identify how pain catastrophizing changes over the perioperative period in adolescents with idiopathic scoliosis who have undergone posterior spinal fusion surgery and how pain catastrophizing relates to other pain-related measures. The main findings revealed that (1) the PCS-C scores of low pain catastrophizers before surgery increased to a moderate level of catastrophizing during the acute postoperative period, before decreasing back to low scores after discharge from the hospital, (2) the PCS-C scores of moderate pain catastrophizers remain relatively constant during the acute postoperative period, before decreasing to lower scores after discharge from the hospital, and (3) the PCS-C scores of high pain catastrophizers remain relatively constant during the acute postoperative period, before decreasing to moderate scores after discharge from the hospital. The observed dynamic nature of pain catastrophizing along with its associations with other distress-related measures may imply that pain catastrophizing does not remain stable over time and, furthermore, may be a malleable target for improving patient outcomes.

Pain catastrophizing before surgery was associated with other pain-related measures including trait anxiety, state anxiety, activity avoidance, pain intensity in the past 24 hours, and anticipated pain intensity 1 week, 1 month, and 1 year after surgery. That is, patients who had higher levels of pain catastrophizing were more likely to be anxious, avoid activity that may cause pain, report higher pain intensity before surgery and anticipate more pain after surgery. These results are intuitive as pain catastrophizing is characterized by magnification, rumination and helplessness; all constructs related to distress.[3] This is consistent with other studies that have shown that pain catastrophizing is associated with anxiety sensitivity,[6] disability, and somatic complaints in children.[4] Specifically, the association with anxiety is in line with previous studies in pediatrics highlighting the importance of mental state before surgery[2,5,6,31] and suggest that these 2 related measures both play a role in determining pain outcomes after surgery. Overall, our results highlight the identification of adolescents with moderate to high pain catastrophizing scores who may possess maladaptive coping behaviors or lack adult-like coping strategies which can be intervened through pain counseling/education.[32]

There was a significant interaction between time and pain catastrophizing level for our sample, meaning that the change in pain catastrophizing scores over time is different depending on group membership. Moreover, the PCS-C scores of low pain catastrophizers increased to a moderate level of pain catastrophizing before decreasing again to low

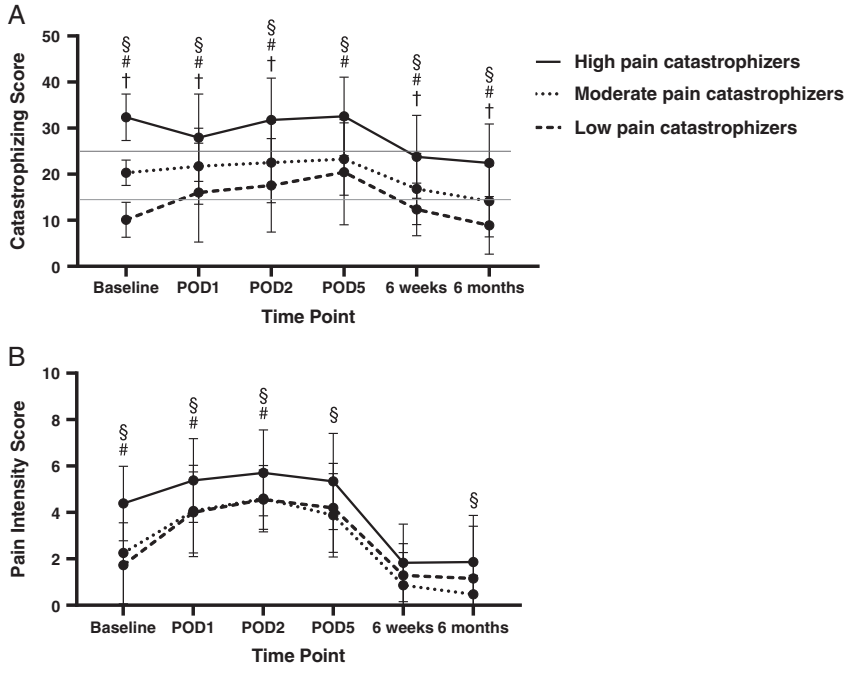

FIGURE 3. Change in pain catastrophizing and pain intensity over time. A, Pain catastrophizing over the perioperative period. The horizontal gray lines indicate the cutoffs for moderate and high pain catastrophizers, respectively. Significant differences in Pain Catastrophizing Scale for Children scores were observed between all groups at baseline, POD1, POD2, and 6 weeks and 6 months after surgery. Significant differences in Pain Catastrophizing Scale for Children scores were also observed between high pain catastrophizers and both other groups at POD5. B, Pain intensity over the perioperative period. Significant differences in pain intensity were observed between high and low pain catastrophizers at baseline, POD1, and POD2. Significant differences in pain intensity were also observed between high and moderate pain catastrophizers at baseline, POD1, POD2, POD5, and 6 months after surgery. Error bars represent the SEM. Differences are significant if $P < 0.05$. Significant difference between †low and moderate, #low and high, or §moderate or high pain catastrophizers. POD indicates postoperative day.

levels after discharge from the hospital. The acute postoperative period is an important time period where the patient may feel like they are not in control when in pain. Durand et al[19] investigated the factor structure, and reliability of a state version of the Pain Catastrophizing Scale, and observed that state catastrophizing scores showed stronger association for pain-related outcomes, such as acute pain. Although we administered the trait version of the pain catastrophizing scale, an increase in pain catastrophizing scores from low to moderate in this group during the acute postoperative period may be a response to the acute pain they experienced and because each item of the questionnaire begins with the stem "When I have pain, …". Hence, the patients in the study may have implicitly reflected their response on the pain catastrophizing scale to the pain intensity experienced in their back.

The moderate pain catastrophizing group also experienced a change in pain catastrophizing scores over time, decreasing to a lower level after discharge from the hospital. In addition, the PCS-C scores of high pain catastrophizers decreased into a moderate level after discharge. These findings coincide with a study conducted by Birnie et al[17] examining child pain catastrophizing before and 6 weeks after surgery, and who highlighted that pain catastrophizing show less stability over time. Similar findings were also seen by Giordano et al[18] in an adult sample where moderate and high pain catastrophizers decreased into a lower level of catastrophizing throughout the perioperative period. The fact that moderate and high pain catastrophizers both decreased into a lower level of pain catastrophizing after discharge may suggest that the patients' experience may not have been as painful as they had anticipated it to be at baseline or may be reflective of the decrease in pain intensity at the follow-up assessments. Furthermore, the decrease in pain catastrophizing at the follow-up assessments may be explained by the phenomenon of "regression to the mean."[33] This implies that repeated measures vary from 1 timepoint to the next due to random error, and extreme scores tend to approach the mean at subsequent timepoints. Although pain catastrophizing has been shown to be a trait-like construct,[16] our findings demonstrate that pain catastrophizing in AIS patients may not remain stable over the perioperative period and its prospective relation over time is of importance for pediatric postsurgical pain. That is, an important painful experience such as surgery may trigger a change in this variable. Therefore, pain catastrophizing should be assessed throughout the perioperative period and observing changes in pain catastrophizing throughout the perioperative period may allow us to know when patients are most vulnerable, whether before or after surgery. This information may be important to clinicians and families who care for patients before surgery, during the hospital stay and after discharge as it can allow for the creation of an individualized psychosocial education and treatment plan for patients that targets pain catastrophizing to help optimize patient outcomes. Therapies such as brief cognitive-behavioral therapy during pain management education, exercise-based behavioral interventions, or a combination of both have been shown to help decrease pain catastrophizing and, in turn, help decrease intensity of pain,

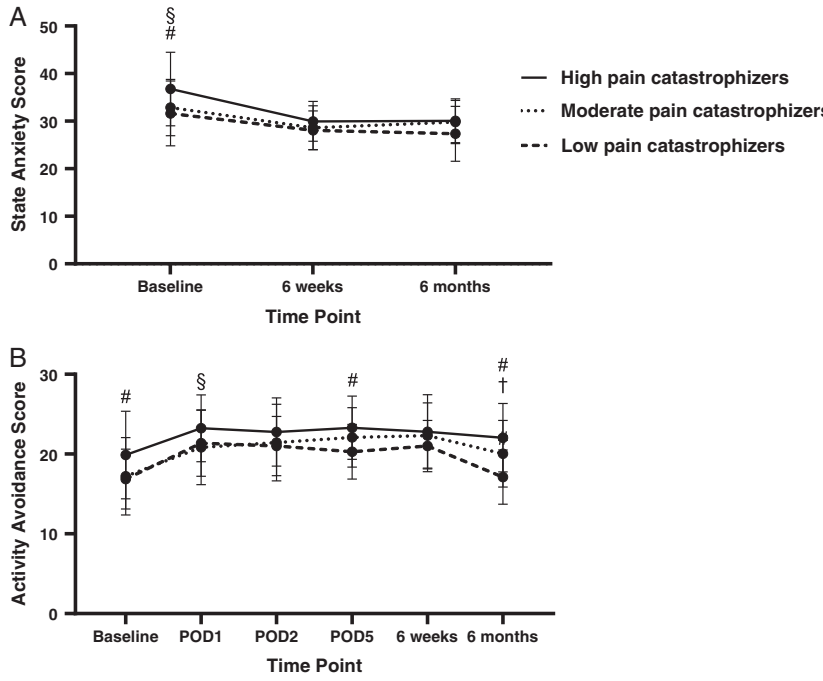

FIGURE 4. Change in state anxiety and activity avoidance over time. A, State anxiety over the perioperative period. Significant differences in state anxiety were observed between high pain catastrophizers and both other groups only at baseline. B, Activity avoidance over the perioperative period. Significant differences were found between low and high pain catastrophizers at baseline and POD5, and between low pain catastrophizers and both other groups at 6 months. A significant difference was also found between moderate and high pain catastrophizers at POD1. Error bars represent the SEM. Differences are significant if $P < 0.05$. Significant difference between †low and moderate, #low and high or §moderate or high pain catastrophizers. POD indicates postoperative day.

pain-related activity interference, and disability.[16] Such therapies given before surgery and reminded after surgery may benefit all pain catastrophizing groups, especially the high pain catastrophizing group. Therefore, decreasing pain catastrophizing before surgery may reduce the patient's likelihood of experiencing unfavorable postoperative outcomes such as postoperative distress.[34]

The results of the present study indicate that the significant differences in pain intensity were between pain catastrophizing groups before and immediately following surgery. These results are consistent with past findings which have shown that children with higher levels of pain catastrophizing report higher pain severity scores,[4] and we have previously shown with a subset of the patients in this study that high pain catastrophizing levels preoperatively predict high pain trajectories in the acute postoperative period.[2] Interestingly, not much significant differences in pain intensity was observed between pain catastrophizing groups 6 weeks or 6 months postsurgery. While the differences between pain intensity did not last throughout the perioperative period, differences in pain catastrophizing did. These findings affirm our understanding of pain intensity and pain catastrophizing as independent constructs. As pain is a complex and multifaceted experience, the measure of pain intensity alone cannot capture the breadth of the pain experience, specifically emotional, and anxiety-related components.[35] Pain catastrophizing is an important part of this pain experience and therefore the fact that its trajectory varies between groups is clinically meaningful, as those with higher pain catastrophizing may have greater distress surrounding their pain despite having similar pain intensity.

In addition to pain intensity, we looked at the trajectory of other measures throughout the perioperative period as they were associated to pain catastrophizing level. We found that state anxiety showed the same trajectory across all pain catastrophizing groups, and that there was a slight decrease in state anxiety 6 months after surgery. These results affirm that pain catastrophizing is a separate construct from anxiety as they behave differently in the perioperative period, and that using state anxiety as a perioperative measure does not capture the full psychosocial experience. Interestingly, we did not see an increase in state anxiety postoperatively as previous studies have shown,[36] but due to the fact that the state anxiety measure was not taken in the few days following surgery, it is possible that we missed this increase and instead captured the decrease as the patient recovered. For activity avoidance, all groups showed similar trajectories of activity avoidance, but at the 6-month timepoint both moderate and high pain catastrophizers had higher activity avoidance than low catastrophizers. Therefore, measures of pain catastrophizing at baseline may inform a patient's fear of movement in the long-term, following surgery, suggesting that if they have moderate or high levels of pain catastrophizing before surgery, they may take longer to return to moving without fear compared with low catastrophizers. Hence, decreasing pain catastrophizing before surgery may increase the patient's likelihood return to daily activities without fear.

Limitations and Future Directions

The main limitation of the study was that data were missing for multiple timepoints. By the 6-month point, data was not collected for around 17% of all participants which

includes participants who dropped out of the study or did not complete questionnaires. Therefore, missing participant data were found at every timepoint after baseline. There may be differences between those who decided to drop out of the study and those who continued to participate. Those who decided to drop out of the study may have done so for a number of reasons which may also have had an impact on their pain or their pain catastrophizing. Another limitation of the study was to group patients strictly on their baseline pain catastrophizing scores. We have previously used cluster or trajectory analyses which are helpful in examining naturally formed groups within the sample and which characteristics are associated to each.[2,22] Giordano et al[18] observed in adults 4 different pain catastrophizing trajectories over the perioperative period: stable, remitting, worsening and unremitting. In their adult sample, both the stable and the worsening groups were comprised of low pain catastrophizers before surgery. The former remained at a stable level of pain catastrophizing while the latter worsened over time. Therefore, a larger sample size, applying an exploratory approach, and extending these analyses to 1 and 2 years after surgery may allow for a more comprehensive and accurate overview of pain catastrophizing and patients' pain experience over the perioperative period.

Future research should also investigate treatments for pain catastrophizing to further improve patient outcomes. A large body of research suggests that parents' pain catastrophizing may also influence the child's pain outcomes. For instance, it has been shown that, due to their distress, catastrophizing parents have a tendency to limit their child's activity,[37] and overall parents' pain catastrophizing can have a direct impact on their child's pain catastrophizing and pain experience.[17,30,38] These behaviors may have an important impact on the child's recovery; therefore, parents may also benefit from therapies that target pain catastrophizing from which their children can benefit indirectly.

Finally, future research may attempt to tease apart the effects of pain intensity and pain catastrophizing by testing patients for pain modulation to provide a semiobjective assessment to support pain catastrophizing measured with a questionnaire.[39] It has been shown that high pain catastrophizers are more likely to report a higher intensity of pain and a lower effect of diffuse noxious inhibitory control (ie, lower pain modulation).[39,40] Quantitative sensory testing could provide an additional semiobjective assessment of pain in this case.[41]

CONCLUSIONS

The findings of the present study demonstrate that pain catastrophizing in AIS patients may not remain stable over the perioperative period. Low pain catastrophizers increased into a moderate level of pain catastrophizing during the acute postoperative period before decreasing again after discharge. Meanwhile, moderate and high pain catastrophizers both decreased into lower levels of catastrophizing throughout the perioperative period. The results of this study suggest that pain catastrophizing may be malleable and, thus, can be a target of treatment.

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