UNDERSTANDING THE TRANSITION FROM ACUTE TO CHRONIC POST-SURGICAL PAIN IN YOUTH

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Abstract

Approximately 20% of youth develop chronic post-surgical pain (CPSP) that is associated with pain-related distress and co-morbid mental health outcomes, such as anxiety and depression. This dissertation examines youth and parent risk/protective factors associated with the development and maintenance of pediatric CPSP, including functional limitations. The three studies which comprise this dissertation (Rosenbloom et al., 2019; Rosenbloom et al., 2020; Rosenbloom et al., 2021) use data collected from a large sample of youth aged 8 to 17 years undergoing major orthopedic or general surgery and their parents (n = 264). Youth completed questionnaires at four time points over the course of 12 months (pre-surgery, in-hospital, 6- and 12-months after surgery). In-hospital physical activity was monitored using actigraphy. Youth and parents completed pain and psychological questionnaires. Study 1 results show that 12 months after surgery, over a third of youth report moderate-to-severe post-surgical pain. Trajectory analyses of youth before and through to 12 months after surgery show that youth can be categorized into two main pain intensity and pain unpleasantness groups: high pain and low pain. Further this study revealed that pre-surgical general functional disability is the best predictor of post-surgical functioning, over and above psychosocial and surgery-related factors. Study 2 examined differential risk factors for pain-specific and general functional limitations 12 months after major pediatric surgery. Hierarchical regression analysis showed that youth 12-month pain-specific functional limitations were predicted presurgical youth (pain-related anxiety and worry factor) and parent factors (anxiety sensitivity, state-trait anxiety, pain anxiety). Youth 12-month general functional limitations were predicted by youth general functional limitations and parent anxiety sensitivity. Study 3 examined the validity of the Tampa Scale of

Kinesiophobia (TSK) for use in youth after surgery. Results showed that the original 17-item TSK is not a valid measure for youth undergoing surgery, but a modified 13-item TSK has promising psychometric properties for this population. Taken together, these three studies advance our understanding of youth and parent risk/protective factors associated with the development and maintenance of pediatric chronic post-surgical pain and functional limitations.

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Dissertation Synopsis

One in five Canadian children and adolescents live with chronic pain ("Census Profile. 2016 Census.," 2016). More than 80,000 pediatric surgeries are performed in Canada each year (Wright, Menaker, & Canadian Paediatric Surgical Wait Times Study, 2011) and approximately 20% of youth develop chronic post-surgical pain (CPSP) that is associated with pain-related distress and co-morbid mental health outcomes, such as anxiety and depression (Rabbitts, Fisher, Rosenbloom, & Palermo, 2017). There is evidence that youth and parent pain-related psychological factors, depression, and avoidance are associated with increased levels of youth acute and chronic pain after surgery. However, few studies have examined the relationships between these variables in the transition from acute pain to CPSP in youth and thus there are few targeted interventions for reducing the suffering these youth experience.

To examine the transition from acute to chronic pain a growing number of studies in the field of perioperative pain have used trajectory analyses to show a range of pain trajectory outcomes in adults (Pagé et al., 2016; Pagé et al., 2015) and youth (Connelly et al., 2014; Pagé, Stinson, Campbell, Isaac, & Katz, 2013; Rabbitts, Zhou, Groenewald, Durkin, & Palermo, 2015; Sieberg et al., 2013). These studies indicate that it is important to examine both the risks and protective factors associated with CPSP as well as the course that pain takes over the months following surgery. However, the existing literature commonly uses small sample sizes (e.g., Rabbitts, Zhou, et al. (2015)) and do not evaluate multiple risk factors within the same sample (e.g., Birnie, Chorney, El-Hawary, and Group (2017)), which limits our ability to fully evaluate the development of CPSP. Further, even though the definition of CPSP highlights the impact of pain on quality of life, the majority of studies evaluate CPSP based on pain severity alone (e.g.,

Rabbitts et al., 2017). A few studies (e.g., Chidambaran et al., 2017b; Pagé, Stinson, Campbell, Isaac, & Katz, 2013) also measured functional limitation, arguably a more meaningful measure of the extent to which youth struggle with CPSP in the long-term. However, there is not one study that examines the risk and protective factors for functional limitations in youth who develop CPSP. Thus, the overarching purpose of this dissertation is to examine youth and parent risk/protective factors associated with the development and maintenance of pediatric CPSP, including functional limitations. This dissertation specifically aims to:

1. Determine the incidence and severity of 12-month CPSP in youth aged 8 to 17 years.
2. Identify pain intensity and pain unpleasantness trajectories beginning before, through to 12 months after, major orthopedic or general surgery.
3. Identify pre-surgical factors that predict group pain and pain unpleasantness trajectory membership. Pre-operative factors include pre-existing chronic pain conditions, baseline pain thresholds to mechanical pressure, depression, youth and parent pain-related psychological distress.
4. Examine pre-surgical factors that predict functional limitations 12-months after surgery. Pre-surgical factors include pre-existing chronic pain conditions, baseline pain thresholds to mechanical pressure, depression, youth and parent pain-related psychological distress.
5. Evaluate the psychometric properties of the Tampa Scale for Kinesiophobia in youth aged 8-17 years.

To address these aims, three separate studies were conducted and published (Rosenbloom et al., 2019, Rosenbloom et al., 2020, Rosenbloom et al., 2021).

The first study (Study 1) included Aims 1, 2, and 3. This first study used a prospective longitudinal design to follow 264 youth and their parents pre-surgically, during surgery and

hospitalization, 6- and 12-months post-surgery. Results from this study showed that 35% and 38% of youth experienced moderate-to-severe CPSP at 6- and 12-months after surgery. Growth mixture modeling revealed a two-class trajectory model for pain intensity (high pain, low pain) and pain unpleasantness (high pain unpleasantness, low pain unpleasantness) over 12 months. Pre-surgical functional disability and cumulative in-hospital opioid consumption predicted pain intensity class membership, whereas pre-surgical functional disability predicted pain unpleasantness class membership. Pre-surgical functional disability and pain unpleasantness trajectory membership predicted 12-month moderate-to-severe functional disability.

The second study (Study 2) included aim 4. This second study was a secondary analysis of data obtained from the Study 1. The sample included 79 youth and parent dyads. Results indicated that parent pre-surgical anxiety sensitivity and youth pre-surgical functional disability significantly predicted 12-month Functional Disability Inventory outcomes, and that parent pre-surgical anxiety sensitivity, trait anxiety, pain anxiety, as well as youth pain-related anxiety and worry significantly predicted 12-month PROMIS Pain Interference Scale outcomes.

The third study (Study 3) included aim 5. This third study examined the psychometric properties of the Tampa Scale for Kinesiophobia (TSK), a measure commonly used among adults living with pain, among the sample of youth from study one. Results from this study revealed that the original 17-item TSK was not a meaningful measure of kinesiophobia in youth after surgery. However, a modified 13-item scale yielded a three-factor structure that is adequately valid and reliable.

In the present dissertation, I will first provide an historical overview of pain as well as our current understanding of pain, followed by a discussion of pediatric chronic pain, its epidemiology and the development of chronic pain within a surgical context. I will then explore

theoretical models that describe the transition from acute to chronic pain and evaluate the risk factors for CPSP and functional limitations that have been examined in the literature. After this introduction, I will present the three studies that comprise this dissertation. Finally, I will conclude this dissertation with a general discussion of study findings and their implications for future research in the area of pediatric CPSP.

This three-study dissertation addresses the course of pain and functional limitations in youth undergoing major surgery in a large sample and examines the risk and protective factors for CPSP and its functional limitations up to 12 months after surgery. It also examines our ability to understand and predict pain and functional limitation outcomes by addressing our measurement of risk factors. This dissertation significantly contributes to our understanding of pediatric CPSP and paves a path forward for developing interventions targeted at preventing the onset of CPSP.

Chapter 1: Introduction

Historical Context for Understanding Pain

Ronald Melzack and Patrick Wall (1965) revolutionized our understanding of pain mechanisms and management with their *Gate Control Theory of Pain* (Katz & Rosenbloom, 2015). Melzack and Wall (1965) combined properties of the specificity theory with pattern response theory to develop a novel theory of pain that is still used today (Melzack & Katz, 2013; Moayedi & Davis, 2013). Specificity theory, the dominant explanation at the time for why we feel pain, proposed that there are dedicated pathways for each somatosensory experience. It hypothesized that injury activates pain receptors and pain fibers which then send neural signals to the spinal cord and on to a pain centre in the brain (Melzack & Katz, 2013). In contrast, pattern theory proposed that there are not specific nerve fibers for pain, but rather there is a convergence and summation of afferent nerve impulses from a multitude of sensory fibers in the dorsal horns of the spinal cord, which then send signals to the brain (Melzack & Katz, 2013). Pattern theory posits that the information conveyed to the brain is proportional to the severity of the stimulus (Melzack & Katz, 2013). However, neither of these theories explained the presence of pain without apparent injury.

The Gate Control Theory consists of three main components which interact with one another to modulate the experience of pain. First, it is hypothesized that the dorsal horn substantia gelatinosa of the spinal cord acts as a gate that modulates afferent nerve patterns before they reach the spinal transmission cells (T-cells) which project to the brain. Second, it is hypothesized that afferent input from neurons located in the dorsal column system control specific brain processes that then modulate, through descending projections, the function of the

gate control system. Third, through their projection to the action system, T-cells activate pain perception and pain response systems via neural mechanisms in the brain. The Gate Control Theory allowed researchers and clinicians to take into consideration that there is a specificity for peripheral nerve function, a pattern recognition for underlying peripheral and central processing of noxious information, and, most importantly for the time, an emotional and cognitive component that can have amplifying effects on nociceptive signals (Gatchel, Peng, Peters, Fuchs, & Turk, 2007). The Gate Control Theory was extended by Melzack and Casey (1968) to propose specialized systems in the brain that are involved in sensory-discriminative, motivational-affective, and cognitive-evaluative dimensions of the experience of pain (Melzack & Katz, 2013). The Gate Control Theory and the extended version of it opened the door for understanding the multidimensional nature of pain.

The Neuromatrix Theory of Pain proposed that pain is a multidimensional experience produced by neuronal signals in a widely distributed brain neural network that is termed the "body-self neuromatrix" (Melzack, 2001). Melzack (2001) proposed that the body-self neuromatrix integrates inputs from sensory-discriminative, cognitive-evaluative, and motivational-affective components. The theory further proposes that the body-self neuromatrix engages three outputs, including pain perception, action programs, and stress-regulation programs. The body-self neuromatrix can function without direct sensory input, which is important for explaining pain phenomena such as phantom limb pain (Gatchel et al., 2007). The Neuromatrix Theory of Pain reinforced and extended the Gate Control Theory of pain which paved the way for understanding pain from a biopsychosocial framework.

Defining Pain

The International Association for the Study of Pain (IASP) recently re-defined pain as "an unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage" (Raja et al., 2020). Six explanatory notes accompany this definition. The first note emphasizes that pain is always a personal experience influenced by biological, psychological, and social factors. Broadly, the biopsychosocial model of pain asserts that pain is not simply a faithful representation of high intensity peripheral sensory neuronal activity (i.e., nociception) that is consciously interpreted by the brain but rather it is an interplay between biological factors (e.g., nociceptive impulses, epigenetic, endocrine, immune), psychological factors (e.g., memories of pain experiences, affective components, cognitive interpretations, behavioural reactions), and external factors (e.g., context in which the unpleasant sensory and emotional experience occurs, attention from others, cultural expectations; Gatchel et al., 2007).

Psychological factors associated with pain include cognitive appraisals (e.g., pain catastrophizing, self-efficacy, coping) and affective components (e.g., pain anxiety, depression, anxiety; Gatchel et al., 2007). For infants and children in pain, parental psychological factors (e.g., catastrophizing about their child's pain) also influence the youth's experience of pain. Williams and Craig (2016) described the importance of the social component of pain and proposed that pain be defined as "a distressing experience associated with actual or potential tissue damage with sensory, emotional, cognitive, and social components" (Williams & Craig, 2016). Although the Williams and Craig (2016) definition of pain was not adopted by the IASP

taskforce that re-defined pain in 2020, first note of the new definition acknowledges that "social factors" are associated with pain.

The second note explains that pain and nociception are different phenomena. Specifically, this note emphasizes that pain is not determined solely by neuronal activity (Raja et al., 2020). Third, individuals learn pain over the course of one's lifetime. Fourth, a person's report of pain should be respected (Raja et al., 2020). The fifth note explains that while pain can be adaptive, it can also have adverse effects on function and social and psychological well-being, especially when it becomes chronic (Raja et al., 2020). Finally, the last note explains that the inability to communicate does not negate the possibility that a person is experiencing pain (Raja et al., 2020). This point is particularly important for infants and young children or persons with intellectual or cognitive disabilities who may not be able to express, in words, that they are experiencing pain (Anand & Craig, 1996; Williams & Craig, 2016). These individuals rely on nonverbal forms of communication to express their pain (e.g., crying, grimacing).

Classifying Pain

From a neurobiological perspective, pain may be separated into three main classes. First, there is pain that serves as an early warning physiological system that acts to minimize interaction with damaging or noxious stimuli (e.g., touching a hot stove; Woolf, 2010). This type of pain is adaptive and protective. The second type of pain is also adaptive and protective as it acts to heighten sensory sensitivity after tissue damage. This heightened sensitivity promotes rest and discourages movement so that tissues can heal thereby preventing further damage (e.g., pain immediately after surgery, pain arising from a swollen, twisted ankle) (Woolf, 2010). The third type of pain is maladaptive and is the result of abnormal functioning of the nervous system and is

considered a disease state. It is pain in the absence of noxious stimuli or peripheral inflammatory pathology. This type of pain is the consequence of amplified sensory signals in the central nervous system and is considered a low threshold pain (e.g., pain that is elicited with little, or no, noxious stimuli). Examples of this pathological pain can include, but are not limited to, fibromyalgia, migraine, joint disease, and irritable bowel syndrome (Woolf, 2010).

Another way that pain can be classified is according to time whereby pain is subdivided into acute and chronic pain. Acute and chronic pain can be thought of as existing on a time continuum with the key difference between being the length of time since the inciting painful event (Kent et al., 2017; Treede et al., 2015). Acute pain lasts for a short time (i.e., less than seven days; Kent et al. (2017)) but there are no 'hard and fast' rules about the outer limit. In some instances, acute pain can persist for up to 30 days after the inciting event, but rarely beyond 90 days (Kent et al., 2017). Research identifies that the period between 30-90 days post-inciting painful event can be classified as "subacute" pain (Kent et al., 2017). Chronic pain is pain that lasts or recurs for longer than three months (Treede et al., 2015).

Defining chronic pain based on duration alone ignores important features associated with pain (Katz, Rosenbloom, & Fashler, 2015). Chronic pain has historically been thought of as pain that persists beyond the usual tissue healing time or pain without a biological value (Merskey & Bogduk, 1994). However, there are chronic pain conditions that do not fit with this classification (e.g., rheumatoid arthritis that will likely never heal, migraine headaches that remit and recur; Katz et al., 2015) and therefore indicate that time is not the best defining feature for chronic pain.

Another way to define chronic pain is by conceptualizing chronic pain, or pathological pain, as a pain alarm system that continues to send signals of danger when there is no apparent danger present (Coakley & Schechter, 2013). Chronic pain is associated with significant

emotional distress and/ or functional disability. It can be primary or secondary. Chronic primary pain represents chronic pain as a disease in and of itself whereas chronic secondary pain is chronic pain where the pain is a symptom of an underlying condition (Treede et al., 2015). The IASP Task Force for the Classification of Chronic Pain recently proposed a new classification for chronic pain in the International Classification of Diseases Eleventh Revision (ICD-11) (Treede et al., 2019). According to ICD-11, chronic pain is subdivided into seven categories based on clinical presentations, including: (1) chronic primary pain (chronic widespread pain, complex regional pain syndrome, chronic primary headache or orofacial pain, chronic primary visceral pain, chronic primary musculoskeletal pain); (2) chronic cancer-related pain; (3) chronic post-surgical or posttraumatic pain; (4) chronic neuropathic pain; (5) chronic secondary headache or orofacial pain; (6) chronic secondary visceral pain; and (7) chronic secondary musculoskeletal pain (Treede et al., 2015).

Pediatric Chronic Pain and its Impact

Chronic pain affects approximately 4% to 53% of children with pain problems ranging from headaches, post-surgical pain, abdominal pain, to back pain (King et al., 2011). Chronic pain presents a challenge for our health care system, accounting for $19.5 US billion annually in direct health care costs for adolescents aged 10-17 years (Groenewald, Essner, Wright, Fesinmeyer, & Palermo, 2014), and more when one includes indirect costs due to absenteeism, lost productivity and compensation (McCarberg & Billington, 2006; Tumin et al., 2018). The total annual cost associated with chronic pain in adolescents approaches £8,000 ($10,240 USD) per patient in the United Kingdom (Sleed, Eccleston, Beecham, Knapp, & Jordan, 2005). In Ontario, Canada, the estimated annual cost to the health care system is $1,663 CAD per

adolescent (12-17 years), which is $956 CAD more than their age-matched peers without chronic pain (Hogan, Taddio, Katz, Shah, & Krahn, 2016). The incremental cost of chronic pain for female adolescents ($1,396/ year) is approximately five times higher than for males ($260/ year). Importantly, pain severity does not appear to play a role in the incremental cost for moderate-to-severe pain ($1,018/ year) as it is only a few dollars more than average pain severity ($956/ year). However, when pain is accompanied by any activity limitation, the incremental cost goes up to $1,548/ year – an increase of 62% over the average incremental cost.

Pediatric chronic pain is also associated with greater odds of using specialty care, using complementary and alternative medicine, and using emergency care (Tumin et al., 2018). In addition to the economic and health care costs of pediatric chronic pain, it is associated with deleterious medical, physiological, and psychological consequences for the child and family affected, as well as disruptions in typical childhood development, including missed school days (Dahlquist & Switkin, 2003; Huguet & Miro, 2008; Konijnenberg et al., 2005; McGrath, 1999; Roth-Isigkeit et al., 2005).

Chronic Post-Surgical Pain

CPSP was first defined by Macrae and Davies (1999) as (1) pain that begins after a surgical procedure; (2) pain of at least 2 months' duration; (3) other causes for the pain have been ruled out, including; (4) the possibility that the pain is continuing from a pre-existing problem (Macrae & Davies, 1999). Recently there have been some changes to the duration domain of this definition as it has been considered too short for appropriate healing from invasive surgeries and is misaligned with the IASP definition of chronic pain, which requires chronic pain be at least three months in duration (Kent et al., 2017; Treede et al., 2019). It has

therefore been proposed that the definition of CPSP be modified to describe pain that is present for at least three months after surgery (Treede et al., 2015; Werner & Kongsgaard, 2014). CPSP, specifically, is now defined as: pain that develops after a surgical procedure or increases in intensity after a surgical procedure, persists for at least three months after surgery and that affects quality of life, that is a continuation of acute post-surgical pain or develops after an asymptomatic period, that is localized to the surgical site or projected to a referred area, and for which other causes of the pain have been excluded (Schug et al., 2019; Werner & Kongsgaard, 2014).

CPSP is further classified into seven sub level diagnoses that include: chronic pain after amputation, chronic pain after spinal surgery, chronic pain after thoracotomy, chronic pain after breast surgery, chronic pain after herniotomy, chronic pain after hysterectomy, and chronic pain after arthroplasty (Schug et al., 2019). This level of specification was developed to be in line with pain states after certain common procedures that lead to chronic pain.

Epidemiology of Pediatric Chronic Post-Surgical Pain

Over the past decade there has been an increase in the number of prospective studies examining pediatric chronic post-surgical pain. Table 1 shows the incidence of chronic post-surgical pain reported by prospective studies, highlighting the type of surgery, sample size, and definition of CPSP used by the authors. The earliest study evaluating the incidence of chronic post-surgical pain was conducted by Landman et al (2011) on patients undergoing spinal fusion surgeries for idiopathic scoliosis, one of the more common surgeries among adolescents. Seven subsequent studies have reported on the incidence of chronic post-surgical pain in children with half of them examining orthopedic and general surgeries combined and the other half focusing

on spinal fusion surgery. The 12-month incidence of chronic post-surgical pain ranges from 11% to 54%, which is similar to the adult literature (Katz & Seltzer, 2009). The variability in the incidence of CPSP is in part due to the type of surgery, intensity of pain use to meet criteria for CPSP (e.g., non-zero pain (Perello, Artes, Pascuets, Esteban, & Ey Batlle, 2017) versus moderate-to-severe pain (Chidambaran et al., 2017a; Pagé, Stinson, et al., 2013; Sieberg et al., 2013b)) and the follow-up time (e.g., 6 months (Ocay et al., 2020), one year (Sieberg et al., 2013b), 2 years (Landman et al., 2011)). Very few prospective studies report the incidence of CPSP beyond one year. Landman et al (2011) showed that 52% of patients who had undergone spinal fusion reported mild to severe pain 2 years after surgery and Sieberg et al. (2013) reported an incidence of ~35% for moderate or severe pain five years after surgery. These alarmingly high statistics highlight the need to better understand the factors that contribute to pediatric CPSP.

In terms of the nature of pediatric CPSP, Batoz et al (2016) reported that of the 11% of children with moderate-to-severe pain three months after a variety of surgical procedures, 7% had pain of neuropathic origin, assessed with the DN4. In a small study of 36 children who underwent surgery for idiopathic scoliosis, 47% had pain of neuropathic origin, assessed with the DN4, one year after surgery (Julien-Marsollier et al., 2017). To my knowledge, no other studies report on the incidence of neuropathic pain using validated measures, or clinical assessment, in the pediatric surgical population. Given the high incidence of neuropathic pain following surgery for scoliosis, more research is needed on the factors that are responsible for neuropathic pain.

Table 1. Incidence of chronic post-surgical pain (CPSP) in children and adolescents following various surgical procedures.

Study	Surgical Procedure	N of patients (age range of patients)	Follow-up Time (months)	Incidence of CPSP (%)	Definition of CPSP
Landman et al 2011	Spinal Fusion	295 (8-22 years)	12 24	53.6 53.2	Mild to severe range on the SRS-30
Pagé et al 2013	Spinal Fusion Osteotomy Ravitch Nuss Laparotomy Thoracotomy	83 (8-18 years)	6 12	23 22	Pain rated as≥ 4 on a 0-10 NRS
Sieberg et al 2013	Spinal Fusion	190 (8-21 years)	12	11	Moderate to severe range on the SRS-30 in the past month
Rabbitts et al 2015	Major orthopedic surgery	60 (10-18 years)	4	18.3	Late pain recovery trajectory

Batoz et al 2016	Orthopedics Thoracic Laparotomy/ Laparoscopic Uro/ Inguinal	291 (6-18 years)	3	10.9	Pain rated as >2 on the VAS (100 mm)
Chidambaran et al 2017	Spinal fusion	144 (10-18 years)	2-3 12	37.8 41.8	Pain rated as NRS >3
Julien-Marsollier et al 2017	Posterior fixation spinal surgery	36 (mean age 15, standard deviation 2)	12	52.8	Pain rated as NRS >3
Perello et al 2017	Surgical posterior vertebral fusion	48 (10-18 years)	6	19.05	Pain rated as NRS > 0)
Ocay et al 2020	Spinal fusion	106 (mean age = 15.4, standard deviation = 2)	6	60.4	Moderate to severe range on the SRS-30 in the past month

SRS-30, Scoliosis Research Scale – 30; NRS, Numeric rating scale

The Transition from Acute to Chronic Pain in the Context of Surgery

Despite the impact that pediatric chronic pain has on the individual and families affected, as well as its economic costs, our understanding of the transition to chronic pain has been slow (McGrath & Ruskin, 2007). Given that all chronic pain was once acute (Katz, McCartney, & Rashiq, 2008; Katz & Pagé, 2010; Katz & Seltzer, 2009), it is important from a preventive perspective to understand the transitional process from acute to chronic pain. In elucidating this process, we can identify factors that predict who will go on to develop persistent pain. Once we understand this process, we can develop and implement prevention programs for those at risk of developing chronic pain and design targeted interventions for those with prolonged pain to help reduce their suffering.

One of the most efficient ways to study the transition from acute to chronic pain among children is to examine in the context of a surgical intervention, which has been extensively studied in adults (Katz & Seltzer, 2009). Elective surgeries provide a predictable context for studying the course of pain because the injury (surgery) and ensuing pain is known in advance (Katz et al., 2008). While most children undergoing major surgeries, such as Ravitch procedure or spinal fusion, return to baseline functioning post-surgically, approximately 20% of children and adolescents go on to develop CPSP (Pagé, Stinson, et al., 2013; Rabbitts et al., 2017). Given the incidence of CPSP and the controlled nature of the surgery (i.e., which are often planned and in children otherwise healthy), it is an appropriate paradigm to evaluate the transition to CPSP.

Pain Trajectories after Pediatric Surgery

Several studies have evaluated the evolution of changes in pain intensity over time by conducting group-based trajectory analysis which evaluates the dynamic nature of pain across

the post-operative period within sub-groups of individuals with similar pain characteristics. For example, Sieberg et al (2013) found five pain trajectories up to five years after adolescent scoliosis surgery as measured by the Scoliosis Research Scale-30 (SRS-30) which included: a no pain group, a pain improvement group, a short-term pain group, a delayed pain group, and a high pain group. Similarly, Ocay et al (2020) found four trajectories using the SRS-30 but their study did not examine pain beyond the 6-month time point. Other studies have found support for a two-pain trajectory model (Connelly et al., 2014; Rabbitts, Zhou, et al., 2015). Although there is heterogeneity in the pain measures used, time frame, number of groups identified, type of trajectory analysis conducted, most children fall into a low pain intensity or mild pain intensity group. Each of the studies also identified a smaller trajectory group of patients with high pain, severe pain, or an increasing pain group, indicating the need to identify predictors of this pain trajectory and develop effective preventive measures or treatment approaches if pain cannot be prevented.

Impact of CPSP on Functioning

Pediatric CPSP interferes with quality of life and while more invasive surgeries, such as spinal fusion, involve a more prolonged recovery trajectory (e.g., months) than hernia repair (e.g., weeks), studies show that measures of quality of life remain low even at time points when patients are expected to have fully recovered (e.g., 12 months after surgery). Chidambaran et al (2017b) showed a significant positive association between pain intensity and functional disability 12 months after spinal surgery. The one study that failed to find a correspondence between CPSP intensity and disability was conducted by Pagé et al. (2013) who reported very low levels of disability in all participants 12 months after surgery, regardless of pain intensity. Given the new

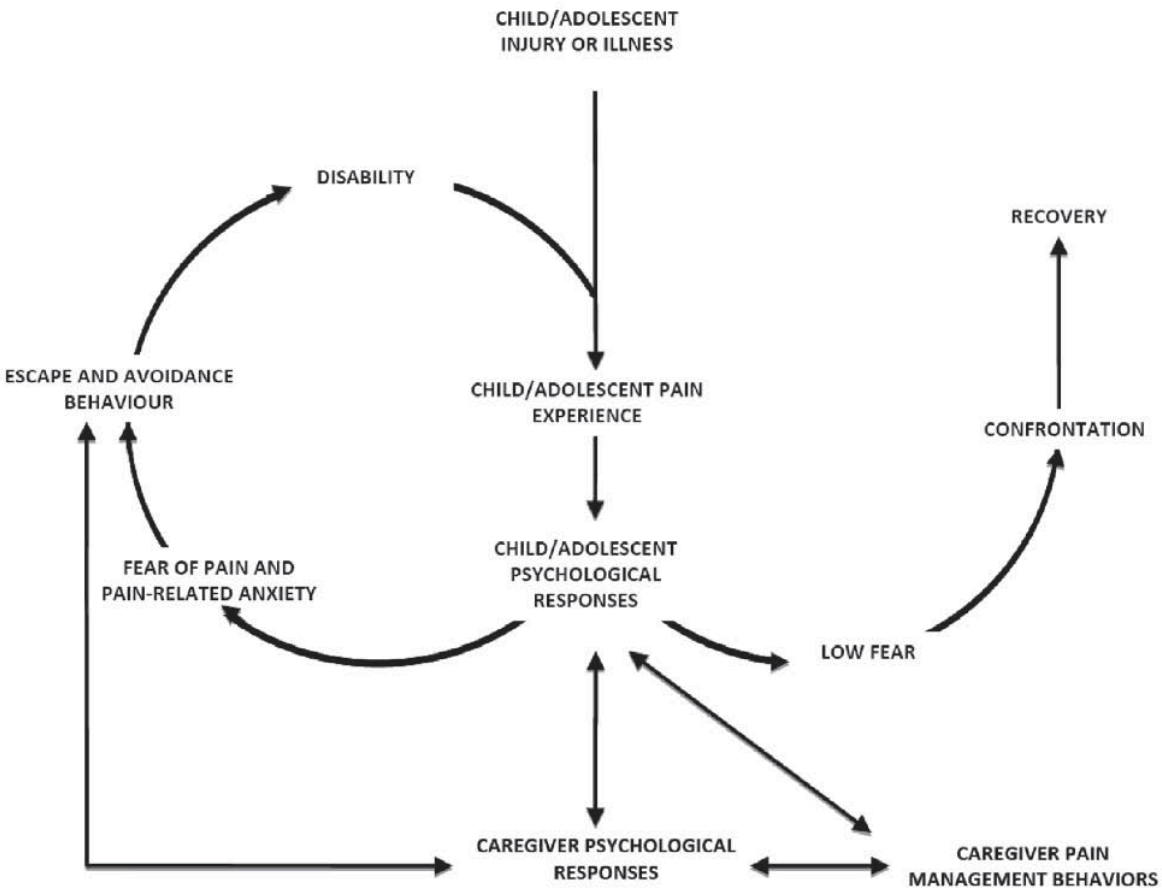
definition of CPSP and the recent findings on CPSP severity, functional disability is an area for evaluation in the pediatric population.

Models of the Transition from Acute to Chronic Pain

Much of the literature to date that examines the transition to CPSP in children does so through the lens of the biopsychosocial model. This model includes child factors, such as genetics, sex, pre-surgical pain, sleep, anxiety, and pain catastrophizing, as well as parent factors, such as parent cognitive appraisals of their child's pain (Williams, Howard, & Liossi, 2017) and parent pain catastrophizing (Pagé, Stinson, et al., 2013). It is predicated on the Diathesis-Stress Model of Chronic Pain and Disability (Turk, 2002), which posits that individuals are more likely to develop avoidance responses and subsequent pain-related disability following a trauma (stress) if they are highly anxiety sensitive (diathesis). The evaluation of both the biopsychosocial model and diathesis-stress model of chronic pain and disability within the context of surgery has provided mixed results thus far. For example, Pagé at al (2013) showed that parent, but not child, pain catastrophizing 48–72 hours after surgery predicted child pain intensity ratings 12 months later. Similarly, Rabbitts and colleagues (2015) found that parent catastrophizing about their child's pain predicted late-pain recovery from major surgery (Rabbitts, Zhou, et al., 2015). Birnie and colleagues (2017), however, found that child, and not parent, pain catastrophizing predicted pre- and post-surgical pain following adolescent spinal fusion surgery (Birnie et al., 2017). While there are mixed results, likely due to different sample sizes and types of surgeries, these studies suggest that the presence of psychological vulnerabilities in both the child and the parent predispose a child to develop CPSP.

A less examined model of the transition to CPSP among children includes the Cognitive-Behavioural Fear Avoidance Model of Chronic Pain. Originally the Cognitive-Behavioural Fear-Avoidance Model of Chronic Pain (Lethem, Slade, Troup, & Bentley, 1983; Vlaeyen, Kole-Snijders, Boeren, & van Eek, 1995; Vlaeyen & Linton, 2000) proposed that pain may be perceived as a threat and that pain-related fears, including pain catastrophizing, dominate thought processes. These pain-related fears then lead to avoidance behaviours as well as hypervigilance to somatic symptoms, like pain. The model then proposes that avoidance and hypervigilance play roles in long term disability and depression, which feed back into the pain experience and thus a reiterative cycle begins. More recently, Asmundson and colleagues (2012) proposed that this cycle involves parents, such that parents', or caregivers', psychological responses to their child's psychological pain responses directly and indirectly impact their child's escape avoidance behaviours, which then feeds back into a never-ending cycle (Figure 1; Asmundson, Noel, Petter, & Parkerson, 2012).

Figure 1. The Pediatric Fear-Avoidance Model of Chronic Pain.



Defining Risk/Protective Factors

Risk is defined as the probability of an outcome occurring in a particular population (e.g., the risk of CPSP among pediatric surgical patients; Kraemer, et al., 1994). A risk/protective factor, on the other hand, refers to an agent or exposure that alters the probability of an outcome occurring in a particular population (Kraemer et al., 1994). More specifically, a risk/protective factor is a measurable construct that can be used to classify patients along a continuum of risk for developing an outcome of interest (e.g., CPSP; Weinrib, et al., 2017). Operationally, a risk factor

refers to a factor that is associated with an increased probability of an event occurring whereas a protective factor is associated with a reduced risk of an event occurring. Risk/protective factors must have been measured before the outcome occurs (Weinrib et al., 2017). Risk/protective factors can be classified according to different dimensions (e.g., causality, modifiability). A risk/protective factor is identified as causal by fulfilling two criteria: (1) the risk/protective factor occurred temporally before the outcome and (2) manipulation of the risk/protective factor changes the risk of the outcome occurring (Weinrib, et al, 2017). If a risk/protective factor does not fulfill these criteria, then it can be considered a correlated risk/protective factor. The goal of this dissertation is to identify causal, modifiable risk/protective factors for CPSP that can be targeted in subsequent interventions aimed at reducing the likelihood that acute pain becomes chronic.

Risk Factors Associated with the Development of Youth CPSP

Surgical Factors. There is little evidence that intraoperative factors, such as type of surgery, instrumentation used, and duration of anesthesia, are associated with chronic post-surgical pain outcomes, especially when psychosocial factors are included in the statistical model (Batoz et al., 2016; Connelly et al., 2014; Julien-Marsollier et al., 2017; Landman et al., 2011; Ocay et al., 2020; Pagé, Campbell, Isaac, Stinson, & Katz, 2013; Pagé, Stinson, et al., 2013b; Rabbitts, Zhou, et al., 2015; Rosenbloom et al., 2019; Sieberg et al., 2013). The sole exception is the study by Chidambaran et al. (2017b) showing that every hour increase in the duration of surgery was associated with an increase of 2.16 in the odds of developing one-year chronic post-surgical pain.

In adults, the surgery type (e.g., amputation, thoracic surgery, CABG surgery) is a risk factor for post-operative pain outcomes particularly as it relates to the development of neuropathic pain (Katz & Seltzer, 2009). The lack of evidence in the pediatric field is due to insufficient information since the majority of studies have examined select pediatric surgeries (Table 1) such as spinal fusion for scoliosis, osteotomies and thoracotomy.

Pain-Related Factors. There is substantial evidence in the adult literature that the most robust predictor of CPSP is prior pain (Katz, 2012; Katz & Seltzer, 2009). This relationship has also been shown in the pediatric literature. For example, the presence or intensity of pain before surgery (Batoz et al., 2016; Chidambaran et al., 2017b; Julien-Marsollier et al., 2017), moderate-to-severe pain intensity trajectory group membership immediately following surgery (Ocay et al., 2020), higher pain in the immediate postoperative period (Chidambaran et al., 2017b), and high levels of pain unpleasantness immediately following surgery (Pagé, Stinson, et al., 2013b) have all been found to uniquely predict pain two to 12 months after surgery. Moreover, high analgesic requirements while in hospital, typically a proxy for intense pain, also predicts pain 12 months after surgery (Chidambaran et al., 2017b; Julien-Marsollier et al., 2017).

Given that 35-62% of children and adolescents report moderate-to-severe pain intensity prior to surgery (Batoz et al., 2016; Sieberg et al., 2013), it is important to control for pre-operative pain status or intensity in predictive models. It is also important to evaluate early post-operative pain experiences. Pagé et al (2013) found that pain two weeks after surgery predicted the development of moderate-to-severe pain one year later. Specifically, children who had a pain score of three or more (on a 0-10 NRS-pain intensity and NRS-pain unpleasantness) two weeks after surgery were ~2.5 times more likely to go to develop and report moderate-to-severe CPSP one year later than kids whose two-week pain scores were less than 3/10. Additionally, Julien-

Marsollier et al. (2017) pre-operative pain and acute post-operative opioid consumption predicted 12-month neuropathic pain (Julien-Marsollier et al., 2017). While this study used a small sample size (n = 36), it highlights that pain predicts pain, including neuropathic pain.

Child Psychosocial Factors. A number of child psychosocial factors have been evaluated in the prediction of the transition from acute to CPSP. These factors span the domains of pain-related anxiety (pain anxiety, pain catastrophizing, fear of movement), anxiety sensitivity, pain self-efficacy, chronic pain acceptance, symptoms of posttraumatic stress disorder, symptoms of depression, and general anxiety.

Child pain catastrophizing, or the tendency to magnify, ruminate about, or feel helpless in the presence of pain (Theunissen, Peters, Bruce, Gramke, & Marcus, 2012), has been evaluated in as a predictive factor in most child surgical studies on pain (Birnie et al., 2017; Chidambaran et al., 2017b; Pagé, Stinson, et al., 2013; Rabbitts, Zhou, et al., 2015). However, only one study found a significant relationship between child pain catastrophizing and pain outcomes (Birnie et al., 2017). The weak relationship between preoperative pain catastrophizing and post-operative pain outcomes (Birnie et al., 2017; Chidambaran et al., 2017b; Pagé, Stinson, et al., 2013; Rabbitts, Zhou, et al., 2015) suggests that child pain catastrophizing does not play a significant role, which is unlike the adult literature (Katz & Seltzer, 2009) but see Katz (2015). Katz (2015a) argues that youth, prior to surgery, would have experienced typical childhood pain exposures (e.g., cuts, bruises) and thus evaluating the youth's pre-surgical level of pain catastrophizing reflects these experiences. He hypothesized that the pre-surgical measure of pain catastrophizing changes as a function of their surgical pain experience. Therefore, youth pain catastrophizing might be a predictor of long-term outcomes if measures a few days after surgery once they have experienced a heightened painful event.

Parent psychosocial factors. The pediatric fear-avoidance model of chronic pain is the predominant model used to explain the development and maintenance of chronic pain in children (Asmundson, Noel, Petter, & Parkerson, 2012). Importantly, it identifies caregiver psychological responses and caregiver pain management as having an influence on their child's development and maintenance of chronic pain. However, to my knowledge, only five prospective studies of CPSP have included parent variables in their modeling of the transition from acute to chronic postsurgical pain (Birnie et al., 2017; Pagé, Campbell, et al., 2013; Pagé, Stinson, et al., 2013; Rabbitts, Zhou, et al., 2015) and not one has tested the entire model.

Pagé, Campbell, et al. (2013) found that parent pain catastrophizing (i.e. catastrophizing about their own pain) two to three days after their child's surgery predicted child pain intensity one year after surgery. Rabbitts, Zhou, et al. (2015) found that before their child's surgery, parental pain catastrophizing (i.e. catastrophizing about their child's pain) predicted their child's late pain recovery 12-months after surgery. In contrast, Birnie et al. (2017) found that child, but not parent, pain catastrophizing was related to child pain outcomes. The authors evaluated the dyadic cross sectional and longitudinal relationships between child pain, child pain catastrophizing, and parent catastrophizing about their child's pain prior to surgery, 4-6 weeks after surgery, and then again 3, 6, and 12 months after surgery. The results showed that baseline child, but not parent, pain catastrophizing, was associated with child pain intensity pre- and post-surgery (Birnie et al., 2017). The authors also noted that the strength of the relationship between child pain catastrophizing and post-surgical pain was strongest in the acute post-operative period and that it faded over time. They caution researchers and clinicians not to classify children and parents as pain catastrophizers based on their pre-operative pain catastrophizing status because pain catastrophizing is a dynamic process during the pre- to post-surgical time (Birnie et al.,

2017). Their caution is line with that of Katz (2015a) who suggested that pain catastrophizing may change over time and especially from before to after surgery due to the intense acute post-operative pain experience associated with surgery – most likely of such an intensity that exceeds anything experienced before. This would have the effect of changing the child's frame of reference with respect to pain and pain catastrophizing and render the baseline ratings irrelevant and no longer potentially predictive of later pain ratings.

Current Dissertation

Understanding the course of pain after pediatric surgery is a growing area of research. Little is known about the long-term functional limitations associated with pain after surgery. Additionally, the risk factors of pain and functional limitations are not well understood. This dissertation aims to examine the course of pain and functional limitations in youth undergoing major surgery and identify the risk and protective factors for CPSP and associated functional limitations up to 12 months after surgery. It also examines our ability to understand and predict pain and functional limitation outcomes by addressing our measurement of risk factors.

This dissertation is comprised of three studies. The first study (Chapter 2; Rosenbloom et al., 2019) uses a prospective longitudinal design to follow 264 youth and their parents pre-surgically, during surgery and hospitalization, 6- and 12-months post-surgery. Study 1 aims to determine the incidence and severity of 12-month CPSP in youth aged 8 to 17 years, identify pain intensity and pain unpleasantness trajectories beginning before, through to 12 months after, major orthopedic or general surgery, and identify pre-surgical factors that predict group pain and pain unpleasantness trajectory membership. Finally, it aims to examine pre-surgical factors that predict functional limitations 12-months after surgery. The second study (Chapter 3;

Rosenbloom et al., 2021) uses a subsample from Study 1 to evaluate the risk factors associated with general and pain-specific functional limitations 12-months after surgery. The third study (Chapter 4; Rosenbloom et al., 2020) aims to evaluate a specific risk factor not previously studied in youth undergoing surgery. Specifically, Study 3 aims to evaluate the psychometric properties of the Tampa Scale for Kinesiophobia in youth aged 8-17 years. There are bridging paragraphs between Studies 2 and 3.

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Chapter 2: Pediatric Chronic Post-Surgical Pain And Functional Disability: A Prospective Study Of Risk Factors Up To One Year After Surgery

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ORIGINAL RESEARCH

Pediatric Chronic Postsurgical Pain And Functional Disability: A Prospective Study Of Risk Factors Up To One Year After Major Surgery

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Background: Chronic postsurgical pain (CPSP) is a surgical complication associated with increased functional disability, psychological distress, and economic costs. The aims of this paper were to prospectively: (1) examine the incidence of CPSP 6 and 12 months after pediatric major surgery; (2) identify pain intensity and pain unpleasantness trajectories before, and up to 12 months after, surgery; (3) identify pre-operative factors that predict pain trajectory group membership; and (4) identify predictors of 12-month functional disability.

Methods: This study followed 265 children aged 8 17 years at four time points (pre-surgical [T0], in-hospital [T1], 6 [T2] and 12 [T3] months after surgery). Children and parents completed pain and psychological questionnaires. In-hospital physical activity was monitored using actigraphy.

Results and discussion: The incidence of moderate-to-severe CPSP at 6 and 12 months was 35% (95% CI 29.1% to 41.9%) and 38% (95% CI 32.4% to 45.1%), respectively. Three percent (95% CI 1.17% to 6.23%) and 4% (95% CI 1.45% to 6.55%) of children reported using opioids to manage pain at 6 and 12 months, respectively. Growth mixture modeling revealed a two-class trajectory model with a quadratic slope best fit the data for both pain intensity (Bayesian information criterion [BIC] = 3977.03) and pain unpleasantness (BIC = 3644.45) over the 12 months. Preoperative functional disability and cumulative in-hospital opioid consumption predicted pain intensity trajectories. Preoperative functional disability predicted pain unpleasantness trajectories. Preoperative functional disability (OR: 1.05, 95% CI: 1.01 to 1.09) and pain unpleasantness trajectories (OR: 2.59, 95% CI: 1.05 to 6.37) predicted 12-month moderate-to-severe functional disability.

Conclusion: Pre-surgical functional disability is the only factor that predicts both 12-month functional disability and the course of pain intensity and pain unpleasantness ratings over the 12-month period.

Keywords: pain, pediatrics, surgery, trajectory analysis, functional disability, anxiety, depression, parents

Introduction

Chronic postsurgical pain (CPSP) is a surgical complication that occurs in approximately 20–50% of the children after major surgeries.[1,2] It is associated with longer recovery, higher risk of infection, greater functional disability, missed school days, psychological distress, and economic costs.[1–5] CPSP is defined as pain that: develops after a surgical procedure; is a continuation of acute post-surgical pain or develops after an asymptomatic period; is localized to the surgical site or projected

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to a referred area; persists for at least 3–6 months after surgery; and affects quality of life. Importantly, other causes of the pain must be excluded.[6]

While there is extensive literature on the transition from acute to chronic post-surgical pain in adults,[7] far fewer pediatric studies have been published on the topic. As with adults, the transition to CPSP in children is thought to follow a biopsychosocial model[8] that includes child factors, such as genetics, sex, pre-surgical pain, sleep, anxiety, and pain catastrophizing, but parent factors as well, such as parent cognitive appraisals of their child's pain[9] and parent pain catastrophizing.[2] The main outcome in many of the biopsychosocial models of chronic pain is functional disability (ie, disability in doing activities of everyday life) or pain-related disability (ie, difficulty due to pain engaging in everyday activities, including social, emotional, cognitive, physical, and recreational aspects).[8,10]

Pain is an important driver of pain-related disability[11] and general functional disability[12,13] though not all studies of pediatric CPSP have measured this construct. Of the studies that actually measured functional disability[2,14,15] or a proxy variable, such as number of days of school missed[16] or activity limitations;[15] only three[2,14,15] reported on the predictive relationship between pain and functional disability[2] or the proxy variable.[15] This is an important omission since disability is the main outcome variable in biopsychosocial models of chronic pain. Both Pagé et al[2] and Chidambaran et al[14] report similar findings: the presence of moderate/severe CPSP[2] or persistent pain[14] one year after surgery was not accompanied by high levels of functional disability (or scores on the Functional Disability Index of 13 or more[17]). Moreover, functional disability inventory scores did not differ significantly between children with moderate-to-severe pain and those with no-to-low CPSP[2] or between those with and without persistent pain.[14] In contrast, Rabbitts et al[15] found that one year after surgery, the late pain recovery group showed worse health-related quality of life, as measured by the Pediatric Quality of Life Scale, and greater activity limitations than the early pain recovery group after controlling for age and sex, but importantly the authors did not control for baseline quality of life or baseline activity limitations. It is therefore not clear whether pain trajectory group membership in fact predicts greater activity limitations one year after surgery when taking into account the variance contributed by the pre-operative values of these variables. That is, it may be that children with worse quality of life and greater activity limitations before surgery have the worst outcome regardless of their pain scores over the year after surgery.

The aims of the present study were to prospectively: (1) examine the incidence of CPSP 6 and 12 months after pediatric major orthopedic or general surgery; (2) identify pain intensity and pain unpleasantness trajectories before, and up to 12 months after, surgery; (3) identify pre-operative psychosocial and demographic factors that predict pain trajectory group membership; and (4) identify predictors of 12-month functional disability after controlling for pre-operative functional disability.

Materials And Methods

Participants

Participants aged 8–18 years undergoing either orthopedic surgery (ie, osteotomy, plate insertion tibial/femur, surgery for scoliosis) or general surgery (ie, thoracotomy, thoracoabdominal surgery, Nuss/Ravitch pectus repair, sternotomy, laparotomy, laparoscopic-assisted; colectomy, ileostomy, J-pouches) and one of their parents were eligible to participate in this study. Children were excluded if (1) they had a documented developmental or cognitive delay, (2) they had a diagnosis of cancer, (3) they did not speak or read English, or (4) their parent or guardian did not speak or read English.

Questionnaires

Table 1 lists the complete study measures and their timing of administration across the study period for children and their parents.

Child Measures

Physical Measures

Pressure Algometry

Pain thresholds in response to mechanical pressure applied to the skin were obtained using a Pressure Algometer, a hand-held device consisting of a 1.5 cm rubber tip attached to a spring-loaded gauge with an analog display that registers the applied force in lbs/sq in and kg/sq cm (Baseline® Dolorimeter, Model PR0379 and PR0376, Algeos Ltd, Liverpool, UK). The algometer was applied with a constantly increasing pressure to a point on the skin over muscle at a rate of 0.5 kg/second. The participant indicated when the pressure first became painful. Pressure pain threshold (PPT) was defined as the force (pressure/unit area) at which the participant first reported pain. Participants were then asked to rate the intensity of the pain using an 11-point NRS. Baseline PPTs were obtained

Table 1 Study Time Chart Depicting When Each Measure Was Administered To Children And Parents Over The Course Of The Study

Measure	Time 0 Pre-Surgery	Daily In-Hospital Measures	Time 1 48–72 Hrs After Surgery	Time 2 6-Month And Time 3 12-Month
Demographic Information Sheet	✓			
Pressure Algometry	✓	✓		
Physical Activity Monitor (Actical)		✓		
Opioid Consumption		✓		
Additional Analgesics		✓		
Numeric Rating Scale Pain Intensity at rest (NRS-R) and movement-evoked (NRS-M)	✓	✓		✓
Numerical Rating Scale Pain Unpleasantness (NRS-U)	✓	✓		✓
Child Pain Anxiety Symptoms Scale (CPASS)	✓		✓	✓
Pain Catastrophizing Scale for Children (PCS-C)	✓		✓	✓
Children Anxiety Sensitivity Index (CASI)	✓		✓	✓
Child Self-Efficacy Scale-Child Version (CSES-C)	✓		✓	✓
Tampa Scale for Kinesiophobia (TSK)	✓		✓	✓
Children's Revised Impact of Events Scale (CRIES)	✓		✓	✓
PROMIS-Pediatric Pain Interference Scale (PPIS)	✓		✓	✓
Centre for Epidemiological Studies – Depression Scale Children (CES-DC)	✓		✓	✓
Multidimensional Anxiety Scale for Children-10 (MASC)			✓	✓
Pain Experiences Questionnaire – Pre-operatively	✓			
Pain Experiences Questionnaire – Post-operatively				✓
Functional Disability Index (FDI)	✓			✓
Chronic Pain Acceptance Questionnaire-Adolescents (CPAQ-A)	✓			✓
Demographic Information Sheet (Parent) and Pain History	✓			
Pain Anxiety Symptoms Scale-20 (PASS-20)	✓			
Pain Catastrophizing Scale (PCS)	✓			
Anxiety Sensitivity Index (ASI)	✓			
Center for Epidemiological Studies-Depression (CES-D)	✓			
State-Trait Anxiety Inventory – Trait (STAI-T)	✓			
Pain Self-Efficacy Questionnaire (PSEQ)	✓			
Semi-Structured Interview (20–30 parents)			✓	
Parent Psychological Flexibility Questionnaire (PPFQ)				✓
Pain Catastrophizing Scale - Parent Version (PCS-P)				✓

at the pre-admission visit, from the proposed incision site and at control sites on the right and left forearm (anterior aspect midway between the wrist and elbow). PPTs were obtained postoperatively on a daily basis 5 cm from the edge of the wound dressing (to assess secondary mechanical hyperalgesia) and at control points on both forearms (anterior aspect midway between the wrist and elbow). Pain pressure thresholds have been tested and validated in a pediatric sample with orthopedic disorders.[18] PPT results are not reported in the present article and will be the subject of a subsequent report.

Physical Activity

The Actical Physical Activity Monitor (Respironics, Inc., Bend, Oregon) is a small, non-invasive, wrist watch-sized device that contains an omnidirectional accelerometer designed to measure physical activity and caloric expenditure on a continuous basis. The physical activity monitor provides an objective, quantifiable measure of average activity levels and changes in activity levels. The physical activity monitor was attached to the child's non-dominant wrist in the Post-Anesthetic Care Unit (PACU) after surgery and remained attached until hospital discharge, thereby providing a continuous measure of physical activity throughout the hospital stay. The Actical physical activity monitor has been used in past studies of children in a post-surgical hospital setting.[19] Total daily (24 hr) activity counts were computed for the days following surgery starting on post-operative day one. Total counts were used because the children were not on regular sleep-wake cycles.

Questionnaires

The Numerical Rating Scale (NRS)

The NRS is an 11-point verbally administered scale that measures the subjective experience of pain intensity (I) or pain unpleasantness (U). The NRS-I ranged from 0 (no pain at all) to 10 (worst possible pain). The NRS-U ranged from 0 (not at all unpleasant/horrible/yucky) to 10 (most unpleasant/horrible/yucky). The NRS has excellent reliability and validity and has been validated for acute post-surgical pain in children aged 7–17 years.[20]

Child Pain Anxiety Symptoms Scale (CPASS)

The CPASS[21] is a 20-item scale that measures the fear and anxiety-related thoughts, feelings, behaviors, and physical sensations that accompany the experience and anticipation of pain. It is a modified version of the adult PASS-20[22] and can be administered to children as young as eight years old.[22] Each item is rated on a scale of 0 (never) to 5 (always) and overall scores range from 0 to 100 with higher scores indicative of greater pain-related anxiety. CPASS has excellent internal consistency (α = 0.89 to 0.903) and strong construct validity.[21,23,24] Internal consistency for the present study was excellent at T0 (α = 0.920), T1 (α = 0.941), T2 (α = 0.925), and T3 (α = 0.932).

Pain Catastrophizing Scale-Children (PCS-C)[25]

The 13-item PCS-C is a child version of the PCS[26] that measures the thoughts and feelings children may experience when they are in pain, including unrealistic beliefs that the current situation will lead to the worst possible pain outcome, negative thoughts about the future and self, and "an exaggerated negative 'mental set' brought to bear during actual or anticipated pain experience" (p. 53,[27]). Each item is rated on a 5-point scale ranging from not at all (0) to all the time (4). The PCS-C yields a total score and three subscale scores assessing (1) rumination, (2) magnification, and (3) helplessness. The PCS-C has excellent internal consistency (α = 0.90) and strongly correlates with pain intensity (r=0.49) and disability (r=0.50).[25] Internal consistency for the present study was excellent at T0 (α = 0.935), T1 (α = 0.942), T2 (α = 0.926), and T3 (α = 0.932).

Childhood Anxiety Sensitivity Index (CASI)

The CASI[28] is an 18-item scale that measures the extent to which the symptoms of anxiety (eg, increased heart rate, shortness of breath, racing thoughts) are feared due to the belief that they will have harmful somatic, psychological, and/or social consequences. Each item is rated on a scale of 1 (none) to 3 (a lot). Total scores range from 18 to 54 with higher scores indicative of greater anxiety sensitivity. The CASI has very good internal consistency (α = 0.87), satisfactory test–retest reliability (r = 0.76) and adequate construct validity.[28] Internal consistency for the present study was very good T0 (α = 0.864), T1 (α = 0.872), T2 (α = 0.850), and T3 (α = 0.856).

Child Self-Efficacy Scale-Child Version (CSES-C)

The CSEC-C[29] is a 7-item measure of a child's belief that they can engage in specific activities, such as going to school, taking care of him/herself, and participating in activities with family or friends, without assistance. Each item is rated on a 5-point scale ranging from 1 (very sure) to 5 (very unsure). Total scores range from 7 to 35 with lower scores indicative of greater self-efficacy. The

CSES-C has good internal consistency (α = 0.80 to 0.83).[29] Internal consistency for the present study was excellent at T2 (α = 0.901), and very good at T0 (α = 0.877), T1 (α = 0.891), and T3 (α = 0.860).

Tampa Scale For Kinesiophobia (TSK)

The TSK[30] is a 17-item scale that measures fear of movement-evoked pain and injury. Scale items ranges from 0 (strongly disagree) to 4 (strongly agree) with 4 reversed-scored items. Total scores range from 25 to 56 with higher scores indicative of a greater fear of movement. The TSK has good internal consistency (α = 0.83) and validity.[31] Internal consistency for the present study was good at T0 (α = 0.921), T1 (α = 0.878), T2 (α = 0.851), and T3 (α = 0.866).

Children's Revised Impact Of Event Scale (CRIES)[32,33]

The CRIES is a 13-item scale that measures posttraumatic stress disorder (PTSD) symptoms in the previous six months. Each item is rated based on its frequency of occurrence on a 4-point scale, from 0 (none) to 5 (a lot). A score of 30 or higher indicates a very likely presence of PTSD. The CRIES has good reliability (α=0.80)[33] and high validity as a screening measure for PTSD.[34] Internal consistency for the present study was excellent at T0 (α = 0.906), and very good at T1 (α = 0.881), T2 (α = 0.879), and T3 (α = 0.894).

PROMIS-Pediatric Pain Interference Scale (PPIS)

The 8-item PPIS[35] assesses how the child's pain has interfered with certain aspects of their life over the past 7 days (eg, sleep, attention, schoolwork, physical activities, emotion). Each item is rated on a 5-point scale ranging from "never" to "almost always". Scores range from 0 to 32 where higher scores indicate greater pain-related functional impairment. The PPIS consistently achieves a reliability of 0.85.[35,36] Internal consistency for the present study was excellent at T0 (α = 0.933) and T3 (α = 0.919) and very good at T2 (α = 0.896).

The Center For Epidemiological Studies-Depression Scale For Children (CES-DC)

Derived from the CES-D for adults,[37] the CES-DC[38] was developed to assess depressive symptoms in children and adolescents. The CES-DC consists of 20 items that examine depressed mood, worthlessness, helplessness, psychomotor retardation, and eating and sleeping problems. Items are rated on a scale from 0 (not at all) to 3 (a lot) to indicate how frequently each statement was experienced "in the past week". Total scores range from 0 to 60 with higher scores indicating more severe depressive symptoms. The CES-DC has excellent internal consistency (α = 0.89) and good convergent validity.[38] Internal consistency for the present study was excellent at T0 (α = 0.921) and T1 (α = 0.900), and very good at T2 (α = 0.894) and T3 (α = 0.898).

Multidimensional Anxiety Scale For Children (MASC-10 and -39)

The MASC-10[39] is a 10-item, shortened version of the 39-item MASC-39.[40] Both versions measure self-reported physiological responses, harm avoidance, social and separation anxiety.[40] Items are rated on a scale from 0 (never true about me) to 3 (often true about me). Total scores range from 0 to 30 (MASC-10) and from 0 to 117 (MASC-39), with higher scores indicating more symptoms of anxiety. The MASC-39 has good internal consistency (α = 0.60 to 0.85), strong test–retest reliability (r = 0.79 to 0.93), good convergent validity (correlates significantly with the Revised Children's Manifest Anxiety Scale), and also has good discriminant validity.[40] Internal consistency of the MASC-39 for the present study was excellent (α = 0.906). The MASC-10 has excellent internal consistency (α = 0.89), strong test–retest reliability (r = 0.86), and good convergent and discriminant validity.[39,40] Internal consistency of the MASC-10 for the current study was poor at T1 (α = 0.796), T2 (α = 0.780), and T3 (α = 0.794).

The Functional Disability Inventory (FDI)

The FDI[41] is a 15-item scale that measures the extent to which children experience difficulties in completing daily tasks and activities (eg, "Walking to the bathroom", "Eating regular meals", and "Being at school all day"). Each item is rated on a 5-point Likert Scale, which ranges from 0 (no trouble) to 4 (impossible). The total score ranges from 0 to 60 with higher scores indicative of increasing difficulty engaging in the activities. A score of 13 or more indicates moderate-to-severe disability and a score of less than 13 indicates no-to-mild disability.[17] FDI has excellent internal consistency (α = 0.90) and has good concurrent validity.[41] The internal consistency of the FDI for the present study was excellent at T0 (α = 0.919) and T3 (α = 0.910) and very good at T2 (α = 0.864).

Chronic Pain Acceptance Questionnaire-Adolescents (CPAQ-A)

The CPAQ-A[42] is a 20-item scale that measures an

adolescent's acceptance of chronic pain. Items are rated on a 5-point scale ranging from 0 (never true) to 4 (always true). The CPAQ-A has two subscales: activity engagement and pain willingness. The internal consistency for the activity engagement subscale has been shown to be good (α = 0.86) and also adequate for pain willingness (α = 0.75).[42] Internal consistency for the present study was very good at T0 (α = 0.876), T2 (α = 0.866), and T3 (α = 0.878).

Parent Measures

Pain Anxiety Symptoms Scale-Short Form (PASS-20)

PASS-20[22] consists of 20 items that measure the fear and anxiety-related thoughts, feelings, behaviors, and physical sensations that accompany the experience and anticipation of pain. Each item is rated on a scale of 0 (never) to 5 (always) and total scores range from 0 to 100. The PASS-20 has four subscales: cognitive, escape/avoidance, fear, and physiological anxiety. The PASS-20 has good internal consistency (α = 0.81) and good construct validity. Internal consistency for the present study was excellent (α = 0.950).

Pain Catastrophizing Scale (PCS) and Pain Catastrophizing Scale-Parents (PCS-P)

The PCS[26] is a 13-item self-report scale that measures the thoughts and feelings that individuals may experience when they are in pain, including unrealistic beliefs that the current situation will lead to the worst possible pain outcome, negative thoughts about the future and self, and "an exaggerated negative 'mental set' brought to bear during actual or anticipated pain experience" (p. 53,[27]). Each item is rated on a 5-point scale ranging from 0 (not at all) to 4 (all the time). The PCS yields a total score and three subscale scores assessing rumination, magnification, and helplessness. The PCS has high internal consistency and validity.[43] The PCS-P[44] is the parent version of the PCS that measures the extent to which a parent catastrophizes about their child's pain. The PCS-P has both strong construct validity and internal consistency (α = 0.81 to 0.93).[44] The internal consistency of the PCS for the present study was excellent (α = 0.937). Internal consistency for the PCS-P was excellent at T0 (α = 0.923) and T3 (α = 0.924).

Anxiety Sensitivity Index (ASI)[45]

The ASI is a 16-item self-report measure assessing the extent to which participants fear the potentially negative consequences of symptoms and sensations related to anxiety. Each item is rated on a scale from 0 (very little) to 4 (very much), for a total score ranging from 0 to 64. Higher scores indicate greater anxiety sensitivity. The ASI has high internal consistency for the total score (α=0.83) and has good convergent and discriminant validity.[46] Internal consistency for the present study was very good (α = 0.896).

The Center For Epidemiological Studies-Depression Scale (CES-D)

The CES-D[37] consists of 20 items and assesses depressive symptoms in adults. The measure surveys the following symptoms: depressed mood, worthlessness, helplessness, psychomotor retardation, and eating and sleeping problems. Items are rated on a scale from 0 (not at all) to 3 (a lot) to indicate how frequently each statement was experienced "in the past week". Total scores range from 0 to 60. CES-D has shown to have high internal consistency (α = 0.85 to 0.90) and strong construct validity.[37] Internal consistency for the present study was good (α = 0.803).

State-Trait Anxiety Inventory – Trait (STAI-T)

The STAI-T[47] is a 20-item scale that measures a wide range of anxiety features. Items are rated on a scale from 0 (almost never) to 4 (almost always). It has shown to have great internal consistency (α = 0.86 to 0.95) and satisfactory test–retest reliability (r = 0.69 to 0.89).[47] It also has good construct and concurrent validity.[48] Internal consistency for the present study was excellent (α = 0.916).

Pain Self-Efficacy Questionnaire (PSEQ)

The PSEQ[49] is a 10-item measure that assesses an individual's belief about their ability to engage in activities despite the pain they experience. Total scores range from 0 to 60; higher scores reflect higher self-efficacy beliefs. The PSEQ has shown to have excellent internal consistency (α = 0.93).[50] Internal consistency for the present study was excellent (α = 0.948).

Parent Psychological Flexibility Questionnaire (PPFQ)

The PPFQ[51] measures the ability of a parent to manage their distress about their child's pain. The questionnaire consists of 17-items that are to be rated on a scale of 0 (never true) to 6 (always true). This measure showed to have excellent internal consistency (α = 0.91).[51] Internal consistency for the present study was good at T0 (α = 0.892) and excellent at T3 (α = 0.903).

Semi-Structured Interview

Semi-structured interviews were conducted with a purposive sample of 36 parents 48–72 hrs after their child's

surgery. Parents were targeted for variation in child age [eg, child age (older (13–18 years old) and younger (8–12 years old)) and sex (male and female)]. Interested parents were asked to sign an additional consent form before beginning the interview. Each interview took approximately 30–45 mins to complete. All of the interviews were audio recorded after written consent was obtained from each participant. Questions in the interview guides were based on our combined experiences, through a literature search and based on our previous work. Questions moved from the more general to the more specific with the overall goal of being able to describe parents' perspectives of their child's post-operative pain experience with probes used to fully explore their experience. The interview questions were pilot tested with 4 participants to further refine the interview guide. As such the interview guide was modified according to previous interviews in order to capture new themes that emerged. Results from these interviews will be reported in another manuscript.

Procedure

The study was reviewed and approved by the Research Ethics Boards at The Hospital for Sick Children (SickKids) (REB file # 1000019644) and the Human Participants Review Committee at York University (Certificate # 2010-276). The study was conducted in accordance with the Declaration of Helsinki. Parents provided informed written consent to participate and children provided informed assent for their participation.

Eligible children and their parents, who had been prescreened by an operating room nurse in the patients' circle of care, were approached by the research assistant. Children and their parents were recruited to participate either at the pre-operative assessment clinic visit or by telephone if they did not attend the pre-operative clinic. This prospective, longitudinal study involved four assessment time points over the course of a year: pre-operative, in-hospital, and 6 and 12 months post-operative.

Pre-Operative Assessment (T0)

The baseline assessment included administration of child and parent questionnaires and child pressure pain thresholds using pressure algometry by the research assistant as described earlier. The child completed questionnaires (see Table 1) asking about previous and current pain experiences, as well as relevant psychological and emotional functioning. Parents completed questionnaires about their psychological functioning (PASS-20, PCS, ASI, CES-D, STAI-T, PSEQ). The order of questionnaire administration was randomized within subjects to minimize fatigue and order effects. The child's pre-operative medication use (analgesics and others) was obtained from the parents and confirmed by the patient's hospital medical record.

Intraoperative Anesthetic Management

Each patient received a general anesthetic. The following intraoperative factors were extracted from the surgical and anesthetic records: duration of surgery, analgesic/anesthetic regime including use of epidural/regional anesthetic techniques, systemic opioids, and non-opioid adjuvants.

In-Hospital Post-Operative Assessment (T1)

Physical activity was measured continuously while in hospital using a non-invasive Actical physical activity monitor. Pain intensity scores (NRS-I), pain unpleasantness scores (NRS-U), and pressure pain thresholds were obtained daily by a research assistant. NRS-I, NRS-U, and pressure pain thresholds were also obtained by a research assistant on one occasion between 48 and 72 hrs postoperative at the same time that the T1 self-report measures were administered. Postoperative analgesic use (eg, opioid consumption, adjunct analgesics) was recorded from the child's medical record. In addition, 48–72 hrs after surgery children completed self-report measures and a purposive sample of parents completed a semi-structured interview conducted by Rosenbloom (See Table 1).

Six- (T2) And 12 (T3)-Month Post-Operative Follow-Ups

Six and 12 months after surgery, the research assistant followed up with participants by telephone to complete a set of measures to determine pain (NRS-I, NRS-U) psychological and emotional adaptation, current pain medications, incidence, intensity, quality of chronic postsurgical pain and the extent to which it interferes with daily activity. At the 12-month follow-up, a research assistant conducted a pain memory interview with children and their parents. At the 12-month telephone follow-up, the research assistant orally led parents through two questionnaires measuring their psychological flexibility and pain catastrophizing about their child's pain.

All of the questionnaires were self-administered. However, we cannot exclude the possibility that the child/adolescent might not have completed them by themselves in the pre-operative period when participants either took them home to complete and return on the day of surgery. Otherwise, for participants who completed the

questionnaires in the pre-anesthesia clinic, a research assistant was present and could see that the participants were completing the forms themselves and was available to help if needed. For the remaining time points, the child/adolescent alone completed the questionnaires: For the in-hospital time point, questionnaires were completed by the child/adolescent and, at times, the questionnaires were read to the participants who responded verbally (eg, when the surgery type made it difficult for the child to write). The 6- and 12-month questionnaires were completed over the phone with the research assistant reading the questions to the children. This was done to be sure that the child was the one completing the questionnaires and also to avoid missing data.

Data Analysis

Pain Intensity And Pain Unpleasantness Trajectory Analyses

A growth mixture model (GMM) was used to characterize pain intensity and pain unpleasantness trajectories for adolescents over four time points including pre-surgical, in-hospital post-surgical, and 6 and 12 months post-surgical. Participants with three or more time points completed were included in the analysis. Previous research in adult surgical populations has shown linear and quadratic shaped post-operative pain trajectories.[52,53] Therefore, we tested a total of 14 different models each for pain intensity and pain unpleasantness that varied based on the number of trajectories (up to 7), and the presence of a linear and a quadratic term. All models were tested using the latent class mixed model (lcmm) package in R version 3.5.1. Model selection was based on the Bayesian information criterion (BIC) and Akaike Information Criterion (AIC), where lower values indicate better model fit. An additional indicator of model fit included a minimum of 5% of the participants classified in each trajectory. Local maxima were tested in the final model.

Predictors Of Pain Intensity And Pain Unpleasantness Trajectories

Once the best-fitting trajectory model was selected, the following biopsychosocial child pre-surgical and surgical variables were individually entered into univariate logistic regressions to predict trajectory class membership for pain intensity and for pain unpleasantness: age, sex, functional disability, fear of movement, pre-surgical pain-related anxiety and worry (pain catastrophizing, pain anxiety), general anxiety and worry (anxiety sensitivity, general anxiety), depression, pre-surgical pain self-efficacy, pain acceptance, symptoms of posttraumatic stress, surgery type, regional anesthesia, activity level on post-operative days 2 and 3, and cumulative five-day opioid consumption. The following parental factors were individually entered into the logistic regression to predict class membership: pre-surgical pain catastrophizing, pre-surgical anxiety sensitivity, pre-surgical pain anxiety, pre-surgical pain psychological flexibility, and pre-surgical depression. We tested for collinearity among variables. Significant predictors (p <0.20) were chosen for inclusion in the multivariable model.

Predictors Of 12-Month Functional Disability

A logistic regression was used to predict moderate-to-severe functional disability on the FDI. The FDI was split by a previously established cut off score of 13 or more indicating moderate-to-severe disability and a score of less than 13 indicating no-to-mild disability.[17] The same predictors as described earlier as well as the trajectory groups for pain intensity and pain unpleasantness were individually entered into the model. Significant ($p<0.20$) variables were then entered into the multivariable model.

Results

Recruitment And Retention Of Participants

Recruitment took place between February 2011 and August 2015. Figure 1 shows recruitment details and participant flow through the study. Records of children who were assessed and found not eligible between February 2011 and August 2014 were lost; therefore, Figure 1 shows eligibility numbers between September 2014 and August 2015.

Of the 349 approached for consent, 270 children and their parents consented to participate. Three children withdrew consent before participating in any part of the study, one patient's surgical procedure was changed and no longer met study criteria, and 27 children were missed (ie, the research assistant was unable to locate or reach them) for their T0 assessment. One patient was diagnosed with cancer after consent and was withdrawn from the study. A total of 264 participants completed at least some part of the in-hospital (T1) assessment (eg, questionnaire, pressure algometer, actigraphy, daily pain measures). Twenty-seven participants were admitted directly to the intensive care unit (ICU) from the operating room and therefore the research assistant was unable to obtain

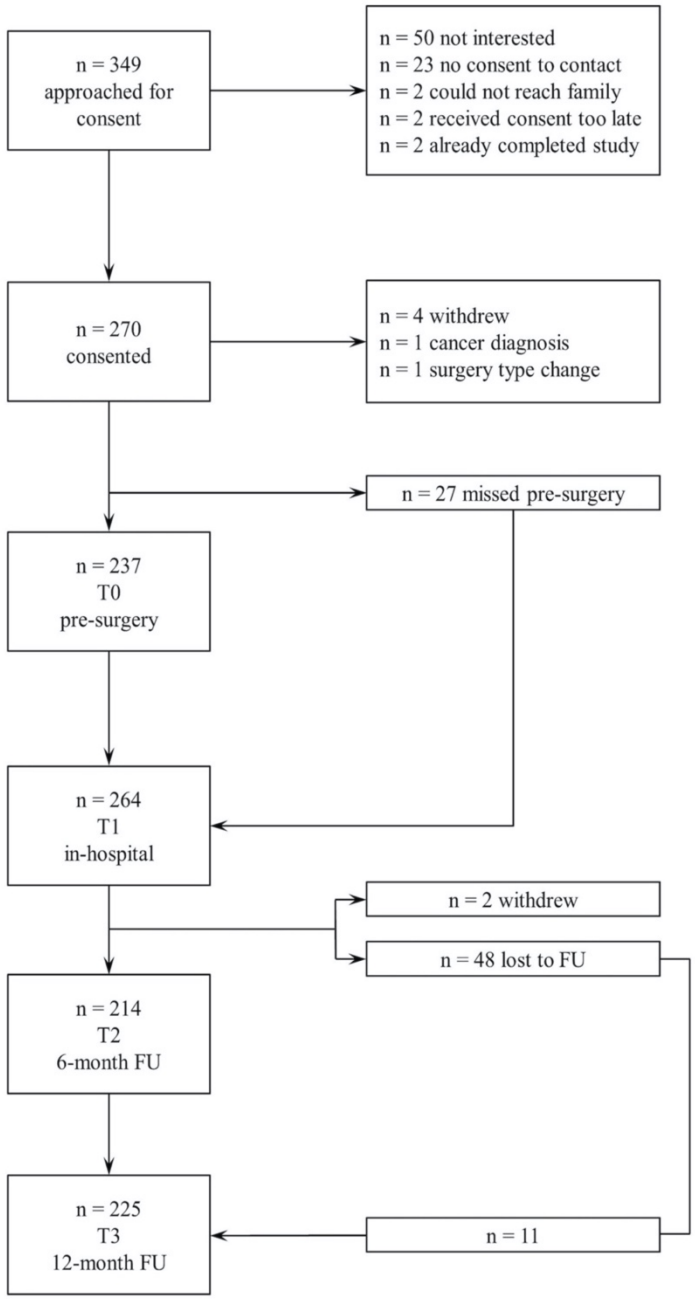

Figure 1 Participant recruitment and flow through the study.

daily pain measures. The 6- and 12-month retention rates of participants in this study were 81.1% (95% CI 75.9% to 86.4%) and 85.3% (95% CI 80.7% to 89.9%), respectively.

Significant differences at baseline were not found between participants who completed the study at 12 months and those who did not on any of the measures, except the PPIS. Participants who completed the study had significantly lower baseline PPIS scores (M = 14.4, SD = 9.6) than those who did not complete the study (M = 23.0, SD = 5.4), $t(162) = 2.162$, $p = 0.031$.

Demographic And Clinical Variables

The final sample consisted of 265 children [n = 155 female (58.5%), M age = 14.1 years (SD = 2.5), range 8–18 years] and their parents or guardians [n = 188 female (83.9%), M age = 45.1 years (SD = 5.9), range 29–70 years, 41 parents did not answer the demographic questionnaire]. The majority of children identified as Caucasian (65.7%; Table 2). Sixty-two percent of participants (n = 166, 62.6%) had a previous surgery, and 61.1% (n = 162) had chronic pain prior to the current surgery. Forty-three percent (n = 103, 43.8%) reported moderate-to-severe pain at the surgical site prior to surgery, and 23.3% (n = 56) also had moderate-to-severe functional disability. Only 8% (n = 21) of participants were taking pain medications prior to their current surgery.

The majority of children underwent surgery for scoliosis (n = 133, 50.2%) and 35.5% (n = 94) underwent an osteotomy. Fourteen children (5.3%) had a Ravitch procedure, four had a Nuss procedure (1.5%), four (1.5%) had a thoracotomy, and fifteen (5.7%) had another type of surgery. The mean duration of surgery was 4.59 hrs (SD = 2.07 hrs, range = 0.70–10.70 hrs) and children stayed in hospital an average of 4.9 days [SD = 2.9, range 1–36 days]. Participants who were transferred to the ICU had significantly longer surgical times ($p < 0.001$) and hospital stays ($p = 0.001$).

Table 2 Ethnicity Of Child And Parents (N = 265; N = 36 Did Not Identify Their Ethnicity)

Ethnicity	n (%)
Caucasian	153 (65.95)
African Canadian	14 (6.03)
South Asian	13 (5.60)
East Asian	11 (4.35)
African Caribbean	4 (1.72)
Hispanic	4 (1.72)
Aboriginal	3 (1.29)
Other	27 (11.64)

Incidence Of CPSP And Functional Disability

Pain and functional disability outcomes for the total sample can be seen in Table 3. In total, 35.5% (95% CI 29.1% to 41.9%, n = 76/214) of children had moderate-to-severe pain (ie, pain rated at a 4 or more out of 10) 6 months after surgery, and of these, 7.5% (95% CI 3.9% to 11.4%, n = 15/201) had been pain-free prior to surgery. A total of 11.9% (95% CI 7.4% to 16.4%, n = 24/201) of children who had moderate-to-severe pain prior to surgery reported being pain-free at 6 months post-operatively. At 12 months after surgery, 38.7% (95% CI 32.4% to 45.1%, n = 86/226) had moderate-to-severe pain, and of these, 9.2% (95% CI 5.3% to 13.1%, n = 19/207) had been pain-free prior to surgery. A total of 9.2% (95% CI 5.3% to 13.1%, n = 19/207) of children who had moderate-to-severe pain prior to surgery reported being pain-free at 12 months post-operatively. Table 4 shows the number and percentage of participants with and without preoperative pain who developed CPSP with no-to-minimal or moderate-to-severe functional disability.

Further, 32.7% (95% CI 26.4% to 39.0%, n = 70) and 29.3% (95% CI 23.4% to 35.3%, n = 66) of children had moderate-to-severe functional disability 6 and 12 months after surgery, respectively. Pain intensity was moderately, positively associated with functional disability at both 6 ($r = 0.357$, $p < 0.001$) and 12 months ($r = 0.209$, $p = 0.002$) after surgery. In terms of co-occurrence, 17.5% (95% CI 12.4% to 22.6%, n = 37) and 13.8% (95% CI 9.2% to 18.3%, n = 31) had both moderate-to-severe pain and moderate-to-severe disability at 6 and 12 months after surgery, respectively.

Medication Use

Opioid Use

Prior to surgery, three children (1.3%, 95% CI 0% to 2.7%) were using opioids to manage their pain. Two children continued to use opioids after surgery, while one child stopped using opioids. In total, 3.7% (95% CI 1.17% to 6.23%, n = 8) reported using opioids 6 months after surgery and 4.0% (95% CI 1.45% to 6.55%, n = 9) were using opioids at 12 months.

Non-Opioid Medication Use

Prior to surgery, 2.5% (95% CI 0.51% to 4.5%, n = 6) reported using acetaminophen and/or non-steroidal anti-inflammatory agents (NSAIDs) for pain management when needed. After surgery, 27.0% (95% CI 21.1% to 33.0%, n = 58) and 27.0% (95% CI 21.2% to 32.8%, n = 61) reported using

Table 3 Pre- And Post-Surgical Pain Intensity, Pain Unpleasantness, And Functional Disability Outcomes Across The Year-Long Period

	Pre-Surgical (n = 238) n (%)	In-Hospital (48 Hr Post-Operative, n = 207) n (%)	6 Months Post-Surgical (n = 213) n (%)	12 Months Post-Surgical (n = 225) n (%)
Pain Intensity				
No Pain (0)	76 (31.9)	9 (5.1)	80 (37.6)	80 (35.6)
Mild (1–3)	59 (24.8)	61 (34.7)	57 (26.8)	58 (25.8)
Moderate (4–7)	84 (35.3)	95 (54.0)	74 (34.7)	77 (34.2)
Severe (8–10)	19 (8.0)	11 (6.3)	2 (0.9)	10 (4.4)
Pain Unpleasantness				
No Pain (0)	73 (31.3)	2 (1.1)	82 (38.7)	82 (36.4)
Mild (1–3)	48 (20.6)	30 (17.1)	59 (27.8)	50 (22.2)
Moderate (4–7)	76 (32.6)	115 (65.7)	61 (28.8)	78 (34.7)
Severe (8–10)	36 (15.5)	28 (16.0)	10 (4.7)	15 (6.7)
Functional Disability				
None/Minimal (0–12)	138 (61.1)	-	138 (65.1)	156 (70.6)
Mild (13–20)	41 (18.1)	-	43 (20.3)	32 (14.5)
Moderate (21–29)	27 (11.9)	-	22 (10.4)	18 (8.1)
Severe (30–60)	20 (8.8)	-	9 (4.2)	15 (6.8)

Notes: Pain intensity and unpleasantness was measured using a 0–10 numerical rating scale. Functional disability was measured using the Functional Disability Inventory at all time points except in-hospital. Pre-surgical pain unpleasantness total n = 233 participants; In-hospital pain unpleasantness total n = 175; 6-month pain unpleasantness n = 212. Pre-surgical functional disability total n = 226; 6-month functional disability n = 212; 6-month functional disability n = 221.

Table 4 Number And Percentage (%) Of Children With And Without Preoperative Pain Who Developed Chronic Post-Surgical Pain (CPSP) At 12 Months With No-To-Minimal Or Moderate-To-Severe Functional Disability

	No-To-Mild Pre-Operative Pain		Moderate-To-Severe Pre-Operative Pain		Total n (%)
	No-To-Mild CPSP n (%)	Moderate-To-Severe CPSP n (%)	No-To-Mild CPSP n (%)	Moderate-To-Severe CPSP n (%)	
No-to-minimal functional disability	58 (28.3)	26 (12.7)	34 (16.6)	25 (12.2)	143 (69.8)
Moderate-to-severe functional disability	24 (11.7)	10 (4.9)	9 (4.4)	19 (9.3)	62 (30.2)
TOTAL	82 (40.0)	36 (17.6)	43 (21.0)	44 (21.4)	205 (100)

acetaminophen and/or NSAIDs when needed 6 and 12 months after surgery, respectively.

Pain Intensity Trajectories

As shown in Table 5, 14 models were tested. The final model was based on the lowest BIC and AIC values, which included a two-class model with a quadric slope. The two different pain intensity trajectories are presented in Figure 2 with the parameters for the final model shown in Table 6. Trajectory one (n = 136) consisted of children who started with mild pain intensity, which remained mild in-hospital, and at 6 and 12 months. Trajectory two (n = 123) consisted of children who started with moderate-to-severe pain intensity and who continued to have moderate-to-severe pain post-surgically. Trajectory two also included a significant decrease in pain intensity from Day 2 to 6 months post-surgically. Table 7 shows the means and standard deviations across time for the two trajectories.

Pain Unpleasantness Trajectories

The 14 models for pain unpleasantness are shown in Table 5. The final model was based on the lowest BIC and AIC values, which included a two-class model with a quadric slope. The two pain unpleasantness trajectories are presented in Figure 3. The characteristics and parameters estimated of the regression equation for each trajectory are shown in Table 6. Trajectory one (n = 187) consisted of children who started with lower pain unpleasantness that remained lower in-hospital, as well as at 6 and 12 months. Trajectory two (n = 72) consisted of children who started with higher pain unpleasantness ratings and who continued to have higher pain unpleasantness post-surgically. Trajectories one and

Table 5 Model Fit For Pain Intensity And Pain Unpleasantness Trajectories

Number Of Trajectories	Linear		Linear And Quadratic	
Pain intensity	**AIC**	**BIC**	**AIC**	**BIC**
1	3998.17	4008.84	3990.20	4004.43
2	3958.62	3979.96	3948.57	3977.03[a]
3	3950.66	3982.67	3938.01	3980.69
4	3947.34	3990.02	3932.06	3988.96
5	3953.34	4006.69	3940.06	4011.19
6	3958.14	4022.17	3942.90	4028.36
7	3964.14	4038.84	3949.68	4049.27
Pain Unpleasantness				
1	3710.42	3721.09	3671.26	3685.49
2	3666.27	3687.61	3615.99	3644.45[a]
3	3670.40	3702.41	3614.01	3656.69
4	3669.37	3712.05	3604.52	3661.42
5	3675.37	3728.72	3612.52	3683.65
6	3681.37	3745.39	3620.52	3705.88
7	3687.37	3762.06	3628.52	3728.11

Note: [a]Model with the best fit to the data that respected all criteria (lower AIC and BIC values, smallest class with n > 5%, parsimony and theoretical soundness).
Abbreviations: AIC, Akaike information criterion; BIC, Bayesian information criterion.

two also included a significant decrease in pain unpleasantness from Day 2 post-surgically to 6 months post-surgically, but the decrease in pain unpleasantness was steeper in trajectory one than two. Table 7 shows the means and standard deviations across time for the two pain unpleasantness trajectories.

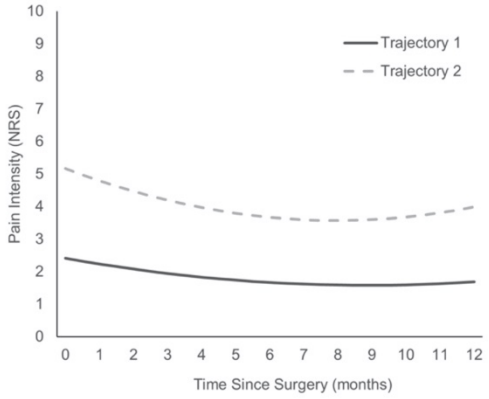

Figure 2 Predicted pain intensity trajectories.

Table 6 Pain Intensity And Pain Unpleasantness Trajectory Characteristics And Parameters

Trajectory Group	n	Intercept	Slopes	
			Linear	Quadratic
Pain Intensity				
1	136	2.41326	−0.18829	0.01063
2	123	5.16758	−0.40125	0.02522
Pain Unpleasantness				
1	187	4.85795	−0.77111	0.04160
2	72	6.29541	−0.33529	0.02066

Baseline Predictors Of Pain Intensity Trajectories

There was a high degree of collinearity between pain catastrophizing and pain anxiety scores. To address this, we averaged the total scores on the PCS-C and CPASS to form a pain-related anxiety and worry variable. Similarly, total scores for anxiety sensitivity (CASI) and general anxiety (MASC) were averaged to form a general anxiety variable.

To determine baseline predictors of pain intensity trajectory class membership, univariate logistic regression analyses were conducted (Table 8). Significant factors associated with pain intensity trajectory group membership at the univariate level included: age, sex, PICU admission, surgery type, use of regional analgesia, cumulative 5-day opioid consumption, baseline functional disability, baseline symptoms of post-traumatic stress, baseline symptoms of depression, baseline pain-related anxiety and worry, baseline non-pain-related anxiety, and baseline parent pain flexibility. Six variables (age, PICU admission, surgery type, use of regional analgesia, cumulative 5-day opioid consumption, and baseline parent pain flexibility) were not significant when building the multivariable model (ie, every other factor individually accounted for more of the variance) and therefore we excluded them from the final model. A multivariable logistic regression was conducted with the final model shown in Table 9. The referent class was mild pain intensity. The final model (χ^2 (7, n = 208) = 36.659, $p < 0.001$, Nagelerke R^2 = 21.6%) included functional disability, cumulative 5-day opioid consumption, sex, general anxiety, pain-related anxiety and worry, symptoms of depression, and post-traumatic stress symptoms. Greater functional disability prior to surgery predicted a higher likelihood of being in the high pain intensity trajectory group (OR: 1.053, 95% CI: 1.019, 1.089, $p = 0.002$). In-hospital cumulative 5-day

Table 7 Mean (Standard Deviation [SD]) Observed Pain Intensity And Pain Unpleasantness Values By Trajectory Group Membership

Trajectory Group	Pre-Surgical M (SD)	In-Hospital (48 Hr Post-Operative) M (SD)	6 Months Post-Surgical M (SD)	12 Months Post-Surgical M (SD)
Pain Intensity				
1	0.93 (0.17)	3.01 (0.25)	1.56 (0.22)	1.78 (0.24)
2	3.35 (0.34)	5.24 (0.23)	3.60 (0.30)	4.29 (0.32)
Pain Unpleasantness				
1	4.54 (0.33)	4.82 (0.26)	1.79 (0.23)	2.24 (0.30)
2	5.64 (0.45)	6.52 (0.34)	5.44 (0.40)	5.80 (0.33)

opioid consumption also significantly predicted group membership in the moderate-to-severe pain intensity trajectory (OR: 1.002, 95% CI: 1.001,1.003, $p = 0.001$). None of the parents, surgical, or activity variables significantly predicted pain intensity trajectory group membership. We conducted logistic regression analyses on 6-month predictors of trajectory membership for both pain intensity and pain unpleasantness. The results from the multivariable analyses revealed the same predictors of group membership, namely FDI, and thus are not reported in full.

Baseline Predictors Of Pain Unpleasantness Trajectories

To determine baseline predictors of pain unpleasantness class membership, univariate logistic regression analyses were conducted (Table 10). Significant factors at the univariate level associated with pain unpleasantness trajectory group membership included: activity level on post-operative days 2–3, baseline functional disability, baseline pain-related anxiety and worry, baseline non-pain-related anxiety, baseline fear of movement, baseline symptoms of post-traumatic stress, and parent pain psychological flexibility. Similar to predicting pain intensity trajectory group membership, the following factors did not contribute significantly to the multivariable model: activity level on post-operative days 2–3, baseline pain-related anxiety and worry, baseline non-pain-related anxiety, baseline symptoms of post-traumatic stress, and parent pain psychological flexibility. Therefore, the final multivariable logistic regression model (χ^2 (2, n = 226) = 7.701, $p < 0.001$, Nagelerke R^2 = 4.8%) included functional disability (FDI) and fear of movement (TSK). Greater functional disability prior to surgery predicted a higher likelihood of being in the high pain trajectory group (OR: 1.028, 95% CI: 1.000, 1.056, p = 0.047). Fear of movement did not significantly predict pain unpleasantness trajectory group membership (OR: 1.027, 95% CI: 0.982, 1.073, p = 0.250).

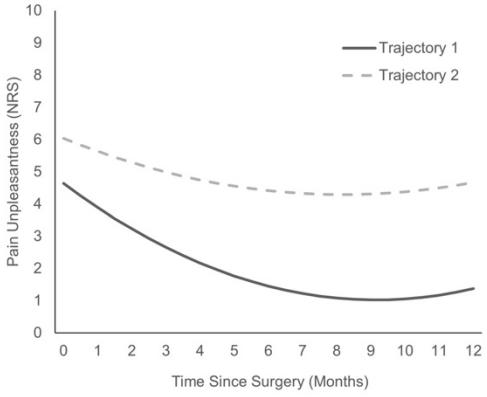

Figure 3 Predicted pain unpleasantness trajectories.

Predictors Of Functional Disability At 12 Months

To determine factors associated with moderate-to-severe functional disability at 12 months after surgery, univariate logistic regression analyses were conducted (Table 11). Significant factors associated with moderate-to-severe functional disability at 12 months included: age, pain intensity trajectory, pain unpleasantness trajectory, baseline functional disability, pain-related anxiety and worry, non-pain-related anxiety, baseline chronic pain acceptance, baseline symptoms of depression, baseline symptoms of post-traumatic stress, and baseline pain self-efficacy. However, given the wide confidence intervals for age and baseline symptoms of post-traumatic stress, these factors were left out of the final model. A multivariable logistic regression was conducted with the final model shown in Table 12. The final model (χ^2 (7, n = 159) = 24.921, $p = 0.001$, Nagelerke R^2 = 20.3%) included baseline functional disability, baseline general

Table 8 Univariate Logistic Regression Analysis Showing The Relationship Between Baseline (T0) And Surgical (T1) Predictors And Group Membership In Pain Intensity Trajectories (referent Group Is No-To-Mild Pain Intensity Trajectory)

	Odds	95% Confidence Interval		P-Value
		Lower	Upper	
Child Factors				
Age	1.086	0.984	1.199	0.102*
Sex[a]	1.822	1.059	3.133	0.030*
PICU	2.263	0.969	5.285	0.059*
Surgery Type	1.202	1.016	1.423	0.032*
Regional Anesthesia	0.552	0.283	1.075	0.080*
Cumulative 5-day Opioid Consumption	1.002	1.001	1.003	0.000*
Activity Level (Post-operative Days 2 and 3)	1.000	1.000	1.000	0.322
Baseline functional disability	1.056	1.029	1.085	0.000*
Baseline pain-related anxiety and worry	1.024	1.005	1.043	0.013*
Baseline non-pain related anxiety	1.030	1.005	1.055	0.017*
Baseline chronic pain acceptance	0.993	0.972	1.016	0.561
Baseline depression symptoms	1.035	1.012	1.058	0.003*
Baseline Fear of Movement	1.017	0.979	1.055	0.394
Baseline Pain Self-Efficacy	1.020	0.982	1.059	0.313
Baseline Symptoms of Posttraumatic Stress	1.030	1.010	1.050	0.003*
Parent Factors				
Baseline Pain Catastrophizing	1.013	0.964	1.066	0.603
Baseline Anxiety Sensitivity	1.004	0.966	1.044	0.831
Baseline Depression	1.007	0.973	1.042	0.697
Baseline Pain Flexibility	0.985	0.966	1.003	0.104*
Baseline Pain Anxiety	1.004	0.991	1.018	0.536

Notes: *P<0.20; [a]Reference category for sex was male.
Abbreviation: PICU, Pediatric Intensive Care Unit.

Table 9 Logistic Regression Of Baseline Predictors Of High Pain Intensity Trajectory Group (Referent Group Is No-To-Mild Pain Intensity Trajectory)

	Odds	95% Confidence Interval		P-Value
		Lower	Upper	
Functional disability	1.053	1.019	1.089	0.002
Non-pain-related anxiety	1.002	0.966	1.039	0.908
Pain-related anxiety and worry	1.001	0.974	1.030	0.925
Depression	0.995	0.960	1.031	0.778
Post-traumatic stress symptoms	1.019	0.991	1.049	0.190
Cumulative 5-day opioid consumption	1.002	1.001	1.003	0.001
Sex[a]	1.673	0.874	3.203	0.121

Note: [a]Reference category for sex is male.

anxiety, baseline pain-related anxiety and worry, baseline symptoms of depression, baseline chronic pain acceptance, as well as pain unpleasantness trajectories and pain intensity trajectories. Greater functional disability prior to surgery predicted a higher likelihood of having moderate-to-severe functional disability 12 months after surgery (OR: 1.051, 95% CI: 1.013, 1.091, $p = 0.008$), while holding all other variables constant. In other words, while controlling for all other variables, a one-point increase on baseline functional disability multiplies the odds of having moderate-to-severe functional disability by 1.051. Pain unpleasantness trajectory was also a significant predictor of moderate-to-severe functional disability (OR: 2.585, 95% CI: 1.049, 6.365, $p = 0.039$). Compared to children in trajectory one, children

Table 10 Univariate Logistic Regression Analysis Showing The Relationship Between Baseline (T0) And Surgical (T1) Predictors And Group Membership In Pain Unpleasantness Trajectories (Referent Group Is No-To-Mild Pain Unpleasantness Trajectory)

	Odds	95% Confidence Interval		P-Value
		Lower	Upper	
Child Factors				
Age	0.990	0.888	1.103	0.851
Sex	0.878	0.483	1.595	0.669
PICU	1.174	0.486	2.833	0.722
Surgery Type	0.986	0.820	1.185	0.881
Regional Anesthesia	0.811	0.386	1.704	0.581
Cumulative 5-day Opioid Consumption	1.001	1.000	1.002	0.237
Activity Level (Post-operative Days 2 and 3)	1.000	1.000	1.000	0.199*
Baseline functional disability	1.033	1.007	1.059	0.011*
Baseline pain-related anxiety and worry	1.015	0.995	1.036	0.148*
Baseline non-pain related anxiety	1.026	0.999	1.053	0.060*
Baseline chronic pain acceptance	0.992	0.968	1.016	0.491
Baseline depression symptoms	1.009	0.986	1.034	0.444
Baseline Fear of Movement	1.044	1.001	1.089	0.046*
Baseline Pain Self-Efficacy	1.007	0.966	1.051	0.731
Baseline Symptoms of Posttraumatic Stress	1.019	0.998	1.041	0.072*
Parent Factors				
Baseline Pain Catastrophizing	0.985	0.931	1.042	0.594
Baseline Anxiety Sensitivity	0.986	0.943	1.031	0.535
Baseline Depression	0.997	0.959	1.036	0.881
Baseline Pain Flexibility	0.985	0.966	1.003	0.104*
Baseline Pain Anxiety	0.999	0.984	1.015	0.900

Note: *P<0.20.

with moderate-to-severe pain unpleasantness (Trajectory 2) were more than twice as likely to have moderate-to-severe disability at 12 months, while controlling for all other variables.

Discussion

The results of the present longitudinal study show that 35% and 38% of the children report moderate-to-severe chronic post-surgical pain 6 and 12 months after surgery, respectively. These results are generally consistent with the incidence reported by recent studies. For example, Chidambaran et al[14] found that 37.8% (48/127) had chronic pain 2–3 months after spinal fusion surgery and 41.7% (46/110) had persistent pain one year after surgery.[14] In another study by Chidambaran et al,[54] 36% (44/121) of patients had chronic pain 2–3 months after surgery.[54] Sieberg et al,[16] however, reported a much lower incidence of 16% (27/169) for moderate-to-severe chronic pain one year after spinal fusion surgery,[16] which is in line with a recent review of earlier studies of pediatric post-operative pain.[1] The differences in incidence rates across studies may be due, in part, to the number of months after surgery when pain is assessed, "caseness" (non-zero vs moderate-to-severe), the pain scales used, and the presence or absence of preoperative pain. Greater incidences are typically found earlier after surgery[14,55] and when reporting the incidence of non-zero pain.[2,15,55,56] The type of pain scale used may also influence the incidence of CPSP. Sieberg et al[16] used (non-numeric) pain items from the Scoliosis Research Society-30 which asks participants directly whether their pain is "mild", "moderate", moderate to severe' or "severe", whereas in the present study, and in past work by our group,[2] we used numeric rating scales and subsequently determined pain severity based on a cut-off score on the NRS of 4.

Regarding the issue of preoperative pain prevalence, we found the incidence of 6-month and 12-month CPSP among participants who did not have preoperative pain to be 7.5% and 9.2%, respectively. In contrast, the incidence in the total sample, of whom, 43% had had moderate-to-severe preoperative pain was 35% and 37%. In our previous study,[2] conducted at the same institution and using the same surgical population, the prevalence of moderate-to-severe preoperative pain was 19.3% and the incidence of moderate-to-severe

Table 11 Univariate Logistic Regression Analysis Showing Baseline (T0) And Surgical (T1) Predictors Of 12-Month Moderate-To-Severe Functional Disability

	Odds	95% Confidence Interval		P-Value
		Lower	Upper	
Child Factors				
Age	0.901	0.804	1.010	0.075*
Sex	1.188	0.628	2.249	0.597
PICU	2.067	0.813	5.254	0.127
Surgery Type	1.018	0.837	1.239	0.856
Regional Anesthesia	1.545	0.739	3.231	0.248
Cumulative 5-day Opioid Consumption	0.999	0.998	1.000	0.224
Activity Level (Post-operative Days 2 and 3)	1.000	1.000	1.000	0.833
Pain intensity trajectory	0.449	0.250	0.808	0.008*
Pain unpleasantness trajectory	0.406	0.218	0.775	0.004*
Baseline functional disability	1.061	1.033	1.090	0.000*
Baseline pain-related anxiety and worry	1.033	1.012	1.055	0.002*
Baseline non-pain related anxiety	1.033	1.005	1.062	0.021*
Baseline chronic pain acceptance	0.967	0.942	0.993	0.012*
Baseline depression symptoms	0.997	1.047	1.022	0.092*
Baseline Fear of Movement	1.013	0.971	1.057	0.561
Baseline Pain Self-Efficacy	1.056	1.010	1.104	0.016*
Baseline Symptoms of Posttraumatic Stress	1.025	1.003	1.047	0.028*
Parent Factors				
Baseline Pain Catastrophizing	1.016	0.959	1.075	0.596
Baseline Anxiety Sensitivity	1.021	0.978	1.067	0.343
Baseline Depression	0.993	0.954	1.034	0.745
Baseline Pain Flexibility	0.996	0.976	1.017	0.721
Baseline Pain Anxiety	1.010	0.995	1.026	0.197

Note: *P<0.20.

Table 12 Logistic Regression Analysis Showing Predictors Of 12-Month Moderate-To-Severe Functional Disability

	Odds	95% Confidence Interval		P-Value
		Lower	Upper	
Baseline functional disability	1.051	1.013	1.091	0.008
Pain intensity trajectory	0.877	0.355	2.167	0.776
Pain unpleasantness trajectory	2.585	1.049	6.365	0.039
Baseline pain-related anxiety and worry	1.009	0.971	1.050	0.637
Baseline non-pain related anxiety	1.021	0.979	1.065	0.333
Baseline chronic pain acceptance	0.979	0.944	1.017	0.274
Baseline depression symptoms	0.964	0.923	1.007	0.100

CPSP was 23% and 22% at 6 and 12 months, respectively. Thus, the higher incidence of CPSP in the present study may be related to the higher prevalence of preoperative pain. The persistence of pain indicates that surgery, in the present study, did not alleviate pre-operative pain – a possibility that might be discussed with families prior to surgery.

Recently, several studies have used trajectory analyses to characterize pain outcomes in children who have undergone major surgery,[3,14–16] but thus far they have been limited by small sample sizes consequently bringing into question the various numbers and characteristics of the reported trajectories. The present study recruited a sample more than twice the size of previous studies. A two-trajectory model provided the best fit for the data for both pain intensity and pain unpleasantness. In the case of pain intensity, the data showed a group of children with

mild pain pre- and post-surgically and a group with moderate-to-severe pain pre- and post-surgically. Both Connelly et al[3] and Rabbitts et al[15] report a two-trajectory model, but unlike their trajectories showing recovery of pain over time, the moderate-to-severe pain trajectory in the present study remained high across the one-year follow-up period. Unique to the present study, we also evaluated pain unpleasantness trajectories. Pain unpleasantness trajectory analysis showed a group with lower pain unpleasantness ratings that remained low up to 12 months and a group with a higher degree of pain unpleasantness that was sustained throughout the year. The pain unpleasantness and pain intensity trajectory groups contained some of the same children.

The results of the present study also show that 33% and 30% of the children report moderate-to-severe functional disability 6 months and 12 months after surgery and that their disability was correlated with pain intensity at each time point. Notably, however, only 18% and 14% had both moderate-to-severe pain and moderate-to-severe functional disability at the two time points, respectively, indicating that not all children with moderate-to-severe pain are functionally disabled. Moreover, greater functional disability before surgery in combination with year-long pain unpleasantness trajectories predicted a significantly greater likelihood of developing moderate-to-severe functional disability at 12 months after controlling for a variety of relevant psychological factors. A corollary to this is that children with better pre-operative functioning and lower levels of pain unpleasantness have better post-operative functioning. Four other studies have reported functional outcomes in children after surgery.[2,14–16] Chidambaran et al[14] reported that children with chronic pain (ie, pain present over 2–3 months) and persistent pain (ie, pain present over 10–12 months) had more severe functional disability than children without pain problems at 4–6 weeks post-surgery, but chronic pain at 6 and 12 months was not associated with greater functional disability in the long term.[14] Rabbitts et al[15] reported that children with late recovery from pain after spinal fusion reported greater activity limitations one year after surgery, but they failed to control for baseline levels of activity limitations. Another study evaluated missed days of school/work prior to surgery and found that the high post-surgical pain group had significantly more missed days than the other pain groups in the study (ie, pain improvement group, no-pain group) but importantly the authors did not report whether pain trajectory group membership predicted number of missed days at the long-term follow-ups.[16] The present results point to the importance of assessing and controlling for preoperative functional disability when examining predictors of CPSP-related functional disability.

A theoretical consideration present in the child CPSP literature involves the role of parent cognitive-affective appraisals and behavioral patterns in relation to their child's pain and recovery after surgery.[14,15,57–59] For example, Pagé et al[2] found that parental pain catastrophizing in the days after surgery predicted child pain intensity outcomes one year after surgery. In contrast, the present study did not find that parental factors, including psychological flexibility, pain catastrophizing, anxiety sensitivity, depression, general anxiety, and pain self-efficacy, were related to child pain intensity or unpleasantness trajectories, or functional disability. The lack of a relationship between parent and child pain factors is consistent with Birnie et al[60] who found that child, but not parent pain catastrophizing, played a role in predicting pain outcomes after spinal fusion surgery. Rabbitts et al[15] found that parental catastrophizing about their child's pain was associated with late pain recovery. Taken together, the results for parent pain catastrophizing in the context of child CPSP suggest that a parent's own level of pain catastrophizing is not directly associated with child outcomes, but that parent worry about their child's pain is. To further evaluate the interpersonal factors theorized to influence child pain outcomes,[59,61] future studies might consider using measures that specifically evaluate parent cognitive and affective reactions to their child being in pain. Future studies should also be designed to have the statistical power necessary to evaluate factors from biomedical, psychosocial, and behavioral aspects of an integrated biopsychosocial model.

There are limitations to the present study. First, as with all other studies in this area we did not conduct physical examinations of the children pre- and post-operatively so we cannot be certain of the percentage of participants whose CPSP was a continuation of the pain that was experienced pre-operatively versus those whose pain was a direct result of the surgery.[7,62] This is especially relevant since 43% of the present sample reported moderate-to-severe pain before surgery. A conservative estimate of the incidence of one-year CPSP is 9.2% based only on patients who did not have preoperative pain, thus, the true incidence of one-year moderate-to-severe CPSP likely lies between 9.2% and 38%. A second limitation is that we did not assess children between hospital discharge and the six-month follow-up. Doing so may have allowed for a more fine-grained trajectory analysis with greater precision to detect additional patterns of pain intensity and pain unpleasantness over time. It would be beneficial for future studies to conduct an assessment 4–6 weeks post-operatively so that the course of

pain trajectories can be more precisely monitored during the transition from acute to chronic pain.[63] A third limitation is that we used a general measure of functional disability (FDI), not a pain-specific measure, and therefore we cannot conclude that the disability reported by children after surgery was due to CPSP. However, we can conclude that moderate-to-severe functional disability and CPSP intensity occur in similar proportions of participants. Additionally, we found that baseline PROMIS Pediatric Pain Interference Scale (PPIS) was lower for those who completed the study than those who did not complete the study, indicating that our sample may be underestimating the level of pain-related disability experienced by youth undergoing major surgery. Future studies should examine both general functional disability and pain-related disability, with measures such as the PPIS.[35]

In conclusion, 38% of the children undergoing major surgeries go on to develop moderate-to-severe CPSP one year after major surgery and have 30% have moderate-to-severe functional disability as well. We found that pre-surgical functional disability and year-long pain unpleasantness ratings predict moderate-to-severe disability 12 months after surgery. These findings raise the possibility that "prehabilitation" interventions[64] administered sufficiently in advance of surgery and addressing functional disability and pain-related psychological factors may minimize functional disability in the long term. Addressing factors that contribute to pain unpleasantness after surgery may also help to reduce long-term functional disability. A Transitional Pain Service[65–67] model adapted to children undergoing surgery may be helpful in this regard.

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Disclosure

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Chapter 3: Differential Risk Factor Profiles In The Prediction Of General And Pain - Specific Functional Limitations 12 Months After Major Pediatric Surgery

The aims of Study 1 (Chapter 2) were to determine the incidence and severity of chronic post-surgical pain in youth undergoing major surgery. Results showed that over a third of youth report moderate-to-severe post-surgical pain. The second aim of this study was to identify pain intensity and pain unpleasantness trajectories over the course of a 12-month timeframe. I show that there are two pain trajectories: high pain and low pain. These results indicate that those youth who have high pain intensity/unpleasantness early in their surgical journey continue to have high pain intensity/unpleasantness 12 month after surgery. Study 1 also examined factors that predicted group pain intensity and pain unpleasantness trajectory membership. Results showed that in-hospital opioid consumption and pre-surgical functioning predict pain group membership and that pre-surgical functioning predicts pain unpleasantness group membership. Fourth, this study identified pre-surgical risk factors that predict functional limitations 12-months after surgery. Results show that pre-surgical functional disability predicts post-surgical functioning, over and above psychosocial and surgery-related factors. Importantly, Study 1 showed that over 30% of youth undergoing major surgery went on to develop moderate-to-severe functional disability as measured by the Functional Disability Inventory. It was not clear from this first study, however, whether there would be a difference in risk factors for general versus pain-specific functional limitations. Therefore, the aim of Study 2 (Chapter 3) was to examine differential risk factor profiles for general and pain-specific functional limitations 12-

months after major pediatric surgery.

children

MDPI

Article

Differential Risk Factor Profiles in the Prediction of General and Pain-Specific Functional Limitations 12 Months after Major Pediatric Surgery

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Abstract: Pediatric chronic post-surgical pain is a surgical complication associated with various levels of functional limitation. Two commonly used measures of functional limitations in youth are the Functional Disability Inventory (FDI) and the PROMIS Pediatric Pain Interference Scale (PPIS), where the former is general, and the latter, pain specific. The aim of the present study was to prospectively compare pre-surgical youth and parent risk factors for youth functional limitations, assessed by the FDI and PPIS, 12 months after major pediatric surgery. Risk factors for the FDI and PPIS were compared in 79 dyads consisting of youth (58% female, M = 14.56 years; SD = 2.31) undergoing major surgery and one of their parents. The FDI and PPIS were highly correlated prior to surgery (r = 0.698, $p < 0.001$) and even more so 12 months after surgery (r = 0.807, $p < 0.001$). Parent pre-surgical anxiety sensitivity and youth pre-surgical functional disability significantly predicted 12-month FDI ($F(6,56) = 4.443$, $p = 0.001$, Adjusted $R^2 = 0.25$), whereas parent pre-surgical anxiety sensitivity, trait anxiety, pain anxiety, as well as youth pain-related anxiety and worry significantly predicted 12-month PPIS ($F(6,45) = 4.104$, $p = 0.002$, Adjusted $R^2 = 0.27$). Risk factors for 12-month general and pain-specific functional limitations differ by dyad member and type. Functional limitations in youth after surgery are predicted by youth and parent factors, however the risk factors differ between the FDI and the PPIS.

Keywords: pain; chronic pain; children; adolescents; parents; functional limitations; functional disability; anxiety

1. Introduction

Chronic post-surgical pain is a surgical complication reported by 11–54% of children and adolescents after major surgery [1–4]. Youth with moderate-to-severe chronic pain are often limited in their age-appropriate everyday activities, such as being social with friends, going to school, and doing physical activity [4–7].

The interpersonal fear-avoidance model of pain (IFAM; [8]) uses a family systems perspective that identifies child (e.g., cognitive, affective, behavioral) and parent (e.g., cognitive, affective, behavioral), parent-child dyad (e.g., parent-child interaction style), and family (e.g., familial environment) factors instrumental in the development and maintenance of functional limitations (e.g., disability, interference) associated with chronic pain. There is evidence in support of the IFAM model from cross-sectional studies showing bi-directional relationships among child chronic pain-related disability and child and parent, parent-youth dyad, and family variables [9,10]. However, this relationship has rarely been evaluated longitudinally. A recent systematic review and meta-analysis of youth with chronic pain [10] found only four prospective studies [11–14] to have evaluated parent and youth factors and their relationship to functional limitations over time using the Functional Disability Inventory (FDI), the Child Activities Limitations Interview (CALI), and the Child Health Assessment Questionnaire (CHAQ). To our knowledge, none has evaluated these relationships in the transition of acute to chronic postsurgical pain.

The Pediatric Initiative on Methods, Measurement, and Pain Assessment in Clinical Trials (PedIMMPACT) consensus guidelines recommend the use of measures to evaluate functional limitations in children with chronic pain [15]. Until recently the FDI [16] was the measure recommended for assessment of general physical functioning in children with chronic pain [15]. More recently the Patient-Reported Outcomes Measurement Information System (PROMIS) developed the short Pediatric Pain Interference Scale (PPIS) designed to evaluate pain-specific functional limitations [17]. These two scales measure similar aspects of functioning; however, they differ in that the FDI is a general measure of functional limitations that does not refer to pain but rather captures social, developmental, and other medical problems, whereas the PPIS is a pain-specific measure. However, they are often used interchangeably in outcome research. The FDI and the PPIS are well validated and widely used measures of functional limitations, but it is unclear what, if any, youth and parent factors differentially predict their outcomes in the transition from acute to chronic pain. This is important for two reasons. First, the FDI and PPIS are conceptually distinct measures, and as such are likely to be impacted by different variables. Second, if there are differences in risk factors, there may be implications for how best to intervene. The present study was designed to prospectively compare pre-surgical youth and parent risk factors for the PPIS and the FDI 12 months after major pediatric surgery. Due to the high level of parent involvement in youth surgical recovery, we hypothesize that parent risk factors will predict youth functional limitations 12 months after surgery. We hypothesize that parent general anxiety will predict general functional limitations (FDI), whereas parent pain-related anxiety will predict pain-related functional limitation (PPIS). Further, we hypothesize that youth general anxiety will be associated with general functional limitations (FDI) and that youth pain-related anxiety will be associated with pain-related functional limitations (PPIS). Secondarily, this study aimed to examine the association between chronic pain status and functional limitations (FDI, PPIS).

2. Materials and Methods

The present article is part of a larger study evaluating the incidence of chronic postsurgical pain in children and adolescents (youth) [4]. The methods and results reported herein pertain only to the objective of the present article, which was to evaluate the differential pre-operative risk factor profiles of pediatric pain-related functional limitations and general functional limitations 12 months after surgery. Therefore, data are presented only from Time 0 (T0) corresponding to the pre-operative assessment and Time 3 (T3) corresponding to the 12-month post-operative assessment.

2.1. Participants

Participants were eligible for the present study if they were 8–18 years of age, undergoing either orthopedic surgery or general surgery, and one of their parents were agreeable. Exclusion criteria for youth were as follows: (1) documented developmental or cognitive

delay, (2) cancer diagnosis, (3) could not speak or read English, or (4) their parent/guardian did not speak or read English.

2.2. *Questionnaires*

2.2.1. Outcome Measures

Pain-related interference, or pain-related functional limitation, was measured by the PROMIS—Pediatric Pain Interference Scale (PPIS). The PROMIS—Pediatric Pain Interference Scale [17] is an 8-item, self-report instrument that measures the extent to which, over the "past 7 days", the youths' pain has interfered with, or limited them from engaging in, important functional facets of their everyday life (e.g., emotions, physical activities, schoolwork, attention, sleep). Participants use a 5-point scale that ranges from "never" to "almost always" to rate each item. Total possible scores range from 0 to 32 with higher scores indicating more pain-related interference or greater pain-related functional limitations. Raw scores are transformed to t-scores. The PPIS consistently achieves a reliability of 0.85 [17,18]. T0 ($\alpha = 0.93$) and T3 ($\alpha = 0.92$) internal consistency for the present study were excellent.

General functional disability, or general functional limitation, was measured by the Functional Disability Inventory (FDI). The 15-item FDI [16] measures how much difficulty youth report in carrying out daily tasks and activities (e.g., "Being at school all day", "Eating regular meals", and "Walking to the bathroom"). Items are rated on a 5-point Likert Scale (0 = "no trouble" to 4 = "impossible". FDI total possible scores range from 0 to 60 with higher scores indicating greater general functional limitations or increasing difficulty with the tasks and activities. The FDI has very good to excellent psychometric properties, including very strong internal consistency ($\alpha = 0.90$) and good concurrent validity [16]. FDI T0 ($\alpha = 0.92$) and T3 ($\alpha = 0.91$) internal consistency were excellent.

2.2.2. Youth Risk Factor Measures

Pain was measured using a Numerical Rating Scale (NRS). The 11-point NRS is 0–10 verbal scale that measures participants' self-reported experience of pain intensity (NRS-I) or pain unpleasantness (NRS-U). The NRS-I ranges from 0 = "no pain at all" to 10 = "worst possible pain". The NRS-U ranges from 0 = "not at all unpleasant/horrible/yucky") to 10 = "most unpleasant/horrible/yucky". The NRS has very good to excellent psychometric properties, including at least adequate reliability, construct validity, and sensitivity to change over time in youth (7–18 years) with acute postoperative pain after a variety of surgical procedures [19,20].

Pain thresholds were measured using Pressure Algometry. A Pressure Algometer (Baseline® Dolorimeter, Model PR0379 and PR0376, Algeos Ltd., Liverpool, UK) was used to obtain pressure thresholds. The algometer is a hand-held device with a 1.5 cm rubber tip attached to a spring-loaded gauge that displays the force applied in kg/sq cm. The algometer was applied a rate of ~0.5 kg/s to a point on the skin over muscle. Pressure pain threshold (PPT) was defined as the applied force (pressure/unit area) corresponding to when the participant first reported pain after which they rated the intensity of the pain using an 0–10 NRS. Baseline PPTs were obtained before surgery (at the pre-admission visit), at the proposed incision site (or sites) and at control sites on the left and right forearm (anterior aspect midway between the elbow and wrist). Pressure algometry has been used and validated in children with orthopedic conditions [21].

Pain acceptance was measured using the following self-report instruments: the Chronic Pain Acceptance Questionnaire-Adolescents (CPAQ-A) and the Child Self-Efficacy Scale-Child Version (CSES-C). The CPAQ-A [22] is a 20-item scale that measures an adolescent's acceptance of chronic pain. The internal consistency for the activity engagement subscale has been shown to be good ($\alpha = 0.86$) and also adequate for pain willingness ($\alpha = 0.75$) [22]. Internal consistency for the present study was very good at T0 ($\alpha = 0.88$). The CSEC-C [23] is a 7-item measure of a child's belief that they can engage in specific activities, such as going to school, taking care of him/herself, and participating in activities with family or

friends, without assistance. The CSES-C has good internal consistency ($\alpha = 0.80$ to 0.83) [23]. Internal consistency for the present study was very good at T0 ($\alpha = 0.88$).

Pain-related anxiety and worry was measured using the following self-report instruments: the Pain Catastrophizing Scale—Children (PCS-C [24]), the Child Pain Anxiety Symptoms Scale (CPASS), and the Tampa Scale for Kinesiophobia (TSK-13). The PCS-C is a child and adolescent version of the 13-item PCS [25]. The PCS-C measures catastrophic thinking about pain, including unrealistic thoughts that the worst possible outcome will arise, negative thoughts about the self and future, and "an exaggerated negative 'mental set' brought to bear during actual or anticipated pain experience" (p. 53, [26]). PCS-C internal consistency ($\alpha = 0.90$) is excellent, and it shows moderate correlations with pain intensity ($r = 0.49$) and pain disability ($r = 0.50$) [24]. T0 PCS-P internal consistency ($\alpha = 0.94$) in the present study was excellent. The 20-item CPASS [27] measures the thoughts, feelings, behaviors, and physical sensations that arise during the experience and expectation of pain. CPASS has excellent internal consistency ($\alpha = 0.89$ to 0.90) and strong construct validity [27–29]. T0 CPASS internal consistency ($\alpha = 0.92$) in the present study was excellent. The 13-item TSK-13 measures fear of movement-evoked pain and injury or re-injury. It has acceptable psychometric properties, including good discriminative and predictive validity and adequate internal consistency [30]. T0 TSK-13 internal consistency ($\alpha = 0.81$) in the present study was good.

General anxiety and worry were measured using the following self-report instruments: Multidimensional Anxiety Scale for Children (MASC-10), the Children's Revised Impact of Event Scale (CRIES; [31,32]), and the Childhood Anxiety Sensitivity Index (CASI). The 10-item MASC-10 [33] is a short version of the 39-item MASC-39. The MASC-10 measures physiological reactions, harm avoidance, and symptoms of social anxiety and separation anxiety. The MASC-10 has excellent internal consistency ($\alpha = 0.89$), strong test-retest reliability ($r = 0.86$), and good convergent and discriminant validity [33,34]. T0 MASC-10 internal consistency ($\alpha = 0.91$) for the current study was excellent at. The 13-item CRIES measures symptoms of posttraumatic stress disorder (PTSD) reported over the past six months. The CRIES has good reliability ($\alpha = 0.80$) [32] and strong validity when screening for PTSD [35]. T0 CRIES internal consistency ($\alpha = 0.91$) for the present study was excellent. The 18-item CASI [36] measures how extensively the symptoms of anxiety (e.g., rapid heart rate, rapid breathing, racing thoughts) evoke fear and beliefs about ensuing harmful somatic, psychological, and social consequences. The CASI has very good internal consistency ($\alpha = 0.87$), adequate test-retest reliability ($r = 0.76$) and satisfactory construct validity [36]. T0 CASI internal consistency ($\alpha = 0.86$) for the present study was very good.

Depressive symptoms were measured using the Center for Epidemiological Studies-Depression Scale for Children (CES-DC). The CES-DC assesses depressive symptoms in children and adolescents, including depressed or low mood, a sense of worthlessness, helplessness, psychomotor retardation (slowed speaking, thinking, movement), as well as sleep and eating problems. The CES-DC has excellent internal consistency ($\alpha = 0.89$) and good convergent validity [37]. Internal consistency for the present study was excellent at T0 ($\alpha = 0.92$).

2.2.3. Parent Risk Factor Measures

Parental pain-related anxiety and worry was measured using the following self-report instruments: the Pain Anxiety Symptoms Scale—Short Form (PASS-20), the Pain Catastrophizing Scale (PCS), and the Pain Catastrophizing Scale—Parents (PCS-P). The 20-item PASS-20 [38] measures the thoughts, feelings, behaviors, and physical sensations that arise during the experience and expectation of pain. Internal consistency ($\alpha = 0.81$) and construct validity for the PASS-20 are good. PASS-20 internal consistency ($\alpha = 0.95$) for the present study was excellent. The 13-item PCS [25] measures catastrophic thinking about pain, including unrealistic thoughts that the worst possible outcome will arise, negative thoughts about the self and future, and "an exaggerated negative 'mental set' brought to bear during actual or anticipated pain experience" (p. 53, [26]). The PCS measures an

individual's catastrophic thinking about their own pain. The PCS has very good internal consistency and validity [39]. The PCS-P [40] is the parent version of the PCS that measures a parent's catastrophic thinking about their child's pain. Construct validity and internal consistency (α = 0.81 to 0.93) [40] of the PCS-P are very good. T0 internal consistency for the PCS (α = 0.94) and PCS-P (0.92) in the present study were excellent.

Parental anxiety and worry were measured with the following self-report instruments: the Anxiety Sensitivity Index (ASI) and the State-Trait Anxiety Inventory-Trait (STAI-T). The ASI [41] measures how extensively the symptoms of anxiety evoke fear and beliefs about ensuing harm. The ASI consists of three subscales: fear of publicly observable anxiety reactions (4 items, e.g., "It embarrasses me when my stomach growls"); fear of cognitive dysfunction (4 items, e.g., "It scares me when I am unable to keep my mind on a task"); and fear of somatic sensations (8 items; e.g., "It scares me when my heart beats rapidly"). The ASI total score has very good internal consistency (α = 0.83) and good convergent and discriminant validity [42]. Internal consistency for the present study was very good at T0 (α = 0.90). The STAI-T [43] is a 20-item scale that measures a wide range of enduring, not state or momentary, symptoms of anxiety. It has been shown to have very good to excellent internal consistency (α = 0.86 to 0.95) and satisfactory test-retest reliability (r = 0.69 to 0.89) [43]. STAI-T construct and concurrent validity are good [44]. Internal consistency for the present study was excellent at T0 (α = 0.92).

Parental symptoms of depression were measured using the Center for Epidemiological Studies-Depression Scale (CES-D). The CES-D [45] is a 20-item scale for adults that measures depressive symptoms, such as depressed or low mood, a sense of worthlessness, helplessness, psychomotor retardation (slowed speaking, thinking, movement), as well as sleep and eating problems. CES-D has shown to have high internal consistency (α = 0.85 to 0.90) and strong construct validity [45]. Internal consistency for the present study was good at T0 (α = 0.80).

Parental psychological flexibility was measured with the Parent Psychological Flexibility Questionnaire (PPFQ). The PPFQ [46] measures the parents' capacity to manage their distress about their child's pain. The PPFQ has excellent internal consistency (α = 0.91) [46]. Internal consistency for the PPFQ at T0 (α = 0.89) in the present study was good.

2.3. *Procedure*

The Research Ethics Board at The Hospital for Sick Children (SickKids) (REB file # 1000019644) and the Human Participants Review Committee at York University (Certificate # 2010-276) reviewed and approved the protocol before recruitment began. A research assistant approached eligible and interested youth and parent dyads after they had been pre-screened by an operating room nurse within in the youths' circle of care and had agreed to hear more about the study. Youth and their parents were recruited into the study by the research assistant either at the pre-operative assessment clinic or, if they did not attend the pre-operative clinic, by telephone. Parents and youth provided written informed consent and assent to participate, respectively.

This prospective, longitudinal study comprised two assessments over a one-year period: pre-operative, and 12 months after surgery. Participants were included in analysis for the present study if they completed both the PPIS and the FDI. We focused on the 12-month post-surgical outcome to evaluate chronic functional limitations.

2.3.1. Pre-Operative Assessment (T0)

The research assistant administered the baseline assessment youth and parent questionnaires and obtained pressure pain thresholds from the participants using pressure algometry. The sequence in which questionnaires were administration was randomized within subjects to reduce the effects of order and fatigue effects. Youth pre-operative medication use was ascertained from the parents and verified by accessing the youths' hospital chart.

2.3.2. 12 (T3) Month Post-Surgical Follow-Up

The research assistant conducted telephone follow-ups with participants 12 months after surgery. Participants completed a package of questionnaires and inventories that measured pain, psychological and emotional functioning, memory for pain, pain medications, chronic postsurgical pain (i.e., pain incidence, intensity, and quality), as well as general and pain-related function limitations. At the 12-month follow-up with the parents, the research assistant read parents, over the telephone, two questionnaires that assessed psychological flexibility and catastrophic thinking about their youth's pain.

2.4. Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 24.0 and R version 3.4.1. Descriptive, correlational, and regression analyses were conducted using two-tailed hypothesis testing ($p < 0.05$). Descriptive statistics, including frequency tables, means, and standard deviations were used to describe sample characteristics. Bivariate relationships between variables were analyzed using Pearson's r. Paired samples t-tests were conducted to compare T0 PPIS to T3 PPIS, and T0 FDI to T3 FDI. We tested for collinearity among variables.

The association between chronic pain status (i.e., T3 presence of chronic post-surgical pain) and T3 FDI was examined through a logistic regression. This approach was repeated for T3 PPIS.

A set of univariate General Linear Models (GLMs) were used to examine the association between risk factors (youth pain intensity, youth pain unpleasantness, youth pain pressure threshold, youth pain-related anxiety and worry, youth non-pain related anxiety and worry, youth depression, youth pain acceptance, and parental pain-related anxiety and worry, parental non-pain related anxiety and worry, parent depression, and parent psychological flexibility) and youth outcome variables at 12 months (PPIS, FDI).

Two sets of identical hierarchical regression analyses were conducted, one predicting 12-month PPIS scores and the other predicting 12-month FDI scores. Each set evaluated three models using the same significant ($p < 0.05$) child and parent risk factors identified from the univariate linear regression analyses. Risk factors were chosen based on statistical significance and theory (i.e., IFAM). Model 1 included an autoregressive term to control for baseline FDI or PPIS, respectively. Since the aim of the study is to determine differential risk factors for functional limitation, not to examine whether one measure of functional limitation predicts another measure of functional limitation, we did not include both measures of functional limitation in each model. Model 2 included Model 1 predictors plus baseline youth factors. Model 3 included Model 2 variables plus baseline parent factors. The overall performance of the multiple regression models was evaluated based on adjusted R^2 and ΔR^2. The order of the models was chosen to evaluate the variance accounted for by youth baseline psychological factors over and above their baseline functioning, as well as the variance accounted for by parent psychological factors over and above the youth variance predicting youth functional limitations 12-months after surgery.

3. Results

3.1. Recruitment and Demographic Information

Recruitment occurred between February 2011 and August 2015. Details about the recruitment procedures have been described in earlier publication [4,47]. Of the 349 children and parents approached, 270 gave their assent and informed written consent to participate, respectively. Three children retracted consent before the start of the study procedures and did not participate in any way, one patient no longer met the study criteria after the surgical team changed the surgical procedure, and 27 children could not be found (i.e., the research assistant was unable to locate or reach them) for their T0 assessment. One participant was withdrawn from the study after informed consent had been obtained because they received a cancer diagnosis. Two hundred and sixty-four (264) participants successfully finished at least one part of the hospital-based assessment (T1) (e.g., completed questionnaires, wore

the Actical physical movement monitor, provided daily measures of pain). Twenty-seven (27) participants were admitted to the intensive care unit (ICU) directly from the operating room (i.e., they bypassed the PACU) and consequently daily pain measures were not obtained, nor was the Actical device secured on the participants' wrist until they had been moved out of the ICU to a surgical floor. More than 80% (81.1% and 85.3%) of participants were successfully followed up at the 6- and 12-month assessments, respectively.

The PPIS was included in the study questionnaire package in 2013. A total of 79 patients completed the PPIS before surgery and after surgery. Therefore, the analysis for this study was conducted on this subsample of patients who completed the PPIS. The sample comprised 79 children [46 female (58.22%), *M* age = 14.56 years (SD = 2.31), range 9–18 years] and their parents/guardians [61 female (84.72%), M age = 45.82 years (SD = 6.76), range 30–70 years, 7 parents did not respond to the demographic questionnaire items]. Half of the children had moderate-to-severe pain prior to surgery (n = 40, 50.63%). Fewer than 33%of parents had ongoing pain issues before their child's surgery (n = 21, 28%). Just under 50% of children had surgery for scoliosis (n = 39, 49.37%) and 41.77% (n = 33) had an osteotomy. Five children (6.33%) had a Ravitch sternotomy procedure for correction of pectus excavatum and two (2.53%) had another type of surgery. The mean duration of surgery was 4.76 h (SD = 1.95 h, range = 1.03–9.25 h) and children remained hospitalized for an average of 4.77 days (SD = 2.08, range 1–11 days). Twenty-four percent (n = 19) of youth had regional anesthesia for their surgery. Detailed demographic and Actical results for the sample are published in Rosenbloom et al. [4].

3.2. Relationship between PPIS and FDI

The FDI and the PPIS were significantly correlated before surgery (r = 0.698, $p < 0.001$) and 12 months after surgery (r = 0.807, $p < 0.001$). The mean score of the PPIS before surgery was significantly higher (M = 16.18, SD = 9.95) than 12 months after surgery (M = 11.65, SD = 8.30), $t(57)$ = 2.564, p = 0.013. Maximum score on the PPIS is 32. In contrast, the mean score of the FDI before surgery (M = 13.80, SD = 12.24) was not significantly different than the mean FDI score 12 months after surgery (M = 12.81, SD = 11.19), $t(70)$ = 0.665, p = 0.508. Maximum score on the FDI is 60.

The 12-month FDI was significantly associated with 12-month pain status (OR = 1.051, 95% CI 1.003, 1.102), in that every unit increase on the FDI was associated with increased odds that the youth had moderate to severe pain. The 12-month PPIS was significantly associated with 12-month pain status (OR = 1.066, 95% CI 1.018, 1.115), in that every unit increase on the PPIS was associated with a greater odds of the youth having moderate to severe pain.

3.3. Risk Factors for 12-Month PPIS and FDI

There was a high degree of collinearity (VIF > 4) between the youth MASC-10, CRIES, CASI, PCS, CPASS, and CSESC. To address this, we performed an Exploratory Factor Analysis on the child variables in R Version 3.4.1 [48] using the packages "car" [49], "GPArotation" [50], and "psych" [51]. Using ordinary least squares (OLS) to find the minimum residual (minres) solution, the number of factors for the child variables were evaluated. The number of factors was determined by an examination of a parallel analysis. The analysis revealed a two-factor model fit the data best, with all factor loadings >0.4 and cross-loadings <0.4. The factor loadings showed that Factor 1 (pain-related psychological factor) consisted of the PCS, CPASS, and CSESC and that Factor 2 (general psychological factor) consisted of the CASI, MASC-10, and CRIES. These factors were used in the linear regression analyses.

To determine significant risk factors for 12-month PPIS and FDI, univariate regression analyses were undertaken (Table 1). Significant baseline factors associated with 12-month PPIS included: youth pain at rest, youth TSK-13, youth pain-related psychological factor, youth general psychological factor, and youth FDI. Significant factors associated with

12-month FDI included: youth pain-related psychological factor, youth TSK-13, parent ASI, parent STAI-T, parent PASS, youth FDI, and youth PPIS.

We separately examined three identical models for each outcome variable. Model 1 predictors included baseline youth FDI or youth PPIS aligned with 12-month FDI or 12-month PPIS as dependent variables, respectively. Model 2 predictors included Model 1 variables as well as youth pain-related anxiety and worry factor and youth general psychological factor. Model 3 predictors included Model 2 variables as well as parent ASI, parent PASS, and parent STAI-T. The results from the hierarchical regression models for the FDI and PPIS are shown in Tables 2 and 3, respectively.

Prediction of 12-month youth FDI: Pre-surgical youth FDI significantly predicted 12 month FDI (Model 1), $F(1, 61) = 14.937$, $p < 0.001$, $R^2 = 0.184$. The addition of the two youth factors to Model 2, $F(3, 59) = 5.194$, $p = 0.003$, $R^2 = 0.169$, did not add a significant proportion of variance to the prediction model, $\Delta R^2 = 0.012$, $p < 0.636$. However, the addition of pre-surgical parent variables, in Model 3, explained an additional 11.4% ($\Delta R^2 = 0.114$, $p = 0.033$) of the variance in 12-month FDI scores, $F(6, 56) = 4.443$, $p = 0.001$, $R^2 = 0.250$. Thus, for Model 3, every unit (standard deviation) increase in pre-surgical youth FDI was associated with a 0.372 unit increase in their child's functional disability 12 months after surgery. And every unit (standard deviation) increase in pre-surgical parent ASI was associated with a 0.373 unit increase in their child's functional disability 12 months after surgery. None of the other risk factors significantly predicted 12-month FDI.

Table 1. Standardized regression coefficients (β) from univariate regression analyses predicting 12-month functional disability (FDI) and pain-related interference (PPIS) from pre-surgical parent and youth risk factors.

	Variable	12-Month Youth FDI β	12-Month Youth PPIS β
YOUTH	Age	−0.050	0.125
	Sex	0.182	0.085
	Pressure algometer	−0.160	−0.061
	NRS pain (rest)	0.175	0.254 *
	NRS pain unpleasantness	0.101	0.018
	TSK-13	0.237 *	0.323 **
	Pain-related anxiety and worry	0.279 *	0.301 *
	General anxiety and worry	0.173	0.320 **
	CES-DC	0.122	0.167
	CPAQ	−0.139	−0.090
	FDI	0.424 ***	0.331 **
	PPIS	0.330 **	0.131
PARENT	Chronic Pain	0.064	0.189
	PCS- about child pain	0.175	0.109
	PCS- about own pain	0.205	0.021
	CES-D	0.227	0.153
	ASI	0.313 **	0.146
	PASS	0.283 *	0.077
	STAI-T	0.237 *	0.199
	PPFQ	0.092	0.093

NRS, Numeric Rating Scale; TSK-13, 13-item Tampa Scale for Kinesiophobia; CES-DC; Center for Epidemiological Studies—Depression Scale for Children; CPAQ, Chronic Pain Acceptance Questionnaire—Adolescents; PPIS, PROMIS—Pediatric Pain Interference Scale; FDI, Functional Disability Index; PCS, Pain Catastrophizing Scale; CES-D, Center for Epidemiological Studies—Depression Scale; ASI, Anxiety Sensitivity Index; PASS-20, Pain Anxiety Symptoms Scale; STAI-T, State-Trait Anxiety Inventory-Trait; PPFQ, Parent Psychological Flexibility Questionnaire. Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 2. Standardized regression coefficients (β) from multivariable regression analyses predicting 12-month youth FDI from youth and parent pre-surgical risk factors.

	Adjusted R^2	ΔR2	Pre-Surgical Variable	12-Month Youth FDI β
Model 1	0.18			
			Youth FDI	0.444 ***
Model 2	0.17	0.01		
			Youth FDI	0.382 **
			Youth pain-related anxiety and worry factor	0.117
			Youth General anxiety and worry factor	0.042
Model 3	0.25	0.11 *		
			Youth FDI	0.372 **
			Youth pain-related anxiety and worry factor	0.001
			Youth General anxiety and worry factor	−0.059
			Parent ASI	0.373 *
			Parent STAIT	0.159
			Parent PASS	−0.109

FDI, Functional Disability Index; ASI, Anxiety Sensitivity Index; PASS-20, Pain Anxiety Symptoms Scale; STAI-T, State-Trait Anxiety Inventory-Trait. Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 3. Standardized regression coefficients (β) from multivariable regression analyses predicting 12-month youth PPIS from youth and parent pre-surgical risk factors.

	Adjusted R^2	ΔR^2	Pre-Surgical Variable	12-Month Youth PPIS β
Model 1	−0.01			
			Youth PPIS	0.089
Model 2	0.15	0.19 **		
			Youth PPIS	−0.181
			Youth pain-related anxiety and worry factor	0.325 *
			Youth general anxiety and worry factor	0.337 **
Model 3	0.27	0.16 *		
			Youth PPIS	−0.244
			Youth pain-related anxiety and worry factor	0.448 *
			Youth General anxiety and worry factor	0.221
			Parent ASI	0.401 *
			Parent STAIT	0.403 *
			Parent PASS	−0.617 **

PROMIS—Pediatric Pain Interference Scale; ASI, Anxiety Sensitivity Index; PASS-20, Pain Anxiety Symptoms Scale; STAI-T, State-Trait Anxiety Inventory-Trait. Note: * $p < 0.05$; ** $p < 0.01$.

Prediction of 12-month youth PPIS: Pre-surgical youth PPIS did not significantly predict 12-month PPIS (Model 1), $F(1, 50) = 0.397$, $p = 0.531$, $R^2 = -0.012$. Model 2, including the two youth factors, significantly predicted 12-month PPIS $F(3, 48) = 3.902$, $p = 0.014$, $R^2 = 0.146$. Youth pre-surgical pain-related anxiety and worry factor was significantly associated with 12-month youth PPIS, such that every unit (standard deviation) increase in the factor there was an associated 0.448 increase in 12-month PPIS. Finally, the addition of pre-surgical parent factors to Model 3 explained an additional 15.8% of the variance, $p = 0.019$, in 12-month PPIS scores, $F(6, 45) = 4.104$, $p = 0.002$, $R^2 = 0.267$. Thus, for Model 3, every unit (standard deviation) increase in pre-surgical parent ASI was associated with a 0.401 unit increase in their child's pain-related interference 12 months after surgery. Similarly, every unit (standard deviation) increase in pre-surgical parent STAIT was associated with a 0.403 unit increase in their child's pain-related interference 12 months after surgery. And for every unit (standard deviation) increase in parent pre-surgical PASS-20 there was a 0.617 decrease in their child's pain-related disability at 12-months post-surgery.

4. Discussion

The present study evaluated differential baseline risk factors in the development of general versus pain-specific functional limitations 12 months after major pediatric surgery. The results show that although the FDI and PPIS are highly correlated, and the strength of their inter-relationship increases over time, the risk factors for general versus pain-specific functional limitations differ. Specifically, 12-month FDI is predicted by pre-surgical child FDI and parent anxiety sensitivity whereas PPIS is predicted by a combination of presurgical youth (pain-related anxiety and worry factor) and parent factors (anxiety sensitivity, state-trait anxiety, pain anxiety). In line with our hypothesis, hierarchical regression analysis showed that the addition of parent factors to Model 3 was significant in predicting both the PPIS and FDI; qualitatively more so for the PPIS than the FDI in that whereas both functional limitation measures were predicted by parent ASI, the PPIS was also predicted by parent trait anxiety and pain-related anxiety.

Increasingly, chronic pain and associated disability among youth has been identified as family issues [10,52] associated with intergenerational transmission [52]. The results of the present study support this suggestion showing that general and pain-specific functional limitations associated with 12-month pediatric CPSP are predicted by parental factors measured preoperatively, one year earlier. Until recently, many studies have focused on parent chronic pain as a risk factor for youth pain interference [52,53]. However, the present results did not confirm the links between the presence of parent chronic pain and youth post-operative pain-related functional limitations or general functional limitations. This is perhaps due, in part, to the nature of the chronic pain (i.e., general chronic pain (e.g., arthritis, headaches) pain versus CPSP). Instead, the present results indicate that parental pre-surgical anxiety (both pain- and non-pain related) are important in the development of youth functional limitations one year after surgery.

The identification of parental anxiety sensitivity as a significant predictor of both youth 12-month pain-related functional limitations (PPIS) and general functional limitations (FDI) is a novel finding. The results suggest that parents' with higher levels of anxiety sensitivity may shape the development of their youth's functional limitations over the first year after surgery. The adult literature proposes that anxiety sensitivity amplifies fear, anxiety, and subsequently increases the likelihood to engage in avoidance or escape behaviors (e.g., limit movement) in response to pain [54,55]. We propose that parents with elevated levels of anxiety sensitivity may be on high alert for signs of pain or anxious distress in their offspring. In high anxiety sensitive parents, the ensuing anxiety triggers alarm and so they search for ways to avoid or escape from their own anxiety by removing the cause of their anxiety and encourage avoidance behaviors in their offspring (e.g., encouraging their child to functionally limit their behaviors and activities).

Pre-operative child functional disability was the only child factor that predicted 12-month post-surgical general functional limitations (FDI). In contrast, pre-surgical pain-related functional limitations did not predict 12-month pain-related functional limitation (PPIS). It is not surprising that the best predictor of functional disability 12-months after surgery was pre-operative functional disability; what is surprising is the lack of a relationship between pre-surgical PPIS scores and 12-month PPIS scores. The discrepancy in predictors for the two outcome measures may be related to the general versus pain-specific nature of the FDI and PPIS, respectively. It is possible that since most youth had not previously experienced pain as intense as that arising from surgery the youths' baseline level of pain-related interference changed as a function of exposure to the intense acute postsurgical pain experience, so that by the 12-month post-surgical assessment, their pre-surgical scores no longer accurately reflected their pain experiences, thereby explaining the lack of a relationship between pre- and post-surgical PPIS scores.

Catastrophic thinking about pain is an important factor in the adult and pediatric chronic pain literature. Both child and parent pain catastrophizing have been shown to have correlations with child chronic pain functional outcomes [24,40,56–58]. Among children and adolescents with chronic pain, the extant literature supports the idea that parent

catastrophic thinking about (their own) pain predicts child functional limitation through their child's catastrophic thinking about pain [59] or adolescent psychosocial responses to pain [60]. Due to the multicollinearity between youth pre-operative measures of pain catastrophizing, pain anxiety and self-efficacy, the individual effects of each measure were not examined on 12-month functional limitations. Given that the pain-related anxiety and worry construct did significantly contribute to 12-month PPIS, it is possible that youth pain catastrophizing played a role in this outcome, but not 12-month FDI. We did not find that pre-surgical parent pain catastrophizing predicted 12-month outcomes and thus our results suggest that parent pre-operative pain catastrophizing is not a significant risk factor involved in functional limitations associated with the transition from acute to chronic pain in youth undergoing surgery. This, again, may be related to the timing of measurement of pain catastrophizing relative to surgery, a point we raised [61] regarding a similarly designed study by Rabbitts et al. who also did not find that pre-operative child catastrophic thinking about pain predicted pain outcomes after surgery [62]. As with pre-surgical PPIS scores which did not predict 12-month PPIS scores, we argue that the child's baseline level of catastrophic thinking about pain may have changed after exposure to the intense acute postsurgical pain, so that by postoperative assessment, the youths' preoperative pain catastrophizing scores no longer accurately reflected their pain experiences. The issue of changing baselines is critical to accurate prediction and could be better studied and understood using qualitative designs to get at the psychosocial mechanisms involved in this process.

Resilience factors for both parent and youth, such as pain acceptance and self-efficacy, also were not significant predictors of either 12-month FDI or PPIS in our study. There are no known studies examining these factors in pediatric surgical samples. Compared to the pediatric chronic pain literature, our results are contrary to Feinstein et al., who studied a sample of pediatric patients with chronic pain (e.g., musculosketal pain, abdominal pain, headache, complex regional pain syndrome) and found that parent pain acceptance was associated with pain interference through child pain acceptance [63]. Several factors that make it difficult to compare the results of the two studies. For example, Feinstein et al. conducted a cross-sectional study of children at the initial visit to a chronic pain clinic. Children reported chronic pain of approximately 30 months' duration and various etiologies. In contrast, the present sample of youth with chronic postsurgical pain was followed prospectively for up to one year. Thus, it possible that differences in the etiology and duration of the pain, as well as in the design and clinical setting may in part be responsible for the difference between the two studies in resilience factor outcomes.

In addition to youth pre-surgical functioning, the results from this study show that it is critically important to consider parental risk factors critical in the development of youth post-surgical general and pain-related function limitations one year after surgery. Parental anxiety and anxiety sensitivity are potentially modifiable variables through, for example, Acceptance and Commitment Therapy (ACT) [64,65] or Cognitive-Behavioural Therapy (CBT) [66]. Through ACT, it is possible that parents can learn to think more flexibly about pain and accept what they struggle to control regarding their youth's pain, and as a result their youth's functional limitation outcome could shift positively. It has been shown that caregivers who endorse greater pain acceptance engage in less catastrophic thinking [67], which indirectly may increase functioning [68]. Further it is possible through directly treating anxiety sensitivity using a 1-session CBT approach [66], parents will learn to cope with their own anxiety sensitivity, which would in turn help them coach their children on how to manage pain.

Study strengths include the prospective methodology used to examine the risk factors for the transition from acute to chronic post-surgical pain and related functional limitations versus pain-specific functional limitations. This study showed that there are different risk factors associated with general versus pain-specific functional limitations and therefore researchers should thoughtfully consider whether they are mainly studying general or pain-specific functional limitations.

There are several limitations to note. First, the sample size was relatively small, limiting potential generalization. Hence, replication in a larger sample is warranted. Likewise, more sophisticated statistical analyses, such as structural equation modeling, could not be performed to examine indirect relationships between parent anxiety and anxiety sensitivity and child pain interference outcomes. Second, this is a secondary analysis, which raises two potential issues: a priori sample size calculations were not conducted for this outcome and therefore there is the possibility of a high risk of bias. Third, it is possible that potentially confounding variables for these secondary analyses were not measured. The analyses indicated that 25% of the variance for the FDI was explained by the model factors leaving 75% unexplained. Similarly, the analyses indicated that 26.7% of the variance for the PPIS was explained by the model factors, leaving 73.3% unexplained. Although we do not know what factors make up the unexplained variance in each set of analyses, future studies should consider evaluating parent factors such as solicitousness and pain resilience, and child factors such as psychological flexibility.

5. Conclusions

In conclusion, although the FDI and the PPIS are highly correlated and used widely in the literature, they represent different constructs and are predicted by slightly different risk factors in the transition from acute to chronic pain and related disability. This underscores the need for researchers and clinicians to carefully consider the construct of interest when choosing a measure. In terms of youth factors, pre-operative youth general functional limitation uniquely predicts post-surgical general functional limitation. Additionally, pain-related anxiety and worry and general psychological anxiety and stress predict 12-month pain-related functional limitation. In terms of parental involvement in the development of disability, we provide support for the inclusion of parental risk factors in studying the transition from acute to chronic pain and identify parental pre-operative anxiety and anxiety sensitivity as significant risk factors. These results suggest that parent anxiety plays a role in intergenerational processes in the development of pain-related interference and general functional disability after surgery and is therefore an area for assessment and intervention in future research.

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Chapter 4: Fear Of Movement In Children And Adolescents Undergoing Surgery: A Psychometric Evaluation Of The Tampa Scale For Kinesiophobia

The aim of Study 2 (Chapter 3) was to compare the risk factors for pain-related functional limitations to those for general functional limitations. Study 2 used a subsample from Study 1 (Chapter 2) that consisted of 79 dyads of youth undergoing major surgery and their parents. The results of Study 2 revealed that while the PROMIS Pediatric Pain Interference Scale (PPIS) and Functional Disability Inventory (FDI) are highly correlated both before surgery and 12 months after surgery, they have slightly different risk factor profiles. The PPIS was predicted by a combination of presurgical youth (pain-related anxiety and worry factor) and parent factors (anxiety sensitivity, state-trait anxiety, pain anxiety), whereas the FDI was predicted by youth FDI and parent anxiety sensitivity.

Interestingly, the Tampa Scale for Kinesiophobia (TSK) was not a significant predictor of post-surgical functional limitations in the multivariate models of Study 1 or Study 2. The TSK measures kinesiophobia, or the "excessive irrational, and debilitating fear of physical movement and activity resulting from feeling a vulnerability to painful injury or re-injury" (Kori et al., 1990). The findings from Study 1 and 2 beg the question of whether kinesiophobia plays a role in perioperative pain among youth or whether the construct is currently limited by the original measure used in each of the studies. The TSK was designed for adults with chronic pain (Kori et al, 1990) and was proposed to predict the development of pain-related functional limitations or disability (Vlaeyen et al, 1995). It is possible that kinesiophobia is involved in post-surgical functioning. To better understand this potential risk factor, the goal of Study 3 (Chapter 4) was to evaluate the psychometric properties of the TSK among youth undergoing major surgery.

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ORIGINAL ARTICLE

Fear of movement in children and adolescents undergoing major surgery: A psychometric evaluation of the Tampa Scale for Kinesiophobia

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Abstract

Background: The objective of this study was to evaluate the psychometric properties of the 17-item Tampa Scale for Kinesiophobia (TSK) in youth.

Methods: Participants were 264 children and adolescents (58.7% female, M_{age} = 14.1 years, SD_{age} = 2.51) scheduled for major surgery who were assessed before surgery, while in hospital postoperatively, and at 6 and 12 months after surgery. Exploratory factor analyses (EFA) were conducted to determine the factor structure of pre-operative TSK scores. Reliability, and convergent, discriminant, and predictive validity were examined.

Results: EFA on the 17-item TSK revealed a two-factor model distinguishing the 13 positively scored items from the 4 reverse scored items, but the fit was poor. A second EFA was conducted on the 13 positively scored items (TSK-13) revealing a three-factor model: Fear of injury, bodily vulnerability, and activity avoidance. The TSK-13 showed adequate internal consistency ($\Omega = 0.82$) and weak convergent validity. The TSK-13 was not correlated with postoperative, in-hospital physical activity (actigraphy; $r\,(179) = -0.10$, $p = 0.18$) and showed adequate discriminant validity, that is correlations less than 0.70, with measures of depression ($r\,(225) = 0.41$, $p < 0.001$) and general anxiety ($r\,(224)$=0.35, $p < 0.001$). Predictive validity for pain-related disability at 12 months ($r\,(70) = 0.34$, $p < 0.001$) was adequate.

Conclusions: The original TSK-17 does not appear to be a meaningful measure of kinesiophobia in youth after surgery possibly because of the syntactic structure of the reverse scored items. In contrast, a modified TSK-13, comprised of only the positively scored items, revealed a 3-factor structure that is reliable and demonstrates adequate convergent, discriminant, and predictive validity.

Significance: Kinesiophobia is an important construct to evaluate in the transition from acute to chronic pain among children and adolescents. The 17 item Tampa Scale for Kinesiophobia (TSK) does not show adequate validity or reliability in youth undergoing major surgery, however, the psychometric properties of a 13-item modified scale (TSK-13) are promising.

1 | INTRODUCTION

Chronic post-surgical pain and disability are surgical complications reported by 11%–54% of children and adolescents after major surgery (Chidambaran et al., 2017; Landman, Oswald, Sanders, Diab, & Spinal Deformity Study, 2011; Rosenbloom et al., 2019; Sieberg et al., 2013). In adults, fear of pain is one of the most prominent predictors of chronic pain and pain-related disability (Keefe, Rumble, Scipio, Giordana, & Perri, 2004; Vlaeyen & Linton, 2000), and, more specifically, fear of physical performance and perceived disability (Al-Obaidi, Nelson, Al-Awadhi, & Al-Shuwaie, 2000; Asmundson, Norton, & Allendings, 1997; Verbunt, Seelen, Vlaeyen, van der Heijden, & Knottnerus, 2003; Vlaeyen, Kole-Snijders, Boeren, & van Eek, 1995). The relationship between pain and disability may be explained more thoroughly by the cognitive-behavioural fear-avoidance model of chronic pain (Vlaeyen et al., 1995; Vlaeyen & Linton, 2000). This model proposes that after injury, one either confronts the pain and recovers, or because of a fear of pain becomes disabled through a pathway involving pain catastrophizing and avoidance.

Asmundson and colleagues (2012) proposed the Pediatric Fear-Avoidance Model of Chronic Pain and recommended use of the Fear of Pain Questionnaire (FOPQ) (Simons, Sieberg, Carpino, Logan, & Berde, 2011), which evaluates kinesiophobia, to empirically test the model (Asmundson et al., 2012). Kinesiophobia is defined as "an excessive irrational, and debilitating fear of physical movement and activity resulting from a feeling of vulnerability to painful injury or re-injury" (Kori, Miller, & Todd, 1990) that is proposed to predict the development of pain-related disability (Vlaeyen et al., 1995). The FOPQ was developed using adult measures (i.e. Tampa Scale for Kinesiophobia (Kori et al., 1990)), Psychological Inflexibility in Pain Scale, Fear Avoidance Beliefs Questionnaire, Pain Anxiety Symptoms Scale-20).

The TSK rarely has been used in pediatric settings. Wicksell et al (Wicksell, Melin, Lekander, & Olsson, 2009) found a significant decrease in TSK scores, measured by a Swedish version, as well as improvements in quality of life following an Acceptance and Commitment Therapy intervention for children with chronic pain. More recently, Ye, Plante, Roy, Ouellet, and Ferland (2020) conducted a principle components analysis and confirmatory factor analysis on the TSK in 55 adolescents undergoing spinal fusion surgery. After excluding four items, the authors report that only the Activity Avoidance subscale of the TSK revealed good psychometric properties (Ye et al., 2020). This finding is not consistent with factor analytic studies conducted in adults showing psychometric soundness for two factors (Goubert et al., 2004; Heuts et al., 2004; Swinkels-Meewisse, Swinkels, Verbeek, Vlaeyen, & Oostendorp, 2003). Moreover, the authors did not examine the convergent, discriminative, or predictive validity of the TSK.

The aim of this study was to evaluate the psychometric properties of the TSK in children and adolescents undergoing major surgery. To achieve this aim, we (a) conducted an exploratory factor analysis (EFA) to determine the factor structure of the TSK, (b) evaluated the convergent and discriminant validity of the TSK, and (c) assessed its predictive validity by examining the relationship between the TSK and chronic pain and pain-related disability 12 months after surgery.

2 | METHOD

The present article reports results from a larger study examining the development of chronic post-surgical pain in youth. Complete methods and measures have been reported in Rosenbloom et al. (2019).

2.1 | Participants

Children/adolescents were eligible to participate if they were aged 8–17 years and scheduled for orthopaedic surgery (i.e. osteotomy, plate insertion tibial/femur, surgery for scoliosis) or general surgery (i.e. thoracotomy, thoracoabdominal surgery, Nuss/Ravitch pectus repair, sternotomy, laparotomy, laparoscopic-assisted; colectomy, ileostomy, J-pouches). One of the child's parents/guardians was also invited to participate. Children were excluded if (1) they had a documented developmental or cognitive delay, (2) they had a diagnosis of cancer, (3) they did not speak or read English, or (4) their parent or guardian did not speak or read English.

2.2 | Measures

2.2.1 | Primary questionnaire

Tampa scale for kinesiophobia

The TSK (Kori et al., 1990) is a 17-item scale designed for use in adults to measure fear of movement-evoked pain and injury (Table 1). Items are scored on a 4-point Likert scale as follows: 1 = strongly disagree; 2 = disagree; 3 = agree; 4 = strongly agree. It contains 13 positively scored items for which endorsing *strong agreement* is associated with the highest Likert scale score (4), and 4 reverse scored items (#4, #8, #12, #16), spread out evenly throughout the scale, for which endorsing *strong disagreement* is associated with the highest score (4) after reverse scoring. Total scores range from 17 to 68 with higher scores indicative of greater fear of movement. The TSK has been shown to

TABLE 1 Items from the Tampa Scale for Kinesiophobia. Items from Kori et al. (1990)

1. I'm afraid that I might injury myself if I exercise
2. If I were to try to overcome it, my pain would increase
3. My body is telling me I have something dangerously wrong
4. * My pain would probably be relieved if I were to exercise
5. People aren't taking my medical condition seriously enough
6. My accident has put my body at risk for the rest of my life
7. Pain always means I have injured my body
8. * Just because something aggravates my pain does not mean it is dangerous
9. I am afraid that I might injure myself accidentally
10. Simply being careful that I do not make any unnecessary movements is the safest thing I can do to prevent my pain from worsening
11. I wouldn't have this much pain if there weren't something potentially dangerous going on in my body
12. * Although my condition is painful, I would be better off if I were physically active
13. Pain lets me know when to stop exercising so that I don't injure myself
14. It's really not safe for a person with a condition like mine to be physically active
15. I can't do all the things normal people do because it's too easy for me to get injured
16. * Even though something is causing me a lot of pain, I don't think it's actually dangerous
17. No one should have to exercise when he/she is in pain

*Reversed scored items.

have good internal consistency with Cronbach alpha's ranging from 0.68 to 0.86 (Swinkels-Meewisse et al., 2003; Vlaeyen et al., 1995). The TSK has demonstrated good test-retest reliability (Swinkels-Meewisse et al., 2003). Some studies favour a two-factor model of the TSK (Clark, Kori, & Brockel, 1996; French, France, Vigneau, French, & Evans, 2007; Goubert et al., 2004), however, others have shown one and three factor models (Roelofs, Goubert, Peters, Vlaeyen, & Crombez, 2004). Some factor analytic studies show that the reverse scored items do not load well onto any factor (Clark et al., 1996; Goubert et al., 2004; Swinkels-Meewisse et al., 2003).

2.2.2 | Convergent validity measures

The numerical rating scale

The NRS is an 11-point verbally administered scale that measures the subjective experience of pain intensity (I) or pain unpleasantness (U). The NRS-I ranged from 0 (no pain at all) to 10 (worst possible pain). The NRS-U ranged from 0 (not at all unpleasant/horrible/yucky) to 10 (most unpleasant/horrible/yucky). The NRS has excellent reliability and validity, and has been validated for acute postsurgical pain in children ages 7–17 years (Pagé et al., 2012; Von Baeyer et al., 2009).

Child pain anxiety symptoms scale

The CPASS (Pagé, Fuss, Martin, Escobar, & Katz, 2010) is a 20-item scale that measures the fear and anxiety-related thoughts, feelings, behaviors, and physical sensations that accompany the experience and anticipation of pain. Each item is rated on a scale of 0 (never) to 5 (always) and overall scores range from 0 to 100 with higher scores indicative of greater pain-related anxiety. CPASS has excellent internal consistency (α = 0.89–0.90) and strong construct validity (Pagé et al., 2011). Internal consistency for the present study was excellent at T0 ($\alpha = 0.92$), T1 ($\alpha = 0.94$), T2 ($\alpha = 0.93$), and T3 ($\alpha = 0.93$).

Pain catastrophizing scale-children (PCS-C (Crombez et al., 2003))

The PCS-C is a child version of the PCS (Sullivan, Bishop, & Pivik, 1995) that measures the thoughts and feelings children may experience when they are in pain. Each of the 13 items is rated on a 5-point scale ranging from not at all (0) to all the time (4) with the total scores ranging from 0 to 52 with higher scores indicative of greater pain catastrophizing. The PCS-C yields a total score and three subscale scores assessing (1) rumination, (2) magnification, and (3) helplessness. The PCS-C has excellent internal consistency ($\alpha = 0.90$) and strongly correlates with pain intensity (r = 0.49) and disability (r = 0.50) (Crombez et al., 2003). Internal consistency for the present study was excellent at T0 ($\alpha = 0.94$), T1 ($\alpha = 0.94$), T2 ($\alpha = 0.93$), and T3 ($\alpha = 0.93$).

Actigraphy

The Actical movement monitor (Respironics, Inc.) is a small, non-invasive, wristwatch-sized device that contains an omnidirectional accelerometer designed to measure physical activity and caloric expenditure on a continuous basis. The movement monitor provides an objective, quantifiable measure of physical movement and has been used in past studies of children in a post-surgical hospital setting (Kudchadkar et al., 2019; Puyau, Adolph, Vohra, Zakeri, & Butte, 2004). The movement monitor was placed on the child's wrist when they arrived in the post-operative care unit after surgery and left in place until they were discharged. The physical activity monitor was placed on the wrist opposite the hand accessed for the intravenous line. The Actical has a sampling frequency of 32 Hz. Data were downloaded in epochs of 30 s. Total daily (24 hr) movement counts were computed daily starting at 00:00 on the day after surgery until 23:59 the day before hospital discharge.

2.2.3 | Discriminant validity measures

Childhood anxiety sensitivity index

The CASI (Silverman, Fleisig, Rabian, & Peterson, 1991) is an 18-item scale that measures the extent to which the symptoms of anxiety (e.g. increased heart rate, shortness of breath, racing thoughts) are feared due to the belief that they will have harmful somatic, psychological, and/or social consequences. Each item is rated on a scale of 1 (none) to 3 (a lot). Total scores range from 18 to 54 with higher scores indicative of greater anxiety sensitivity. The CASI has good internal consistency ($\alpha = 0.87$), satisfactory test-retest reliability ($r = 0.76$) and acceptable construct validity (Silverman et al., 1991). Internal consistency for the present study was very good at T0 ($\alpha = 0.86$), T1 ($\alpha = 0.87$), T2 ($\alpha = 0.85$) and T3 ($\alpha = 0.86$).

Children's Revised Impact of Event Scale (CRIES; Horowitz, Wilner, & Alvarez, 1979; Smith, Perrin, Dyregrov, & Yule, 2003*)* The CRIES is a 13-item scale that measures posttraumatic stress disorder (PTSD) symptoms in the previous six months. Each item is rated based on its frequency of occurrence on a 4-point scale, from 0 (none), 1 (rarely), 3 (sometimes) to 5 (a lot), with total scores ranging from 0 to 65. A score of 30 or higher indicates a very likely presence of PTSD. The CRIES has good reliability ($\alpha = 0.80$) (Smith et al., 2003) and high validity as a screening measure for PTSD (Perrin, Meiser-Stedman, & Smith, 2005). Internal consistency for the present study was excellent at T0 ($\alpha = 0.91$), and good at T1 ($\alpha = 0.88$), T2 ($\alpha = 0.88$) and T3 ($\alpha = 0.89$).

Multidimensional anxiety scale for children (MASC-10, and −39)

The MASC-10 (March & Sullivan, 1999) is a 10-item, shortened version of the 39-item MASC-39. Both versions measure self-reported physiological responses, harm avoidance, and social and separation anxiety. Items are rated on a scale from 0 (never true about me) to 3 (often true about me). Total scores range from 0–30 (MASC-10) and 0–117 (MASC-39), with higher scores indicating more symptoms of anxiety. The MASC-39 has good internal consistency ($\alpha = 0.60$–0.85), strong test-retest reliability ($r = 0.79$–0.93), good convergent validity (correlates significantly with the Revised Children's Manifest Anxiety Scale) and also has good discriminant validity (March, Parker, Sullivan, Stallings, & Conners, 1997). Internal consistency of the MASC-39 for the present study was excellent ($\alpha = 0.906$). The MASC-10 has excellent internal consistency ($\alpha = 0.89$), strong test-retest reliability ($r = 0.86$), and good convergent and discriminant validity (March et al., 1997; March & Sullivan, 1999). Internal consistency of the MASC-10 for the current study was acceptable at T1 ($\alpha = 0.80$), T2 ($\alpha = 0.78$), and T3 ($\alpha = 0.79$).

The center for epidemiological studies-depression scale for children

The CES-DC consists of 20-items that examine depressed mood, worthlessness, helplessness, psychomotor retardation, eating and sleeping problems. Items are rated on a scale from 0 (not at all) to 3 (a lot) to indicate how frequently each statement was experienced 'in the past week'. Total scores range from 0 to 60 with higher scores indicating more severe depressive symptoms. The CES-DC has excellent internal consistency ($\alpha = 0.89$) and good convergent validity (Faulstich, Carey, Ruggiero, Enyart, & Gresham, 1986). Internal consistency for the present study was excellent at T0 ($\alpha = 0.92$), T1 ($\alpha = 0.90$), and good at T2 ($\alpha = 0.89$) and T3 ($\alpha = 0.90$).

Chronic pain acceptance questionnaire-adolescents

The CPAQ-A (McCracken, Gauntlett-Gilbert, & Eccleston, 2010) is a 20-item scale that measures an adolescent's acceptance of chronic pain. Items are rated on a 5-point scale ranging from 0 (never true) to 4 (always true) with total scores ranging from 0 to 80, higher scores indicating greater acceptance of pain. The CPAQ-A has two subscales: activity engagement and pain willingness. The internal consistency for the activity engagement subscale has been shown to be good ($\alpha = 0.86$) and also adequate for pain willingness ($\alpha = 0.75$) (McCracken et al., 2010). Internal consistency for the present study was good at T0 ($\alpha = 0.88$), T2 ($\alpha = 0.87$), and T3 ($\alpha = 0.88$).

2.2.4 | Predictive validity measures

PROMIS-pediatric pain interference scale (PPIS)

The 8-item PROMIS-Pediatric Pain Interference Scale (Varni et al., 2010) assesses how the child's pain has interfered with certain aspects of their life over the past 7-days (e.g. sleep, attention, schoolwork, physical activities, emotion). Each item is rated on a 5-point scale ranging from "never" to "almost always." Scores range from 0 to 32 where higher scores indicate greater pain-related functional impairment. The PPIS consistently achieves a Cronbach's α of 0.85 (Varni et al., 2010). Internal consistency for the present study was excellent at T0 ($\alpha = 0.93$) and T3 ($\alpha = 0.92$), and good at T2 ($\alpha = 0.90$).

The functional disability inventory

The FDI (Walker & Greene, 1991) is a 15-item scale that measures the extent to which children experience difficulties in completing daily tasks and activities (e.g. "Walking to the bathroom," "Eating regular meals," and "Being at school all day"). Each item is rated on a 5-point Likert Scale, which ranges from 0 (no trouble) to 4 (impossible). The total score ranges from 0 to 60 with higher scores indicative of increasing difficulty engaging in the activities.

FDI has excellent internal consistency ($\alpha = 0.90$) and has good concurrent validity (Walker & Greene, 1991). The internal consistency of the FDI for the present study was excellent at T0 ($\alpha = 0.92$) and T3 ($\alpha = 0.91$), and good at T2 ($\alpha = 0.86$).

2.3 | Procedure

The study was reviewed and approved by the Research Ethics Boards at The Hospital for Sick Children (SickKids) (REB file # 1000019644) and the Human Participants Review Committee at York University (Certificate # 2010 – 276). This prospective, longitudinal study involved four assessment time points over the course of a year: pre-operative, in-hospital, and 6- and 12-months post-operative.

2.3.1 | Pre-operative assessment (T0)

The baseline assessment included administration of child and parent questionnaires. The research assistant was available for consultation if needed. The child completed questionnaires asking about previous and current pain experiences, as well as relevant psychological and emotional functioning (TSK, PCS-C, MASC-10, CRIES, CES-DC, CASI, CPAQ, FDI, PPIS). The order of questionnaire administration was randomized between subjects to minimize fatigue and order effects. The child's pre-operative medication use (analgesics and others) was obtained from the parents and confirmed by the patient's hospital medical record.

2.3.2 | Intraoperative anesthetic management

Each patient received a general anaesthetic. The following intraoperative factors were extracted from the surgical and anaesthetic records: duration of surgery, analgesic/anaesthetic regime including use of epidural/regional anaesthetic techniques, systemic opioids, non-opioid adjuvants.

2.3.3 | In-hospital post-operative assessment (T1)

Physical movement was measured continuously while in hospital using a non-invasive Actical physical activity monitor beginning when participants arrived at the PACU after surgery. Pain intensity scores (NRS-I) and pain unpleasantness scores (NRS-U) were obtained daily by a research assistant. Postoperative analgesic use (e.g. opioid consumption, adjunct analgesics) was recorded from the child's medical record. In addition, 48–72 hr after surgery children completed self-report measures (TSK, PCS-C, MASC-10, CRIES, CES-DC, CASI, CPAQ). The research assistant was available for consultation if needed. The FDI and the CPAQ were not provided to the children to complete at T1 because they are not validated for in-hospital measurement.

2.3.4 | Six (T2) and 12 (T3) month post-operative follow-ups

Six and twelve months after surgery, the research assistant followed up with participants by telephone to complete a set of measures to determine pain, psychological and emotional adaptation, current pain medications, incidence, intensity, quality of chronic postsurgical pain and the extent to which it interferes with daily activity (TSK, PCS-C, MASC-10, CRIES, CES-DC, CASI, CPAQ, FDI, PPIS).

2.4 | Data analysis

2.4.1 | Factor analysis

All factor analytic procedures were conducted in R Version 3.4.1 (R Core Team, 2014) using the packages "car" (Fox, Weisberg, & Price, 2020), "GPArotation" (Bernaards & Jennrich, 2014) and "psych" (Revelle, 2019). Polychoric correlation matrix for the 17 items were analysed and observed for the strength and direction of the relationships between variables. An EFA was chosen over a confirmatory factor analysis because the TSK has not yet been evaluated among youth. Using ordinary least squares (OLS) to find the minimum residual (minres) solution, the number of factors within the TSK at T0 was evaluated. Specifically, the number of factors was determined by an examination of the (1) eigenvalue scree plot, (2) parallel analysis, (3) standardized root mean square residual (SRMR), (4) residual correlations, and (5) factor loadings, communality, and uniqueness and residual correlations, as well as the factor loadings with oblimin rotation.

2.4.2 | Reliability

Reliability analyses were conducted in R using the package "psych". Cronbach's alpha (α) and McDonald's omega (Ω) were used to examine the internal consistency of the TSK prior to surgery. Cronbach's α was interpreted as: Excellent: $0.9 \leq \alpha$; Good: $0.8 \leq \alpha < 0.9$; $0.7 \leq \alpha < 0.8$ Acceptable; $0.6 \leq \alpha < 0.7$ Questionable; $0.5 \leq \alpha < 0.6$ Poor; $\alpha < 0.5$ Unacceptable (DeVellis, 2012).

2.4.3 | Construct validity

Construct validity was examined through convergent validity and discriminant validity. Convergent validity was determined by examining correlations between the TSK and psychological constructs linked to the fear-avoidance model (Asmundson et al., 2012); specifically the NRS pain intensity, NRS pain unpleasantness, CPASS avoidance subscale, pain catastrophizing and physical movement levels. High correlations (i.e., $r > .70$) indicated convergent validity (Jackson, 2009). Discriminant validity was determined by examining correlations between the TSK and theoretically dissimilar (or less similar) psychological constructs, specifically general anxiety, anxiety sensitivity, symptoms of post-traumatic stress disorder, general depression, and chronic pain acceptance. A correlation below 0.70 between the TSK and these measures would indicate adequate discriminant validity.

Convergent and discriminant validity were also examined by comparing the magnitude of the difference in correlation coefficients between: (1) the TSK and CPASS Avoidance Subscale versus the TSK and MASC-10; (2) the TSK and CPASS Avoidance Subscale versus TSK and CES-DC; (3) the TSK and PCS-C versus the TSK and MASC-10; and (4) the TSK and PCS-C versus the TSK and CES-DC. Significantly larger correlations (i.e. minimum difference of 0.2) between the TSK and pain-related fear avoidance (CPASS Avoidance Subscale and PCS-C) as compared to the TSK and non-pain-related fear avoidance (MASC-10 and CES-DC) would suggest sufficient convergent and discriminant validity. Through the use of a web-based calculator, Fisher's *r*-to-*z* transformation was performed to convert each correlation coefficient to a *z*-score (Lee & Preacher, 2013) and Steiger's equations 3 and 10 (Steiger, 1980) to compute the covariance of the estimates.

2.4.4 | Predictive validity

Predictive validity, or the extent to which the TSK correlated with theoretically related constructs measured at a later time, was evaluated by examining correlations between the pre-operative scores on the TSK and disability (FDI, PPIS) 12-months after surgery.

3 | RESULTS

3.1 | Recruitment and demographic information

Recruitment took place between February 2011 and August 2015. Recruitment details have been reported in previous articles (Noel et al., 2019; Rosenbloom et al., 2019). Of the 349 children and parents approached for consent, 270 provided assent and informed written consent to participate, respectively. Three children withdrew consent before participating in any part of the study, one patient's surgical procedure was changed and no longer met study criteria, and 27 children were missed (i.e. the research assistant was unable to locate or reach them) for their T0 assessment. One patient was diagnosed with cancer after consent and was withdrawn from the study. A total of 264 participants completed at least one component of the in-hospital (T1) assessment (e.g. questionnaire, actigraphy and daily pain measures). Twenty-seven participants were admitted directly to the intensive care unit (ICU) from the operating room (i.e. they did not go to the PACU) and therefore the research assistant was unable to obtain daily pain measures or place the Actical physical movement monitor on the child until they were admitted to a regular surgical unit. The 6- and 12-month retention rates of participants in this study were 81.13% and 85.28%, respectively.

Significant differences at baseline were not found between participants who completed the study at 12-months and those who did not on any of the measures, except in the PPIS. Participants who completed the study had significantly lower baseline PPIS scores ($M = 14.42$, $SD = 9.59$) than those who did not complete the study ($M = 23.00$, $SD = 5.40$), $t(162) = 2.162$, $p = 0.031$.

The final sample consisted of 264 children [155 female (58.49%), *M* age = 14.07 years ($SD = 2.51$), range 8–18 years] and their parents or guardians [188 female (83.92%), *M* age = 45.10 years ($SD = 5.88$), range 29–70 years, 41 parents did not answer the demographic questionnaire]. The majority of children identified as Caucasian (65.74%). The majority of children underwent surgery for scoliosis ($n = 133$, 50.2%) and 35.5% ($n = 94$) underwent an osteotomy. Fourteen children (5.3%) had a Ravitch procedure, four (1.5%) had a Nuss procedure (1.5%), four (1.5%) had a thoracotomy, and 15 (5.7%) had another type of surgery. The mean duration of surgery was 4.59 hr ($SD = 2.07$ hr, range = 0.70–10.70 hr) and children stayed in hospital an average of 4.94 days ($SD = 2.91$, range 1–36 days). Participants who were transferred to the ICU had significantly longer surgical times ($p < 0.001$) and hospital stays ($p = 0.001$).

3.2 | Exploratory factor analysis

An examination of the polychoric correlation matrix among TSK items (Table 2) showed that most items were moderately positively correlated with one another. As expected, many of the reverse scored items were negatively correlated with the positively scored items. However, this was not consistent across the items (e.g. items 4 and 11 have a correlation

of 0.11). Additionally, the reverse scored items were weakly correlated with most of the positively scored items.

The initial EFA was conducted on all 17 TSK items (TSK-17). Parallel analysis with 100 iterations suggested a five-factor model. However, Cattel's scree plot suggested that a one- or two-factor model would work best because there was a noticeable decrease between one and two factors and another decrease between two and three factors, levelling off after that point.

Given these results, the SRMRs and residual correlations were examined for one-, two-, and five-factor models. The SRMR for the one-factor. Model was 0.091. The SRMR for the two-factor model was 0.063 indicating a good fit. The SRMR for the five-factor model was 0.028 indicating a better fit than the two-factor model. However, this decrease in the SRMR is reflective of the fact that more factors were added resulting in smaller residual correlations. The residual correlation matrix for the one-factor model reveals mostly low residual correlations with the exception of the reverse scored items where the residual correlations range between 0.004 and 0.121, with the majority closer to 0.121. The residual correlation matrices for the two- and five factor models reveal no high residual correlations between any of the items. As a result, the factor loadings, communality, and uniqueness were evaluated.

The factor loadings for the two-factor model (Table 3) were evaluated for parsimony in both columns (i.e. within factors) and rows (i.e. between factors). The positively scored items (1, 2, 3, 5, 6, 7, 9, 10, 11, 13, 14, 15 and 17) load well onto Factor 1, whereas the reverse scored items (4, 8, 12 and 16) load well onto Factor 2. There was significant cross-loading for item 6. In this model each variable can also be evaluated for the amount of total variance that is due to each factor. For example, 40% of the variance in item 1 is explained by the common factors. Only items 1, 13 and 15 have communalities greater than 0.40, indicating a good fit with the factors. However, the rest of the items had communalities less than 0.40 (i.e. $h^2 = 0.08–0.39$), indicating poor correlations with the factors. Inter-factor correlations were also examined and it was found that the factors in the two-factor model were very weakly correlated ($r = 0.01$).

In the five-factor model (Data in Appendix), the items do not load well onto any of the five factors apart from Items 1 (loaded onto factor 1) and 4 (loaded onto factor 2). The five-factor model varied in the strength of the inter-factor relationships with one another with correlations ranging from 0.00 to 0.43.

These results for the TSK-17 are consistent with what has been found in the adult literature (Goubert et al., 2004; Heuts et al., 2004; Swinkels-Meewisse et al., 2003) in that the two-factor model fits the data best. In keeping with the adult literature, we conducted an EFA on only the positively scored items, excluding the reverse scored items from analysis. The TSK-17 EFA yielded results indicative of a poor fit (e.g. very weak correlation between factors in the two-factor model, factors separated by positively and reverse scored items). Moreover, TSK-17 convergent, discriminant and predictive validity were worse than the TSK-13. Due to space restrictions, we report the TSK-17 EFA and psychometric results in the Appendix and the results from the TSK-13 in this manuscript.

The second EFA was conducted on the 13 positively scored TSK items (henceforth referred to as the TSK-13). Parallel analysis with 100 iterations suggested a five-factor model. However, Cattel's scree plot suggested that a one-, two- or three-factor model would fit the data because there was a noticeable decrease between one, two and three factors after which the graph levelled off. The ratio between eigenvalues was further evaluated. Given that the scree plot and parallel analysis suggest a one-, two- or three-factor model, the SRMRs, and residual correlations were examined for the two- and three-factor models.

The SRMR for the one-factor model was 0.07 and the SRMR for the two-factor model was 0.06 indicating a good fit and providing support for these models. However, the SRMR for the three-factor model was 0.04 indicating a slightly better fit than the one- and two-factor models. A close look at the residual correlations in the residual correlation matrix reveals that there are no high residual correlations between any of the items in the one-, two- or three-factor models. As a result, the factor loadings, communality, and uniqueness were evaluated for the one-, two- and three-factor model.

The factor loadings for the one-factor model were evaluated. Items loaded well onto the one factor; however, communality was low for each item (i.e., $h^2 = 0.12–0.44$).

The factor loadings for the two-factor model were evaluated for parsimony in both columns (i.e. within factors) and rows (i.e., between factors). Items 1, 2, 5, 9, 10, 14 and 15 load well onto Factor 1 (fear of injury) and items 3, 6, 7, 11, 13 and 17 load well onto Factor 2 (activity avoidance). There was significant cross-loading among items 5, 10, 13 and 17. In this model each variable can also be evaluated for the amount of total variance that is explained by each factor. For example, 54% of the variance in item 1 was accounted for by the common factors. Only items 1 and 15 have communalities greater than 0.40, indicating a good fit with the factors. The rest of the items had communalities less than 0.40 (i.e., $h^2 = 0.13–0.36$), indicating poor correlations with the factors. The inter-factor correlation for the two-factor model was moderate ($r = 0.54$).

The factor loadings for the three-factor model (Table 4) were evaluated for parsimony in both columns (i.e. within factors) and rows (i.e. between factors). Items 1, 2, 9, 14 and 15 load well onto Factor 1 (fear of injury); items 3, 5, 6, 7, and 11 load well onto Factor 2 (bodily vulnerability; and items 10, 13, 14 and 17 load well onto Factor 3 (activity

TABLE 2 Polychoric correlations between TSK items. For ease of viewing and to be consistent with data analyses, positively scored TSK items are listed first (i.e. items 1, 2, 3, 5, 6, 7, 9, 10, 11, 13, 14, 15, 17) and reverse scored TSK items are listed after (i.e. items 4, 8, 12, 16)

TSK Item #	1	2	3	5	6	7	9	10	11	13	14	15	17	4	8	12	16
1.	–																
2.	0.55	–															
3.	0.32	0.44	–														
5.	0.33	0.19	0.31	–													
6.	0.26	0.20	0.39	0.38	–												
7.	0.10	0.20	0.26	0.22	0.33	–											
9.	0.51	0.34	0.28	0.35	0.23	0.13	–										
10.	0.37	0.34	0.35	0.12	0.24	0.18	0.38	–									
11.	0.26	0.18	0.42	0.23	0.31	0.30	0.28	0.29	–								
13.	0.29	0.32	0.27	0.06	0.18	0.27	0.39	0.47	0.25	–							
14.	0.49	0.37	0.31	0.28	0.26	0.35	0.33	0.35	0.33	0.21	–						
15.	0.55	0.43	0.32	0.30	0.27	0.21	0.48	0.46	0.20	0.22	0.62	–					
17.	0.10	0.29	0.23	0.03	0.06	0.19	0.20	0.30	0.18	0.27	0.28	0.33	–				
4.	0.05	0.11	−0.09	−0.11	−0.22	0.00	−0.11	−0.06	−0.14	−0.02	0.11	−0.06	0.16	–			
8.	0.13	−0.01	0.01	0.01	−0.15	−0.05	0.01	−0.24	−0.15	−0.10	−0.02	0.02	0.03	0.28	–		
12.	0.05	0.16	−0.07	−0.07	−0.09	0.08	−0.05	−0.08	−0.10	−0.08	0.17	0.03	0.16	0.51	0.18	–	
16.	0.02	0.06	0.10	0.01	0.09	−0.01	−0.02	−0.08	0.02	−0.10	0.02	−0.07	−0.01	0.13	0.34	0.18	–

Note: TSK; Tampa Scale for Kinesiophobia.

TABLE 3 Pattern matrix including factor loadings, communality and uniqueness for the two-factor model with quartimin rotation. For ease of viewing and to be consistent with data analyses, positively scored TSK items are listed first (i.e. items 1, 2, 3, 5, 6, 7, 9, 10, 11, 13, 14, 15, 17) and reverse scored TSK items are listed after (i.e. items 4, 8, 12, 16)

	Λ			
Item	f_1	f_2	Communality (h^2)	Uniqueness (u^2)
1	0.62	0.08	0.40	0.60
2	0.58	0.16	0.37	0.63
3	0.53	0.04	0.28	0.72
5	0.35	−0.08	0.13	0.87
6	0.37	−0.23	0.19	0.81
7	0.35	−0.03	0.12	0.88
9	0.57	−0.11	0.34	0.66
10	0.56	−0.16	0.34	0.66
11	0.42	−0.19	0.21	0.79
13	0.47	−0.16	0.47	0.75
14	0.61	0.12	0.39	0.61
15	0.66	0.02	0.44	0.56
17	0.36	0.14	0.15	0.85
4	−0.01	0.65	0.42	0.58
8	−0.04	0.41	0.17	0.83
12	0.06	0.60	0.37	0.64
16	0.03	0.27	0.08	0.93

Note: TSK; Tampa Scale for Kinesiophobia

avoidance). There was significant cross-loading among items 2, 5 and 14. Fifty-seven percent of the variance in item 1 was accounted for by the common factors. Only items 1, 10, and 15 have communalities greater than 0.40, indicating a good fit with the factors. However, the rest of the items had communalities less than 0.40 (i.e., h^2 = 0.21–0.39), indicating poor correlations with the factors, but better overall than the two-factor model. Inter-factor correlations in the three-factor model were moderate ($r_{f1,f2}$ = 0.49, $r_{f1,f3}$ = 0.45, $r_{f2,f3}$ = 0.38).

In conclusion, using the TSK-13 (positively scored items only), the one-, two- and three-factor models yield similar results with respect to overall model statistics, however, the three-factor model is more parsimonious and yields more meaningful factors. Furthermore, 10 of the 13 items load well onto either Factor 1 (fear of injury), Factor 2 (bodily vulnerability) or Factor 3 (activity avoidance), whereas three items have some cross-loading.

3.3 | Reliability

Using Cronbach's α, the TSK-13 yielded adequate overall internal consistency (α = 0.81). Cronbach's α per factor was adequate, specifically the fear of injury factor had an Ω of 0.77, the bodily vulnerability factor had an Ω of 0.62, and the activity avoidance factor had an Ω of 0.59.

Using McDonald's Ω, the TSK-13 showed good overall internal consistency (Ω = 0.82). The internal consistency per factor was adequate, specifically the fear of injury factor had an Ω of 0.77, the bodily vulnerability factor had an Ω of 0.62, and the activity avoidance factor had an Ω of 0.59.

3.4 | Construct validity

The means and standard deviations for each measure used to asses construct validity are shown in Table 5.

TABLE 4 Pattern matrix including factor loadings, communality and uniqueness for the three-factor model with quartimin rotation using the TSK-13 (positively scored items only)

	Λ				
Item	f_1	f_2	f_3	Communality (h^2)	Uniqueness (u^2)
1	0.80	−0.05	−0.04	0.57	0.43
2	0.44	0.03	0.21	0.34	0.66
3	0.11	0.43	0.16	0.33	0.67
5	0.30	0.35	−0.24	0.24	0.76
6	0.04	0.56	−0.09	0.30	0.70
7	−0.11	0.48	0.14	0.25	0.75
9	0.48	0.04	0.16	0.35	0.65
10	0.20	0.07	0.49	0.41	0.59
11	−0.04	0.46	0.17	0.38	0.72
13	0.04	0.07	0.58	0.39	0.61
14	0.46	0.21	0.04	0.37	0.63
15	0.67	0.02	0.08	0.52	0.48
17	0.06	0.01	0.42	0.21	0.79

Note: TSK; Tampa scale for kinesiophobia.

3.4.1 | Convergent validity

The TSK-13 was significantly and moderately correlated with NRS pain intensity (r (228) = 0.25, $p < 0.001$), NRS pain unpleasantness (r (162) = 0.41, $p < 0.001$), the avoidance subscale of the CPASS (r (227) = 0.53, $p < 0.001$) and the PCS (r (226) = 0.56, $p < 0.001$), indicating weak convergent validity with those measures given the requirement that $r > 0.7$. The TSK-13 was not significantly correlated with actual physical movement on post-operative day 2 (r (179) = −0.10, $p = 0.18$) as measured by actigraphy, indicating poor convergent and predictive validity with physical movement levels. Correlations between the TSK and other measures as well as partial correlation coefficients, controlling for age and sex, are shown in Table 6.

3.4.2 | Discriminant validity

The TSK-13 was significantly and moderately correlated with the MASC-10 (r (224) = 0.35, $p < 0.001$), CRIES (r (119) = 0.41, $p < 0.001$), CES-DC (r (225) = 0.41, $p < 0.001$), CASI (r (227) = 0.40, $p < 0.001$) and CPAQ (r (180)= −0.52, $p < 0.001$), indicating adequate discriminant validity given the requirement that $r < 0.7$. Partial correlation coefficients, controlling for age and sex, are summarized in Table 6.

TABLE 5 Means and standard deviations for pre-surgical and in hospital factors used in the validation of the TSK-13

Pre-surgery variables	Mean	Standard deviation
TSK	37.74	6.94
TSK-13	27.59	6.52
NRS Pain at Rest	2.00	2.33
NRS pain unpleasantness	2.55	2.97
CPASS	32.88	18.55
PCS	19.64	11.93
Movement post-operative day 2	56924.86	69965.88
CASI	29.65	6.74
CRIES	22.96	14.32
MASC-10	11.45	5.55
CED-DC	16.72	12.13
CPAQ	46.68	13.16
FDI	11.66	11.23
PPIS	14.73	9.59

Note: TSK, Tampa Scale for Kinesophobia; NRS, Numeric Rating Scale; CPASS, Child Pain Anxiety Symptoms Scale; PCS, Child Pain Catastrophizing Scale; CASI, Childhood Anxiety Sensitivity Index; CRIES, Children's Revised Impact of Event Scale; MASC-10, Multidimensional Anxiety Scale for Children; CES-DC; Center for Epidemiological Studies-Depression Scale for Children; CPAQ, Chronic Pain Acceptance Questionnaire - Adolescents; PPIS, PROMIS-Pediatric Pain Interference Scale; FDI, Functional Disability Index

3.4.3 | Comparison of convergent and discriminant validity

Convergent and discriminant validity were examined by comparing the magnitude of the correlation coefficients. The TSK-13 was significantly more highly correlated with the Avoidance Subscale of the CPASS than with the MASC-10, $Z = 2.89$, $p = 0.004$, however, this difference was not greater than the 0.20 cuff off. Furthermore, the TSK −13 was not significantly more correlated with the Avoidance Subscale of the CPASS than with the CES-DC, $Z = 1.89$, $p = 0.06$, and this difference was under the 0.20 cut off. The TSK-13 was significantly more correlated with the PCS-C than with the MASC-10, $Z = 3.314$, $p < 0.001$, and this difference was greater than 0.20. However, while the TSK-13 was significantly more correlated with the PCS-C than the CES-DC, $Z = 2.66$, $p = 0.008$, the difference was less than 0.20.

3.5 | Predictive validity

The means and standard deviations for the FDI and PPIS are shown in Table 5. Baseline TSK-13 scores, measured prior to surgery, were weakly correlated with functional disability 12 months after surgery (r (198) = 0.17, $p < 0.05$) and moderate with pain related disability (r (70) = 0.36, $p < 0.001$), indicating adequate predictive validity for the latter measure.

4 | DISCUSSION

The aim of this study was to evaluate the psychometric properties of the Tampa Scale for Kinesiophobia (TSK) among children and adolescents undergoing major surgery. EFA showed a poor fit with a one-factor model (17-items) and a slightly better fit with a two-factor model that distinguished 13 positively scored items from 4 reverse scored items. This latter finding is consistent with the results of three studies in adults that found better model fit without the reverse scored items (Clark et al., 1996; Goubert et al., 2004; Swinkels-Meewisse et al., 2003). In the present study, the model fit indices were not ideal for a two-factor model with all 17 items included. With the reverse scored items removed, the EFA conducted on the 13 positively scored items revealed a stronger model fit with three factors defined as: Fear of injury (fear of moving due to risk of re-injury), bodily vulnerability (belief that the body is vulnerable to pain and injury) and activity avoidance (belief that activities should be avoided).

TABLE 6 Correlation coefficients (below the diagonal) and partial correlation coefficients (above the diagonal) between the TSK-13 (positively scored items only) measured at baseline before surgery (T0) and other variables measured at various times in relation to surgery

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. T0 TSK−13		0.23**	0.40**	0.53**	0.52**	−0.11	0.35**	0.40**	0.40**	0.39**	−0.52**	0.18*	0.33*
2. T0 NRS Pain Intensity	0.25**		0.82**	0.11	0.28**	0.01	0.18**	0.22**	0.35**	0.15*	−0.15*	0.12	0.17
3. T0 NRS unpleasantness	0.41**	0.83**		0.33**	0.46**	0.004	0.27**	0.26**	0.34**	0.24**	−0.35**	0.10	0.11
4. T0 CPASS Avoidance	0.53**	0.12	0.33**		0.61**	−0.11	0.40**	0.30**	0.357**	0.32**	−0.64**	0.15*	0.27*
5. T0 PCS	0.56**	0.30**	0.46**	0.61**		−15*	0.39**	0.50**	0.51**	0.42**	−0.57**	0.27**	0.45**
6. POD2 Movement	−0.10	−0.01	0.01	−0.12	−0.13		−0.14	−0.12	−0.16*	−0.04	0.01	−0.09	0.11
7. T0 MASC−10	0.35**	0.18**	0.25**	0.39**	0.38**	−0.18*		0.47**	0.46**	0.55**	−0.35**	0.16*	0.29*
8. T0 CRIES	0.41**	0.26**	0.29**	0.30**	0.51**	−0.09	0.43**		0.59**	0.53**	−0.27**	0.22**	0.25*
9. T0 CES-DC	0.41**	0.38**	0.35**	0.36**	0.51**	−0.17*	0.45**	0.59**		0.52**	−0.43**	0.19*	0.17
10. T0 CASI	0.40**	0.19**	0.26**	0.32**	0.43**	−0.05	0.54**	0.54**	0.54**		−0.28**	0.20	0.30*
11. T0 CPAQ	−0.52**	−0.16*	−0.36**	−0.64**	−0.57**	−0.01	−0.31**	−0.28**	−0.42**	−0.27**		−0.24*	−0.16
12. T3 FDI	0.17*	0.10	0.11	0.15*	0.27**	−0.11	0.17*	0.21**	0.19**	0.12	−0.24**		−0.84**
13. T3 PPIS	0.34**	0.19	0.13	0.30*	0.44**	0.043	0.33**	0.25*	0.22	0.32**	−0.17	0.81**	

Note: Pearson correlation coefficients are presented below the diagonal space. Partial correlation coefficients after controlling for age and gender are presented above the diagonal space.

T0 TSK, Tampa Scale for Kinesiophobia assessed prior to surgery; T0 PCS, Pain Catastrophizing Scale assessed prior to surgery; POD2, Post-Operative Day 2; T0 MASC, Multidimensional Anxiety Scale for Children assessed prior to surgery; T0 CRIES, Children's Revised Impact of Events Scale assessed prior to surgery; T0 CESDC, Centre for Epidemiological Studies – Depression Scale Children assessed prior to surgery; T0 CASI, Childhood Anxiety Sensitivity Inventory assessed prior to surgery; T0 CPAQ, Chronic Pain Acceptance Questionnaire for Adolescents assessed prior to surgery; T3 FDI, Functional Disability Inventory assessed 12 months after surgery; T3 PPIS, PROMIS Pediatric Pain Interference Scale assessed 12 months after surgery.

*$p < 0.05$.

**$p < 0.01$.

The 13-item TSK yielded adequate internal consistency and weak convergent validity with measures of pain intensity, pain unpleasantness and pain avoidance while in hospital after surgery. These findings are in-line with the cognitive-behavioural fear-avoidance model of chronic pain (Vlaeyen et al., 1995; Vlaeyen & Linton, 2000), where a higher level of fear of movement/ re-injury is associated with greater pain experiences. The TSK-13 was shown to be distinct enough from a measure of general anxiety to demonstrate some discriminant validity. However, the TSK-13 was not distinct enough from a measure of depression or the avoidance subscale of a measure of pain-related anxiety.

The pre-surgical TSK-13 measure was not correlated with actual acute postoperative physical movement on Day 2 after surgery as measured by continuous actigraphy. It is possible that fear of movement/re-injury has a negative relationship with long-term movement, not evident in the short-term. The lack of a significant correlation may be due to a floor effect in post-operative physical movement which was low across all patients. Low levels of physical movement immediately after surgery may be explained by children having strict physiotherapy protocols to follow that restrict movement in the days after surgery (e.g. sitting first, then standing, then walking). It is also possible that low levels of physical movement may be due to the residual effects of anesthetics and surgery (e.g., fatigue, nausea, indwelling catheters, sedation). Additionally, it is likely that some movements (e.g. eating, hand gestures while talking) may have inflated total activity counts while at the same time not being a source of fear of movement/injury thereby diluting the relationship between activity and the TSK-13 scores. The low correlation between fear of movement/re-injury and physical movement is also consistent with lack of a significant association found between the TSK and treadmill tests of aerobic conditioning and maximal strength tasks (French et al., 2007).

However, another possibility is that the baseline, pre-surgical measure of the TSK-13 was a poor reflection of the participants' fear of movement/re-injury on Day 2 when physical movement was assessed given the fact that participants underwent major surgery between the two assessment times. Administration of the TSK-13 on Day 2 after surgery may have produced a stronger correlation between fear of movement/re-injury and Day 2 physical movement. Exposure to intense acute postoperative pain may have altered participants' baseline level of fear of movement/re-injury rendering the pre-surgical results invalid. A similar argument has been made regarding the validity of pre-operative child pain catastrophizing as a predictor of post-operative pain and health-related quality of life two weeks after surgery (Katz, 2015). Taken together, these "negative" findings question the usefulness of pre-operative measures in predicting acute post-operative pain and function since the intense postsurgical pain experienced in the days after surgery may, for certain vulnerable children, establish a new baseline. Future studies should examine the TSK-13 and physical movement concurrently in the acute post-operative period.

In terms of long-term outcomes, the TSK-13 showed adequate predictive validity for pain-related disability at 12 months after surgery but its relationship to general functional disability 12 months after surgery was less compelling. These results are similar to Swinkels-Meewisse et al.'s (2003) cross-sectional study in adults, showing a positive association between the TSK and disability, as measured by the Roland Disability Questionnaire, among acute low back pain patients. Together these results support the relationship between fear of movement/re-injury and subsequent disability, such that greater fear of movement/re-injury is associated with greater disability.

There are several limitations to the present study. First, participants who completed the study had significantly lower baseline pain interference scores than those who did not complete the study. Consequently, the sample is likely not representative of the level of pain interference in the population of youth who undergo major surgery. It is not known whether, or in what way, the lack of representativeness of the sample influenced the psychometric properties of the TSK. Second, the TSK-17 had poorer model fit statistics than the TSK-13 because of the four reverse scored items in the former scale. It is not known whether these reverse scored items were a poor fit because of the wording (syntax) or content (meaning). Future studies might evaluate whether changing the wording of the reverse scored items to make them positively scored would improve the psychometric properties of the 17-item TSK. For example, changing item 8 from "Just because something aggravates my pain does not mean it is dangerous" to "Things that aggravate my pain are dangerous," or other similar wording, would help to determine whether the problem we, and others, encountered with the reverse scored items is due to item wording/syntax or item content/meaning.

Overall, the results of the present study provide initial support for the use of the TSK-13 as an adequately valid and reliable measure of the fear of movement/re-injury construct in children and adolescents undergoing surgery. The TSK-13 revealed a 3-factor structure that is reliable and demonstrates adequate convergent, discriminant and predictive validity within the context of paediatric surgery. Further validation of this measure is warranted in other populations, such as youth with referred to paediatric chronic pain clinics.

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APPENDIX A: Results from the exploratory factor analysis (EFA) and validity testing on the TSK-17

EFA

The following table show the results from the five-factor model with quartinim rotation in terms of factor loadings, communality and uniqueness. For ease of viewing, the items are ordered first with positively scored items and second with reverse scored items.

Item	A					Communality (h^2)	Uniqueness (u^2)
	f_1	f_2	f_3	f_4	f_5		
1	0.63	0.00	0.06	0.08	0.17	0.59	0.41
2	0.28	0.17	0.18	0.29	0.10	0.37	0.63
3	0.06	0.02	0.61	0.20	0.02	0.50	0.50
5	0.23	−0.19	0.28	−0.16	0.18	0.24	0.76
6	−0.04	−0.30	0.37	−0.02	0.25	0.32	0.68
7	−0.28	0.00	0.23	0.14	0.39	0.29	0.71
9	0.44	−0.12	0.08	0.27	0.04	0.41	0.59
10	0.11	−0.05	0.03	0.54	0.10	0.42	0.58
11	−0.09	−0.18	0.31	0.21	0.17	0.28	0.72
13	0.06	−0.03	0.05	0.67	−0.09	0.45	0.55
14	0.09	0.10	0.03	−0.01	0.72	0.59	0.41
15	0.37	−0.01	−0.07	0.09	0.51	0.58	0.42
17	−0.07	0.25	0.01	0.42	0.14	0.26	0.74
4	0.00	0.67	−0.06	0.03	0.05	0.45	0.55
8	0.23	0.35	0.17	−0.17	−0.18	0.25	0.75
12	−0.07	0.59	0.11	−0.05	0.13	0.38	0.62
16	0.09	0.21	0.45	−0.21	−0.16	0.28	0.72

CONSTRUCT VALIDITY

Convergent validity

The TSK-17 was significantly and moderately correlated with NRS pain intensity (r (228) = 0.24, $p < 0.001$), NRS pain unpleasantness (r (162) = 0.43, $p < 0.001$), the avoidance subscale of the CPASS (r (227) = 0.54, $p < 0.001$) and the PCS (r (226) = 0.55, $p < 0.001$), indicating weak convergent validity with those measures given the requirement that $r > 0.7$.

The TSK-13 was not significantly correlated with actual physical movement on post-operative day 2 (r (179) = −0.08, $p = 0.319$) as measured by actigraphy, indicating poor convergent and predictive validity with physical movement levels. Correlations between the TSK and other measures are shown in the table below.

Discriminant validity

The TSK-13 was significantly and moderately correlated with the MASC-10 (r (224) = 0.30, $p < 0.001$), CRIES (r (219) = 0.34, $p < 0.001$), CES-DC (r (225) = 0.37, $p < 0.001$), CASI (r (227) = 0.35, $p < 0.001$) and CPAQ (r (180)=−0.53, $p < 0.001$), indicating adequate discriminant validity given the requirement that $r < 0.7$.

PREDICTIVE VALIDITY

Baseline TSK-17 scores, measured prior to surgery, were not correlated with functional disability 12-months after surgery (r (198) = 0.12, $p = 0.085$) or pain related disability (r (70) = 0.22, $p = 0.061$), indicating poor predictive validity.

Correlation coefficients between the TSK-17 measured at baseline before surgery (T0) and other variables measured at various times in relation to surgery.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. T0 TSK–17													
2. T0 NRS Pain Intensity	0.239**												
3. T0 NRS unpleasantness	0.426**	0.826**											
4. T0 CPASS Avoidance	0.537**	0.124	0.326**										
5. T0 PCS	0.550**	0.295**	0.463**	0.609**									
6. POD2 Activity	−0.075	−0.008	0.008	−0.119	−0.13								
7. T0 MASC–10	0.301**	0.176**	0.253**	0.392**	0.375**	−0.178*							
8. T0 CRIES	0.344**	0.256**	0.289**	0.300**	0.507**	−0.092	0.434**						
9. T0 CES-DC	0.374**	0.378**	0.351**	0.361**	0.513**	−0.174*	0.452**	0.592**					
10. T0 CASI	0.351**	0.188**	0.259**	0.322**	0.429**	−0.047	0.544**	0.537**	0.535**				
11. T0 CPAQ	−0.531**	−0.161*	−0.360**	−0.636**	−0.566**	−0.005	−0.312**	−0.278**	−0.420**	−0.269**			
12. T3 FDI	0.122	0.100	0.105	0.147*	0.266**	−0.11	0.168*	0.213**	0.189**	0.121	−0.242**		
13. T3 PPIS	0.222	0.194	0.13	0.301*	0.442**	0.043	0.328**	0.252*	0.217	0.320**	−0.172	0.807**	

T0 TSK, Tampa Scale for Kinesiophobia assessed prior to surgery; T0 PCS, Pain Catastrophizing Scale assessed prior to surgery; POD2, Post-Operative Day 2; T0 MASC, Multidimensional Anxiety Scale for Children assessed prior to surgery; T0 CRIES, Children's Revised Impact of Events Scale assessed prior to surgery; T0 CESDC, Centre for Epidemiological Studies – Depression Scale Children assessed prior to surgery; T0 CASI, Childhood Anxiety Sensitivity Inventory assessed prior to surgery; T0 CPAQ, Chronic Pain Acceptance Questionnaire for Adolescents assessed prior to surgery; T3 FDI, Functional Disability Inventory assessed 12-months after surgery; T3 PPIS, PROMIS Pediatric Pain Interference Scale assessed 12 months after surgery. *$p < 0.05$. **$p < 0.01$.

Chapter 5: General Discussion

This dissertation contributes to our understanding of youth and parent risk/ protective factors associated with the development and maintenance of pediatric chronic post-surgical pain and functional limitations. The three studies which comprise this dissertation use data collected from a large sample of youth aged 8 to 17 years undergoing major orthopedic or general surgery and their parents (n = 264). Youth completed questionnaires at four time points over the course of 12 months (pre-surgery, in-hospital, 6- and 12-months after surgery) and, while in hospital, underwent daily pressure algometer assessments and wore an Actical which continuously monitored physical activity. Parents of these youth completed questionnaires at two time points (pre-surgery, 12-months post-surgery).

The first study aimed to determine the incidence and severity of chronic post-surgical pain in youth undergoing major surgery. Results showed that 12 months after surgery, over a third of youth report moderate-to-severe post-surgical pain, which indicates that this is an area of clinical care that requires research. The second aim of this study was to identify pain intensity and pain unpleasantness trajectories beginning before, through to 12 months after, major surgery. I show that there are two pain trajectories: high pain and low pain. Third, this study examined factors that predicted group pain and pain unpleasantness trajectory membership. Results show that in-hospital opioid consumption and pre-surgical functioning predict pain group membership and that pre-surgical functioning predicts pain unpleasantness group membership. Fourth, this study identified pre-surgical factors that predict functional limitations 12-months after surgery within the large sample. This is the first study to demonstrate that pre-surgical functioning is the

best predictor of post-surgical functioning, over and above psychosocial and surgery-related factors, not a surprising finding but one that others have missed or not examined.

The second study focused on a subsample of youth and their parents from the first study to identify differential pre-surgical predictors of functional limitations using two measures of functional limitations, one a pain-related measure [PROMIS Pediatric Pain Interference Scale (PPIS)] and the other a general measure [Functional Disability Index (FDI)]. Findings from this study show that parents play an important role in their youth's 12-months post-surgical functional limitations outcomes. Specifically, it was found that youth 12-month pain-related functional limitations were predicted presurgical youth (pain-related anxiety and worry factor) and parent factors (anxiety sensitivity, state-trait anxiety, pain anxiety). Youth 12-month general functional limitations were predicted by youth general functional limitations and parent anxiety sensitivity. These results are important for driving theory forward on the transition from acute to chronic pain in pediatric samples.

The aim of the third study was to evaluate the psychometric properties of the Tampa Scale for Kinesiophobia (TSK) among youth prior to their surgery. I showed that the original 17-item TSK is not a valid measure for youth undergoing surgery, but that a modified 13-item TSK has promising psychometric properties for this population.

These three studies advance our understanding of perioperative factors that are associated with long-term pain and functional limitation outcomes after major surgery. Youth's functional limitations are rarely evaluated in the surgical literature and this dissertation shows that functioning is an important factor that needs to be considered in predicting post-surgical outcomes. Further, I show that parent's pre-surgical anxiety sensitivity is a factor in their youth's post-surgical functioning. These two novel findings have implications for both research and

clinical work. In the sections that follow, a summary of findings from each study are discussed. An integrated synthesis of all three studies is presented as well as a review of general study limitations, clinical implications, and directions for future research.

Summary of Findings from Study 1

The incidence of 12-month pediatric chronic post-surgical pain to varies from 11 to 60% (Chidambaran et al., 2017; Julien-Marsollier et al., 2017; Landman et al., 2011; Ocay et al., 2020; Pagé, Stinson, et al., 2013; Sieberg et al., 2013). The rates likely vary due to differences in measurement, "caseness" (e.g., non-zero pain versus moderate-to-severe pain), and the presence or absence (and intensity) of pre-surgical pain. Study 1 of this dissertation revealed that 35% and 38% of youth undergoing major surgery report moderate-to-severe chronic post-surgical pain six and 12 months after surgery, respectively. This study collected data from a sample of youth undergoing major surgery which was nearly double the size of previous studies. The rates are similar to those reported by Chidambaran et al. (2017) who found, in a smaller sample of youth aged 10-18 years undergoing spinal fusion surgery, that one year later, 41.8% rated their pain at a three or more on an 11-point numeric rating scale.

The rate of change in pre- to post-surgical pain intensity has been evaluated by four research groups in North America with different results. For example, Sieberg et al (2013) found five different pain trajectories following spinal fusion surgery as measured by the Scoliosis Research Scale-30 (SRS-30). Ocay et al. (2020) found four trajectories with the same measure. Other studies using the numeric rating scale (NRS) or visual analogue scale (VAS) have found two pain trajectories (Connelly et al., 2014; Rabbitts et al., 2015). Using the NRS to measure pain intensity, Study 1 also identified two main trajectories consisting of a high pain group and a

low pain group which follow a quadratic function. Consistent with the literature, Study 1 found that most youth fell within a low or mild pain group and a smaller subset of youth were classified in a high or severe pain group that increased in intensity over time. Study 1 also evaluated pain unpleasantness through trajectory analysis to find two groups (high pain unpleasantness and low pain unpleasantness), indicating an area for further examination and replication.

The prediction of pain intensity and pain unpleasantness trajectory group membership is important for identifying areas for clinical interventions. Greater functional disability prior to surgery and cumulative 5-day in-hospital opioid consumption significantly predicted membership in the moderate-to-severe pain intensity group. Greater functional disability prior to surgery predicted membership in the moderate-to-severe pain unpleasantness group. Unlike Rabbitts et al. (2015), who found that parent pain catastrophizing predicted membership into a late pain recovery group, Study 1 did not find that parent pre-surgical catastrophizing predicted trajectory group membership.

Over a third of the youth in Study 1 reported moderate-to-severe functional limitations as measured by the FDI. Functioning after surgery is critical for youths' social, emotional, physical, and cognitive development and, therefore, it was important to evaluate how pre-surgical factors as well as pain intensity and pain unpleasantness trajectories predicted 12-month functional limitations. Results indicated that while holding other psychological variables constant (i.e., pre-surgical anxiety, pre-surgical pain-related anxiety and worry, pre-surgical depression, pre-surgical chronic pain acceptance, pain intensity trajectory group membership), pre-surgical functional limitations and membership in the moderate-to-severe pain unpleasantness group trajectory significantly predicted moderate-to-severe functional limitations 12 months after surgery. Rabbitts et al. (2015) found that membership in a late pain recovery group was related to

poorer health related quality of life as well as activity limitation 12-months after surgery. Taken together it is clear that pre-surgical functional limitations play an important role in both pain, pain unpleasantness, and functional limitations up to 12 months after surgery. None of the surgical factors, pain-related psychological constructs (e.g., pain catastrophizing), or general psychological constructs (e.g., anxiety, depression) predicted 12-month functional outcomes after surgery as measured by the FDI.

Overall, these results show that almost 40% of youth undergoing major surgery experience moderate-to-severe chronic post-surgical pain and just over 30% experience moderate-to-severe functional limitations. Study 1 also reveals the importance of pre-surgical moderate-to-severe functional limitations 12-months after surgery. This strongly implies that interventions need to start prior to surgery.

Summary of Findings from Study 2

The goal of Study 2 was to compare the risk factors for pain-related functional limitations (as measured by the PROMIS Pediatric Pain Interference Scale (PPIS)), to those for general functional limitations (as measured by the Functional Disability Index (FDI)). This is the first study to investigate pain-related functional limitations in youth undergoing major surgery. Study 2 used a subsample from Study 1 that consisted of 79 dyads of youth undergoing major surgery and their parents. The results revealed that while the PPIS and FDI are highly correlated both before surgery and 12 months after surgery, they have slightly different risk factor profiles. Two sets of hierarchical regression analyses were conducted: one for 12-month PPIS scores and the other for 12-month FDI scores. The PPIS was predicted by a combination of presurgical youth (pain-related anxiety and worry factor) and parent factors (anxiety sensitivity, state-trait anxiety,

pain anxiety). The FDI, on the other hand, was predicted by youth FDI and parent anxiety sensitivity.

Study 2 analysis highlights the role that parents play in their youth's functional limitations post-surgery and reinforces the theory that chronic pain and pain related disability are a family issue associated with intergenerational transmission (Donnelly et al., 2020; Stone & Wilson, 2016). This is the first time that parent anxiety sensitivity has been measured in the literature examining youth transition from acute to chronic pain and it was found that both the PPIS and FDI are predicted by parent anxiety sensitivity. This result suggests that parent's with higher levels of anxiety sensitivity may shape the development of their youth's functional limitations over the year following their surgery. This extends the pediatric fear avoidance model of chronic pain (Asmundson et al., 2012) to propose that parents with elevated levels of anxiety sensitivity may be on high alert for signs of pain or anxious distress in their offspring. In high anxiety sensitive parents, the ensuing anxiety triggers alarm and so they search for ways to avoid or escape from their own anxiety by removing the cause of their anxiety and encourage avoidance behaviours in their offspring (e.g., encouraging their child to functionally limit their behaviours and activities). As this is a novel finding, replication is warranted, and future research should include parent anxiety sensitivity in studies evaluating risk factors for the transition from acute to chronic pain.

Summary of Findings from Study 3

Kinesiophobia is defined as "an excessive irrational, and debilitating fear of physical movement and activity resulting from feeling a vulnerability to painful injury or re-injury" (Kori et al., 1990). Kinesiophobia is proposed to predict the development of pain-related functional

limitations or disability (Vlaeyen et al., 1995). The Tampa Scale for Kinesiophobia (TSK) has been used widely in the adult pain literature, however, it has been rarely used in pediatric settings and therefore it is not known the extent to which kinesiophobia may be an important predictor of chronic pain in youth. Study 1 showed that at a univariate regression level, pre-surgical youth TSK scores were predictive of pain unpleasantness trajectory group membership, however, pre-surgical TSK scores were no longer significant at the multivariate level when pre-surgical general functioning was included in the analysis. This finding suggests that the TSK is related to pain unpleasantness to a certain extent, but it is unclear whether the TSK was a valid measure for youth undergoing surgery. Therefore, the goal of Study 3 was to evaluate the psychometric properties of the TSK among youth undergoing major surgery.

Exploratory factor analysis showed a poor model fit with a one-factor model (17-items) TSK and a slightly better fit with a two-factor model that separated four reverse scored items from the remaining 13 positively scored items. The model fit indices were not ideal for a two-factor model, which was consistent with the studies conducted in adults (Clark et al., 1996; Goubert et al., 2004; Swinkels-Meewisse et al., 2003). The reverse scored items were removed and an exploratory factor analysis on the 13-item TSK showed a stronger model fit with three factors defined. The three factors included: Fear of injury (fear of moving due to the risk of re-injury), bodily vulnerability (belief that the body is vulnerable to pain and injury), and activity avoidance (belief that activities should be avoided).

The 13-item TSK yielded adequate internal consistency. It had weak convergent validity with measures of pain intensity, pain unpleasantness, and pain avoidance while in hospital after surgery. The 13-item TSK was shown to be distinct from a measure of general anxiety, showing some discriminant validity. However, it was not distinct from a measure of depression or the

avoidance subscale of pain-related anxiety, and it was not correlated with actual acute postoperative physical movement on the second day after surgery. The 13-item TSK showed adequate predictive validity for pain-related disability 12-months after surgery. It is possible that the 13-item TSK would yield stronger convergent, divergent, discriminant, and predictive validity if measured after the youth's experienced the pain from surgery.

The results from this psychometric analysis of the TSK provide initial support for the use of the 13-item TSK in youth undergoing surgery. It also supports the association between fear of movement/ re-injury and subsequent disability. These findings are consistent with the cognitive-behavioural fear-avoidance model of chronic pain (Vlaeyen et al., 1995; Vlaeyen & Linton, 2000).

Integrative Synthesis

Over the last decade, the field of pediatric perioperative pain has grown. Nine prospective longitudinal studies have been conducted using various measures and timepoints to assess post-surgical pain. Generally, these studies have used small sample sizes and evaluated a limited number of youth risk factors for the development of post-surgical pain to the exclusion of parent factors. With methodology and risk/protective factors informed by the adult perioperative pain literature (Katz & Seltzer, 2009) and the pediatric fear-avoidance model of chronic pain (Asmundson et al., 2012), this dissertation contributes significantly to filling this gap in our literature and understanding the course of perioperative pain in youth undergoing major surgery as well as the risk/protective factors for the development of pediatric chronic post-surgical pain and functional limitations. The first study showed that 35% and 38% of youth undergoing major surgery report moderate-to-severe chronic post-surgical pain six and 12 months after surgery,

respectively. It also revealed two trajectories for pain intensity and pain unpleasantness (moderate-to-severe pain intensity/ unpleasantness versus none-to-low pain intensity/ unpleasantness). The results showed that just over 30% experience moderate-to-severe functional limitations, which is an important finding because when pain is accompanied by any activity limitation, the incremental cost is $1,548/ year as compared to average pain intensity incremental costs of $956/ year (Hogan et al., 2015). These incidence rates and trajectories indicate that evaluating the factors contributing to the transition from acute to chronic post-surgical pain in children and adolescents is crucial for improving outcomes.

This dissertation examined several risk/protective factors for group pain intensity and pain unpleasantness trajectory membership and 12-month functional limitations, which included youth general anxiety, youth depression, youth pain-related anxiety and worry, youth symptoms of posttraumatic stress, youth functioning, youth fear of movement/ re-injury, parent general anxiety and worry, parent pain-related anxiety and worry, parent depression, parent pain flexibility. Greater functional disability prior to surgery and cumulative 5-day in-hospital opioid consumption significantly predicted membership in the moderate-to-severe pain intensity group. A unique contribution to the field was the finding that greater functional disability prior to surgery predicted membership in the moderate-to-severe pain unpleasantness group. The second study showed that there are differential predictor profiles for general versus pain-related functional limitations 12-months after surgery. Namely, general functional limitations are best predicted by youth pre-surgical general functional limitations and parent baseline anxiety sensitivity whereas pain-related functional limitations are best predicted by a combination of presurgical youth (pain-related anxiety and worry factor) and parent factors (anxiety sensitivity, state-trait anxiety, pain anxiety).

However, as found in Study 3, we are limited by the measurement tools available to assess psychological constructs in youth perioperatively. The TSK is one such example of this limitation, where a modified 13-item version of the tool is a psychometrically better measurement of a fear of movement/ re-injury than the original 17-item TSK. Overall, second and third study highlight the need for researchers and clinicians to be thoughtful about which measures they use to evaluate risk/ protective factors as well as outcome measures within the context of pediatric chronic post-surgical pain.

Research & Clinical Implications

There are several research and clinical implications to these three studies. First, youth with moderate-to-severe pain intensity/unpleasantness prior to surgery are likely to stay on a moderate-to-severe pain intensity/unpleasantness trajectory up to 12-months after surgery. This finding is in line with previous studies that conducted trajectory analyses showing that there are a small group of patients with high pain intensity who maintain a high pain intensity for up to a year after surgery (Connelly et al., 2014; Rabbitts et al., 2015; Sieberg et al., 2013) however they did not also measure (or report) pre-surgical functional limitations. One of the original and novel findings of this dissertation is that pre-surgical general functional limitations predict post-surgical general functional limitations. That is, without intervention, greater pre-surgical functional limitations are associated with moderate-to-severe functional limitations 12-months after surgery. Replication of these findings is important; therefore, future studies should include a measure of functional limitations in their assessment of risk factors for chronic-post surgical pain and chronic functional limitations. Clinically, it will be helpful to set expectations of recovery for patients and their families because, based on their pre-surgical pain and functional

limitations pain, and pain and functional limitations can be predicted up to one year after surgery.

Second, since Pagé, Campbell, et al. (2013), this was the first study to include multiple measures of parent psychological distress and functioning, including measures of anxiety, depression, pain flexibility, and pain-related anxiety and worry. Specifically, the role of parent/caregiver psychological responses to their youth's pain experience was evaluated. The second study showed that parent anxiety sensitivity plays a significant role in youth 12- month post-surgical functional limitations (general and pain-related). While data collection for this dissertation began prior to the inception of the pediatric fear-avoidance model of chronic pain (Asmundson et al., 2012), the results provide support for the notion that parents do influence their youth's pain-related functional outcomes after surgery. The empirical evidence gleaned from this study supports the need to fully test the pediatric fear-avoidance model of chronic pain within the context of major surgery.

Third, the third study of this dissertation provides promising results for the validation of a modified Tampa Scale for Kinesiophobia (TSK-13) that can be used in future studies. With this new measure, it is possible to test the fear of movement/ re-injury construct among children and adolescents. This is an important step in understanding whether, and to what extent, a fear of movement/ re-injury plays a role in the development and maintenance of pediatric chronic post-surgical pain.

General Limitations

There are several limitations to this dissertation. First, the generalizability of the large study is affected by the sample used. While this study recruited 34% of participants from diverse

racial backgrounds and this is the most diverse samples studied in this area of research, the sample consisted of primarily White and Caucasian youth and their parents. Nafiu et al. (2020) found that being African American was associated with an increased likelihood of a youth experiencing post-surgical complications and mortality. The generalizability of this study is limited by the immigration status of the sample (i.e., participants were required to speak and read English) and self-selection bias with both the youth and parent agreeing to be followed pre-surgically to a year following surgery. Future studies should strive for a more inclusive and representative sample of youth undergoing major surgeries and their parents. Second, as with all other studies in this area, we did not conduct physical examinations on the youth pre- and post-surgically which means that we cannot be certain of the percentage of youth whose chronic post-surgical pain developed post-operatively or whose pain started prior to surgery. Third, this study measured parent psychosocial factors pre-surgically and 12-months after surgery. It is possible that their cognitive appraisals and emotional reactions change over time and with the experience of their youth having major surgery. Future studies should more closely examine the role that parent's play in their youth's pain and functional outcomes following surgery. Finally, although Studies 1 and 3 use the full sample (n = 264), Study 2 is limited by its smaller size and therefore more sophisticated analyses, such as structural equation modelling, that could evaluate the indirect relationship between parent anxiety sensitivity and youth 12-month functional limitations were not conducted. However, even with a small sample size, parent factors were shown to play a role in youth pain-related and general functional limitations, therefore future studies should aim to have a larger sample size with more frequent assessment timepoints to fully examine the influence that they have on their youth's outcome.

Directions for Future Research

This dissertation promotes two main directions for future research within the field of pediatric pain.

First, given that the third study provided initial validation of the 13-item Tampa Scale for Kinesiophobia (TSK-13), it will be important for future studies evaluate the psychometric properties of this new scale. Specifically, the factor structure of the TSK-13 has to be confirmed through, for example, a confirmatory factor analysis conducted in a sample of youth undergoing surgery. The validity of the TSK-13 could also be strengthened by testing face validity among youth undergoing major surgery as well as through in chronic pain clinics. Further, evaluating the test-retest reliability will be helpful to understand if a fear of movement/ re-injury is a construct that is stable over time or whether it changes as a function of experience (e.g., pre- to post-surgery).

Second, youth anxiety and worry as well as parent anxiety sensitivity were found to be significant predictors of chronic post-surgical pain and pain-related functional outcomes. The association seen between these factors is commonly seen in children with chronic pain. To the extent that these risk factors are causal, it is reasonable that the next step in this area is to develop a perioperative intervention for reducing the impact that anxiety, worry, and anxiety sensitivity have on pain-related outcomes after surgery. Preventing chronic post-surgical pain is a top priority for youth in need of surgery, as well as for provincial and federal healthcare systems (Birnie et al., 2019). Early pain interventions can reduce progression of chronic pain, pain severity, disability, and healthcare costs (Groenewald et al., 2014; Huguet & Miro, 2008). For pediatric chronic pain, the optimal treatment model is an interdisciplinary “3-P” approach

(pharmacological, physical, psychological; Peng et al. (2007)) that reflects the fact that that pain is a biopsychosocial phenomenon (Simons et al., 2011; Stone & Wilson, 2016). A 3-P approach is in line with Transitional Pain Services (TPS; tertiary care interdisciplinary health service models designed for the prevention of the transition from acute to chronic pain) for adults that have preliminary support for their effectiveness (Azam et al., 2017; Katz et al., 2015; Weinrib et al., 2017). In light of this dissertation's finding that parents play a role in pediatric perioperative pain outcomes, it is likely that a "4-P" approach, including parent factors, is fitting for treatment. The psychological component for youth of this service is also important, as it works to reduce suffering from pain and to enhance what is being offered by physicians, nurses, and physiotherapists. Specific goals of psychological intervention could include pain management planning, treatment of distress and associated mental health issues that have the potential to amplify pain and increase opioid use, and enhancing values-based activities thereby reducing pain-related disability (Katz et al., 2015). Psychological perioperative intervention, as part of a TPS and as a stand-alone treatment (Davidson et al., 2016; Williams et al., 2017), has not yet been developed for pediatric patients—a major gap in both research and clinical care that is leaving thousands of young people with post-surgery chronic pain.

Conclusions

Research on the transition from acute to chronic pain is an area of growth in the pediatric pain field. This dissertation presents the results of three studies based on a large sample of youth undergoing major orthopedic and general surgery and the youth's parent. It evaluates the course of pain experienced by youth, predictors of the transition to pain chronicity, and the measurement of a commonly used risk factor scale in adults. Results indicate that this is an at-

risk population for chronic pain, with 35% and 38% of youth reporting moderate-to-severe chronic post-surgical pain six and 12 months after surgery, respectively. Importantly, this dissertation shows that 30% of youth undergoing surgery have moderate-to-severe general functional limitations 12 months after surgery. This deleterious outcome is best predicted by pre-surgical functional limitations and parent pre-surgical anxiety sensitivity. Pain-related functional limitations are predicted by a combination of presurgical youth (pain-related anxiety and worry factor) and parent factors (anxiety sensitivity, state-trait anxiety, pain anxiety). These results indicate that there are areas for pre-surgical intervention that include both youth and their parent.

Further, this dissertation found that the measurement for a fear of movement/ re-injury is better served by a modified Tampa Scale for Kinesiophobia that includes 13 items, not the original 17 items. There is psychometric promise for this scale, but it requires additional validation and reliability testing in similar pediatric surgical populations as well as chronic pain populations.

This dissertation provides information about the transition from acute to chronic pain. Specifically, it improves our understanding of youth and parent risk/protective factors associated with the development and maintenance of pediatric chronic post-surgical pain and functional limitations. It paves the way for developing novel interventions to prevent the development of chronic post-surgical pain.

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