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Validating a home based quantitative sensory testing (QST) paradigm for two pediatric/young adult patient groups: I. Orthopedic surgery with regional anesthesia, and II. Sickle cell disease

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BOSTON UNIVERSITY

ARAM V. CHOBANIAN & EDWARD AVEDISIAN SCHOOL OF MEDICINE

Thesis

VALIDATING A HOME BASED QUANTITATIVE SENSORY TESTING (QST)

PARADIGM FOR TWO PEDIATRIC/YOUNG ADULT PATIENT GROUPS:

I. ORTHOPEDIC SURGERY WITH REGIONAL ANESTHESIA, AND

II. SICKLE CELL DISEASE

by

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DEDICATION

I would like to dedicate this work to my beloved parents, whose unwavering support and sacrifices have made this journey possible.

ACKNOWLEDGMENTS

I would like to express my deepest gratitude to Dr. Izabela Leahy for granting me the opportunity to participate in the Pediatric Anesthesia Clinical and Research Internship (PACaRI) and for her invaluable guidance throughout the program. I am also sincerely grateful to Dr. Charles Berde for welcoming me into his lab and working closely with me to advance and complete my research. Lastly, my heartfelt appreciation goes to Dr. Don Daniel Ocay, whose unwavering support and mentorship have guided me through every step of this research journey. Their encouragement, expertise, and dedication have been instrumental in my growth as a researcher, and I am truly thankful.

VALIDATING A HOME BASED QUANTITATIVE SENSORY TESTING (QST)

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ABSTRACT

Pain assessment and management in pediatric patients is crucial for improving health outcomes and quality of life. Quantitative Sensory Testing (QST) is a valuable tool for evaluating sensory function and pain processing, but traditional laboratory-based QST (L-QST) is often limited by its cost, complexity, and accessibility. This study aimed to validate the feasibility, safety, and effectiveness of proxy- or self-administered QST (P/SA-QST) for remote pain assessment in pediatric patients with sickle cell disease (SCD) and those undergoing orthopedic surgery with regional anesthesia.

Two independent studies were conducted at Boston Children's Hospital, enrolling patients aged 6–18 years with SCD and patients aged 8–25 years undergoing orthopedic procedures with regional anesthesia. P/SA-QST assessed mechanical and thermal detection and pain thresholds, and results were compared to L-QST. Statistical analyses, including correlation coefficients and Bland-Altman plots, were used to evaluate agreement between P/SA-QST and L-QST. Additionally, participants and caregivers completed a questionnaire on P/SA-QST's acceptability and safety.

Results demonstrated significant weak-to-moderate associations between P/SA-QST and L-QST in assessing vibration detection, pressure pain threshold, and pinprick sensitivity. The P/SA-QST tool-kit successfully detected changes in sensory function following regional anesthesia, with significant alterations in mechanical and vibratory sensitivity across postoperative time points. High participant acceptability was observed, with no adverse events reported. Identified challenges included minor usability concerns related to certain tools and the need for clearer instructional materials.

Findings demonstrated strong agreement between P/SA-QST and L-QST, supporting its potential of P/SA-QST as a cost-effective, accessible alternative to L-QST for pediatric pain assessment. Further research should explore its long-term reliability and applicability across broader patient populations.

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LIST OF ABBREVIATIONS

ASA	American Society of Anesthesiologists
BU	Boston University
DMA	Dynamic Mechanical Allodynia
H-QST	Home-based Quantitative Sensory Testing
L-QST	Laboratory-based Quantitative Sensory Testing
MDT	Mechanical Detection Threshold
MPT	Mechanical Pressure Threshold
PACU	Post Anesthesia Care Unit
PinPS	Pinprick Sensitivity
POD	Postoperative Day
PPT	Pressure Pain Threshold
PrePS	Pressure Pain Sensitivity
P/SA-QST	Proxy- or Self-administered Quantitative Sensory Testing
QST	Quantitative Sensory Testing
SCD	Sickle Cell Disease
SMA	Static Mechanical Allodynia
SMD	Static Mechanical Detection
VDT	Vibration Detection Threshold
WUR	Wind up Ratio

CHAPTER ONE

Introduction

Statement of the Problem

Assessment and treatment of pain are core aspect of health care. Patients' pain experiences involves an interplay of injury, inflammation and peripheral nerve activation along with complex processing in the central nervous system. Pain experiences vary among individuals, and a similar injury or stimulus can cause different pain intensities on different occasions, partly based on how the central nervous system can be influenced by past pain experiences. The term "acute pain" refers to pain associated with a specific triggering tissue injury, such as surgery, trauma, or acute inflammatory conditions. Pain in pediatric patients is particularly important because it can significantly impact their physical and emotional development (Andersson et al., 2022). Children experience pain in various ways, from acute conditions like orthopedic surgery to chronic illnesses such as sickle cell disease. Proper pain management is crucial to prevent long-term psychological distress, improve healing, and enhance overall quality of life (IASP 2021).

Acute Postoperative Pain

Acute pain due to surgery or an injury is usually most severe for several days, and in a majority of patients, it steadily improves over the next week or two. However, children undergoing orthopedic procedures may experience significant postoperative pain that requires careful assessment and management (Johnson et al., 2021). If inadequately treated, acute pain can lead to prolonged discomfort, delayed recovery, and even long-

term complications such as chronic pain or heightened pain sensitivity (Fitzgerald & Walker, 2009). A small but significant subset of patients continues to have moderate to severe pain for many months after surgery or major injuries, with the estimated incidence ranging from 20-30% for chronic pain at 6 to 12 months after surgery (Rosenberger et al., 2022). Understanding the mechanisms that contribute to persistent acute pain and identifying strategies to treat or prevent prolonged pain after surgery or injuries are of considerable clinical importance.

Regional Anesthesia

Regional anesthesia and analgesia involve the administration of local anesthetic medications to provide pain relief during and after surgery. For many types of surgery, regional anesthesia has been shown to provide pain relief, while reducing the need for opioid analgesics. A major technical advancement in regional anesthesia is the widespread use of ultrasound-guided peripheral nerve blocks and plexus blocks for accurate needle placement (Obal et al., 2011). Currently available local anesthetics such as bupivacaine and ropivacaine typically provide pain relief for approximately 4-12 hours in pediatric patients after a single injection (Lönnqvist 2022). Pain relief can be prolonged by administering these local anesthetics on an infusion pump, either in hospital or at home. For some types of surgery, regional anesthesia might also reduce the frequency and severity of prolonged postoperative pain. In pediatric patients, regional anesthesia reduces opioid consumption, decreases length of stay, and increases patient/parental satisfaction when error traps, such as failure to recognize diseases with

abnormal anatomy that may require other blockers, are avoided (Masaracchia et al., 2021).

Chronic Pain

Chronic pain, as defined by the International Association for the Study of Pain, persists for more than three months and can manifest either as recurrent episodes or a continuous state of discomfort (Treede et al., 2019). This condition can have severe effects on quality of life, particularly for pediatric patients. Chronic pain in children and adolescents is not only associated with physical discomfort but also impacts social, emotional, and educational aspects of their lives. For instance, children suffering from chronic pain may have trouble maintaining social relationships and achieving academic success due to frequent school absences and reduced participation in social activities (Groenewald et al., 2020). A systematic review conducted in 2024 found that the prevalence of chronic pain among children and adolescents ranges from 11% to 38% (Chambers et al., 2024). Although significant research has been undertaken to elucidate these statistics, inconsistencies in findings complicate our understanding of chronic pain in this vulnerable population.

Sickle Cell Disease

Among the myriad conditions that contribute to chronic pain in pediatrics, sickle cell disease (SCD) stands out as a particularly impactful disorder. In the United States, approximately 1 in 2000 births results in a child diagnosed with SCD (Asnani et al., 2016). This genetic condition in the *HBB* gene is characterized by the production of abnormal hemoglobin, leading to a range of complications that can ultimately cause

significant organ damage. Early manifestations of SCD often include jaundice, anemia, and susceptibility to infections, but the complications escalate with age. The quality of life for children with SCD, along with that of their caregivers, is severely affected. For example, many complications, including strokes and pulmonary disease, manifest during childhood, leading to frequent hospital visits and prolonged school absences (Asnani et al., 2016). These medical challenges often hinder children's ability to engage fully in social and academic settings. Moreover, coping with SCD frequently results in reduced social interaction, anxiety, and depression due to the myriad implications of this aggressive disease (Anie & Green, 2015). The burden of managing a child's health can also take a toll on parents, both emotionally and financially, leading to coping issues and strained family relationships (Asnani et al., 2016).

The most significant complication faced by patients with SCD is pain, which can begin in infancy (Smith & Scherer, 2010). The pain caused by SCD is linked to the formation of sickle-shaped hemoglobin, particularly in its deoxygenated state. This abnormal hemoglobin can aggregate, causing red blood cells to become rigid and sticky, leading to occlusions in the microvasculature (Smith & Scherer, 2010). Pain episodes, commonly referred to as "crises," result from episodic tissue ischemia and injury, and pediatric patients typically experience these crises an average of once a year (Karafin et al., 2019). These episodes are often unpredictable, adding another layer of stress for patients and families. Additionally, SCD pain is associated with colder temperatures, touch, and increased wind speed and barometric pressures (Brandow et al., 2011). To manage this pain, patients often receive oral or intravenous opioids. While opioids are

effective in managing acute pain, their use raises concerns about long-term consequences, including opioid misuse and psychiatric morbidity in adulthood (Tutelman et al., 2021). Understanding the multifaceted nature of pain in pediatric patients with SCD, comprising both acute and chronic components, is essential for effective assessment and management.

Quantitative Sensory Testing

In recent years, quantitative sensory testing (QST) has emerged as a valuable tool for understanding pain in various populations, including those with SCD (Miller et al., 2019). QST assesses sensory responses to systematically applied and quantifiable stimuli, utilizing psychophysical methods to neurologically examine somatosensory function (Rolke et al., 2006). This methodology is particularly important in populations with complex pain conditions, such as SCD and post operative patients who have experienced regional anesthesia, as it may enable researchers and clinicians to identify unique pain profiles and develop tailored treatment strategies. QST addresses one of the main limitations in treatment outcomes for chronic pain, the diversity of the population, by phenotyping patients for potential personalized approaches (Ocay et al., 2022). Furthermore, its noninvasive nature makes it a suitable approach for children and adolescents, who may otherwise find clinical assessments such as nerve conduction/EMG studies daunting. QST is able to assess small fiber neuropathies whereas nerve conduction/EMG assess large fiber neuropathies. QST has been well tolerated in healthy volunteer children and adolescents and even in children with diverse chronic pain conditions (Blankenburg et al., 2010).

Rationale

However, the application of QST in pediatric SCD and post- regional anesthesia patients faces several limitations. Laboratory-based QST (L-QST) can be complex and time-consuming, creating challenges within the constraints of clinical routines (Ocay et al., 2025). These limitations hinder its feasibility in routine pediatric care, where time and resource efficiency are paramount. In the sickle cell population, there are additional barriers to conducting QST during resting steady-states compared to during or after vaso-occlusive episodes. Pain reports from children are subjective and can vary significantly based on their immediate circumstances and emotional states, leading to potential bias (Miller et al., 2019). Despite these challenges, advancements in technology and methodology have demonstrated the utility of bedside QST tools for clinical screenings (Stinson et al., 2022). For example, bedside QST tools have been employed successfully in pediatric orthopedics to streamline pain assessment and enhance patient outcomes (Stinson et al., 2022).

The concept of home-based quantitative sensory testing (H-QST) builds on these advancements, aiming to make pain assessment even more accessible and patient friendly. H-QST allows patients to conduct pain assessments in a familiar and comfortable environment, potentially improving compliance and reducing the burden of frequent hospital visits. The COVID-19 pandemic underscored the importance of remote methodologies in clinical care and research, highlighting the necessity of flexible and accessible pain assessment tools. By enabling patients to perform evaluations in their homes, H-QST not only minimizes logistical barriers but also facilitates repeated

monitoring of pain perception and sensory function over time. This approach aligns with the broader trend toward telemedicine and remote health monitoring, which have gained significant traction in recent years.

QST has also been used to study the time course and intensity of regional anesthesia in healthy volunteers (Lobo et al., 2015) and in patients undergoing surgery (Curatolo et al., 2000). With the increasing trend towards sending patients home on the day of surgery, even after extensive operations, there is practical importance in having home-based methods of assessing pain and function that do not rely on in-person face-to-face measurements.

Our team has already developed and validated self-administered QST in healthy young adult volunteers, demonstrating its feasibility (Ocay et al., 2025). However, the translation of these methodologies into a home setting for pediatric/young adult clinical populations remains largely unexplored.

Therefore, the objective of this research study is to determine whether proxy- or self-administered QST (P/SA-QST) is cost-effective for repeated measures across time and easy to use in two groups of youth: 1) those with SCD, and 2) those undergoing orthopedic surgery with regional anesthesia. We hypothesize that there will be a correlation between the results from P/SA-QST and L-QST in our samples of youth with postoperative pain following orthopedic surgery or with SCD. Moreover, we hypothesize that P/SA-QST is safe and easy to use, making it a viable option for remote pain assessment in this population.

Study Aims

- Evaluate whether P/SA-QST is comparable to L-QST
- Assess the safety of P/SA-QST
- Assess the convenience and ease of use of P/SA-QST
- Determine whether P/SA-QST can assess changes in sensory and pain processing after regional anesthesia

CHAPTER TWO

Methods

Experimental Design

Validation of the P/SA-QST toolkit in pediatrics was conducted through two independent, yet related, studies in youth with sickle cell disease, and youth undergoing regional anesthesia for orthopedic procedures. Collaborations were established with individuals both internally within and externally from the Department of Anesthesiology, Critical Care and Pain Medicine at Boston Children's Hospital, with diverse interests, such as Dr. Natasha Archer, MD, the Associate Director of the Sickle Cell program at the Dana Farber/Boston Children's Cancer and Blood Disorders Center, and Dr. Walid Alrayashi, MD, the Director of the Regional Anesthesiology program. Both protocols were approved by the IRB at Boston Children's Hospital (IRB#: P00044877 & P00047222). This approach harnessed data from two different populations leading to diverse feedback on the P/SA-QST toolkit.

Study 1 participants

Participants included patients aged 6–18 years with a confirmed diagnosis of sickle cell disease (SCD), being who were in their baseline state of health, and were not experiencing any acute complications of SCD or other acute illnesses (i.e., steady state). Exclusion criteria included having a chronic dermal disease (e.g., eczema) in the tested areas, an inability to speak, understand, or write in English, physical limitations or developmental delays that would interfere with completing or understanding measures, or

having experienced an acute painful event severe enough to require inpatient treatment with opioids within the past two weeks.

For recruitment, the research team collaborated with the clinical staff at the Dana-Farber/Boston Children's Cancer and Blood Disorders Center. Clinical staff introduced the study to eligible patients through word-of-mouth. If clinical staff identified a patient as eligible, a study coordinator or research team member met with the patient and their parent/legal guardian in the clinic, if possible, or contacted them by phone. Interested individuals participated in a brief meeting with a study coordinator or research team member to determine eligibility and discuss study details before obtaining informed consent. If consent was not given during the meeting, the research team followed up by phone a minimum of three days later. A maximum of three follow-up attempts were made, with at least three days between each attempt.

Study 2 participants

Participants included patients aged 8–25 years who were scheduled for an orthopedic procedure (e.g. shoulder, knee or ankle arthroscopy) with planned regional anesthesia, along with their parent, legal guardian, or another adult with whom they had a close relationship.

Exclusion criteria included having a chronic dermal disease (e.g., eczema) in the tested areas, an inability to speak, understand, or write in English, physical limitations or developmental delays that would interfere with completing or understanding measures, or having an expected test area rendered inaccessible postoperatively due to casting, splinting, or a sling on the extremity undergoing surgery and regional anesthesia.

Additionally, participants with an ASA (American Society of Anesthesiologists) status of 4 or higher were excluded.

Recruitment took place at the Boston Children's Hospital Waltham location. The research team screened patients scheduled up to one month before upper or lower extremity surgery with planned regional anesthesia through a query of medical records. Clinical staff at orthopedic clinics assisted in introducing the study to potential participants. If clinical staff or medical record screening identified a patient as eligible, a study coordinator met with the patient and their parent/legal guardian in the clinic, if possible, or sent a recruitment letter introducing the study. If interest was expressed but consent was not given during the initial contact, the research team followed up by phone a minimum of three days later to confirm interest. If there was no response opting out within two weeks of the recruitment letter, the research team attempted to contact the participants by phone. The study team contacted each dyad up to three times, with at least three days between attempts, or until the day of surgery, whichever came first.

Study 1 procedures

This study was an amendment to the initial study conducted in healthy young adults with a modified experimental design. This study also employed a cross-sectional design to validate the feasibility, safety, and efficacy of a proxy/self-administered-based quantitative sensory testing, P/SA-QST toolkit, for assessing pain in youth with sickle cell disease. Quantitative sensory testing (QST) was performed using both laboratory-based (L-QST) and proxy/self-administered-based (P/SA-QST) toolkits. The sensory testing was conducted in the following order:

- **Laboratory-based QST in person on the forearm:**
 - QST was performed by research students or research staff who received thorough training from experienced members of the research team, specifically Dr. Ocay. Students or staff conducting the tests did so under the supervision and guidance of Dr. Ocay.
- **Proxy (self-administered) QST in a virtual setting on the forearm:**
 - The virtual setting (**Figure 1**) consisted of placing the participant in a room separate from the research staff, with the necessary equipment provided for the P/SA-QST, guided over video communication.

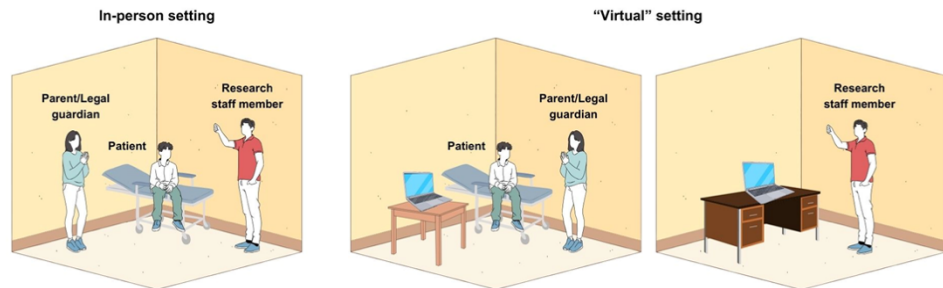


Figure 1. Setting for P/SA-QST

- **Questionnaires:**
 - These were administered electronically using Research Electronic Data Capture (REDCap) survey software to ensure HIPAA compliance or in a paper format.

Laboratory QST Set: The laboratory QST set included a von Frey hair sensory testing kit, a pinprick sensory testing kit, a Somedic SenseLab brush, a Rydell-Seiffer tuning fork, a pressure algometer, and a thermal cutaneous stimulator (TCS 1.II.b). The scores

recorded included mechanical detection threshold, mechanical pain threshold, dynamic mechanical allodynia, vibration detection threshold, pressure pain threshold, cool and warm detection thresholds, and cold and heat pain thresholds and tolerance.

P/SA-QST Toolkit: The P/SA-QST toolkit included a Chicago Medical Supply (CMS) nylon filament wheel, a Q-tip, a foam brush, a 128 Hz medical-grade tuning fork, a Rydel-Seiffer tuning fork, a neurotip, two 10 mL syringes with blocked tips (one filled with air and one with frozen water), and a digital hand warmer. The P/SA-QST was conducted by the participant or, if requested, by their parent, legal guardian, or another adult for patients with SCD. The P/SA-QST scores included:

- **Static mechanical detection:**
 - Starting with the smallest filament of the rotating filament wheel (1g), the tip of the filament was applied for 2 seconds three times, and the participant's perceived sensation was documented (yes/no).
- **Static mechanical allodynia:**
 - Using the largest filament (75g), the tip was applied for 2 seconds three times, and participants indicated whether the stimulus felt like a blunt touch or a pinprick. If it felt like a pinprick, participants rated pain intensity on the NRS-11 scale (0 = no pain, 10 = worst imaginable pain).
 - With a neurotip, the rounded plastic probe was applied for 2 seconds three times, and participants indicated whether the stimulus felt blunt or like a

pinprick. If it felt like a pinprick, pain intensity was rated on the NRS-11 scale.

- **Dynamic mechanical allodynia:**
 - Using a Q-tip, participants brushed their forearm in an “X” shape three times and indicated if the stimulus was painful (yes/no), rating pain intensity on the NRS-11 scale.
 - Using a foam brush, participants brushed their forearm in an “X” shape three times and indicated if the stimulus was painful (yes/no), rating pain intensity on the NRS-11 scale.
- **Vibration detection:**
 - Using a 128 Hz medical-grade tuning fork, participants induced vibration and applied the blunt end to their forearm three times, indicating whether the vibration was perceived at contact (yes/no) and 5 seconds after contact (yes/no).
 - Using a Rydel-Seiffer tuning fork, participants induced vibration and applied the blunt end to their forearm three times, noting the number when they no longer perceived any vibration (x/8).
- **Pinprick sensitivity:**
 - Using a neurotip, the sharp tip was applied for 2 seconds three times, and participants rated pain intensity on the NRS-11 scale.
- **Pressure pain sensitivity:**

- Using the 10 mL syringe filled with air, participants compressed the syringe onto their forearm up to 4 mL for 2 seconds three times and rated pain intensity on the NRS-11 scale.
- Using the 10 mL syringe filled with air, participants compressed the syringe onto their forearm at about 1 mL per second three times and indicated the pressure (mL of compressed air in the syringe) at which it was perceived as painful.
- **Cold pain sensitivity:**
 - Using the 10 mL syringe filled with frozen water, participants applied and held the long surface of the syringe on their forearm three times until they could no longer tolerate the cold (max: 60 seconds).
 - Using the 10 mL syringe filled with frozen water, participants applied and held the long surface of the syringe on their forearm for 30 seconds three times and rated pain intensity on the NRS-11 scale.
- **Heat pain sensitivity:**
 - Using the digital hand warmer at the lowest and medium temperature levels, participants applied and held the hand warmer on their forearm three times until they could no longer tolerate the heat (max: 60 seconds).
 - Using the digital hand warmer at the lowest and medium temperature levels, participants applied the hand warmer to their forearm for 30 seconds three times and rated pain intensity on the NRS-11 scale.

Questionnaire on the Safety and Satisfaction of the P/SA-QST Toolkit: A

questionnaire based on the theoretical framework of acceptability was administered. It consisted of 10 items spanning seven domains (affective attitude, burden, perceived effectiveness, intervention coherence, opportunity costs, self-efficacy, and ethicality), with Likert scales ranging from 1 to 5, leading to a maximum score of 50. Higher scores represented greater acceptability. Participants were encouraged to provide comments on the P/SA-QST toolkit regarding different domains of acceptability.

Study 2 procedures

Quantitative sensory testing (QST) was performed similarly with a few differences. A repeated-measure, within-subject, prospective study was conducted (**Figure 2**). To reduce the burden of clinical perioperative routines, half of the sample was allocated to undergo mechanical QST only, while the other half underwent thermal QST only. At most one hour prior to their scheduled surgery, all patients underwent mechanical or thermal sensory testing using the following protocol:

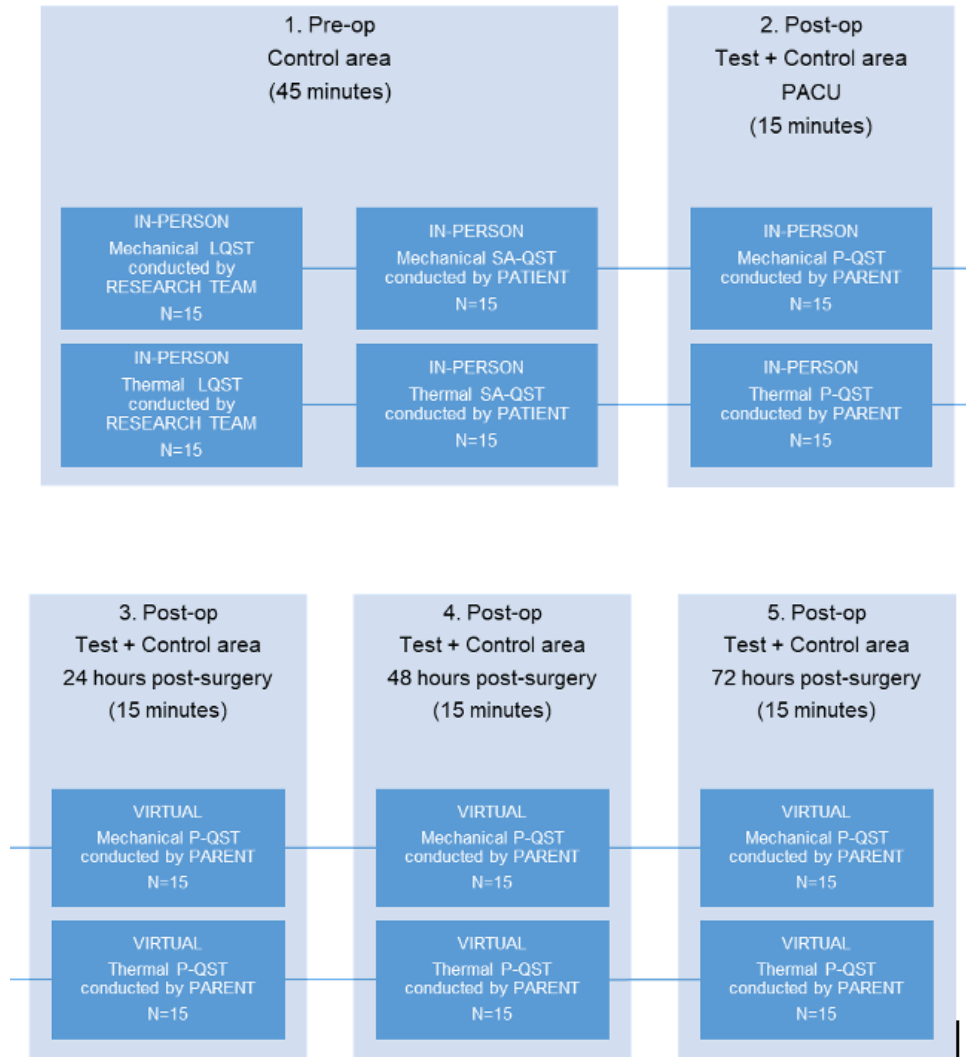


Figure 2. Experimental design of study 2 in youth undergoing regional anesthesia for orthopedic procedures

1. Laboratory-based QST conducted by a member of the research team.
2. SA-QST conducted by the patient.

After full recovery of sensorium in the PACU, all patients underwent P-QST conducted by the same parent/legal guardian/other adult (at least 18 years old) with whom they had a close relationship. Postoperative testing was performed at the following time points:

- PACU
- 24 hours
- 48 hours
- 72 hours

The sensory testing was conducted in the following order:

- **Laboratory-based QST in person on the control area:**
 - QST was performed by trained research students or staff under the supervision and guidance of Dr. Ocay. Testing followed a script to ensure consistency.
 - The control area was the limb contralateral to the limb undergoing surgery, dependent on the surgery, and accessible postoperatively (i.e. dorsal hand, medial lower calf, and hallux).
- **SA-QST in person on the control area by the patient:**
 - The participants were equipped with the necessary tools to complete the P/SA-QST under guidance by the research staff.
- **P/-QST on the control and test area by the parent/legal guardian/other adult:**

- The test area corresponded to the region affected or to be affected by regional anesthesia, and accessible postoperatively (i.e. dorsal hand, medial lower calf, and hallux)
- Postoperative QST was conducted by the same adult to ensure reliability.
- In the PACU, the parents were equipped with the necessary tools to complete the P/SA-QST under guidance by the research staff in person. All other postoperative time points were conducted over video communication guidance by the research staff.

During P/SA-QST assessments, the research team read aloud the instructions to participants. Demonstrations were given in person during laboratory QST and via video communication during P/SA-QST. All participant questions were answered for clarification.

- **Questionnaires**

- Questionnaires were administered electronically using Research Electronic Data Capture (REDCap) Survey Software or in paper format.

Laboratory QST Set: The laboratory QST set included a von Frey hair sensory testing kit, a pinprick sensory testing kit, a Somedic SenseLab brush, a Rydell-Seiffer tuning fork, a pressure algometer, and a thermal cutaneous stimulator (TCS 1.II.b). The scores recorded included mechanical detection threshold, mechanical pain threshold, dynamic mechanical allodynia, vibration detection threshold, wind-up ratio, and pressure pain threshold.

P/SA-QST Toolkit: The P/SA-QST toolkit included a Chicago Medical Supply (CMS) nylon filament wheel, a Q-tip, a neurotip, a Rydel-Seiffer tuning fork, and a 10 mL syringes with a blocked tip (filled with air). The P/SA-QST scores included:

- **Static mechanical detection:**
 - The smallest filament of the rotating filament wheel (1g) was applied for 2 seconds three times, and the participant's perceived sensation was documented (yes/no).
- **Dynamic mechanical detection:**
 - Using a Q-tip, participants brushed a 5-cm area on the test area three times and compared stimulus intensities between regions affected and unaffected by regional anesthesia.
- **Static mechanical allodynia:**
 - With a neurotip, the rounded plastic probe was applied for 2 seconds three times, and participants indicated whether the stimulus felt blunt or like a pinprick. If it felt like a pinprick, pain intensity was rated on the NRS-11 scale.
- **Dynamic mechanical allodynia:**
 - Using a Q-tip, participants brushed the test area in an “X” shape three times, indicating if the stimulus was painful (yes/no) and rating pain intensity on the NRS-11 scale.
- **Vibration detection:**

- Using a Rydel-Seiffer tuning fork, participants induced vibration, applied the blunt end to the test area three times, and noted the number when vibration was no longer perceived (x/8).
- **Pinprick sensitivity:**
 - Using a neurotip, the sharp tip was applied for 2 seconds, and participants rated pain intensity on the NRS-11 scale. After rating a single pinprick stimulus, the sharp tip was applied 10 times in succession, and participants rated the intensity of their pain after the tenth stimulation. This test was repeated three times.
- **Pressure pain sensitivity:**
 - Using a 10 mL syringe filled with air, participants compressed the syringe onto the test area at about 1 mL per second three times, indicating the pressure (mL of compressed air in the syringe) at which pain was perceived.
 - Participants then compressed the syringe onto the test area up to 4 mL for 2 seconds three times, rating pain intensity on the NRS-11 scale.
- **Cold pain sensitivity:**
 - Using the 10 mL syringe filled with frozen water, participants applied and held the long surface of the syringe on their forearm three times until they could no longer tolerate the cold (max: 60 seconds).

- Using the 10 mL syringe filled with frozen water, participants applied and held the long surface of the syringe on their forearm for 30 seconds three times and rated pain intensity on the NRS-11 scale.
- **Heat pain sensitivity:**
 - Using the digital hand warmer at the lowest and medium temperature levels, participants applied and held the hand warmer on their forearm three times until they could no longer tolerate the heat (max: 60 seconds).
 - Using the digital hand warmer at the lowest and medium temperature levels, participants applied the hand warmer to their forearm for 30 seconds three times and rated pain intensity on the NRS-11 scale.

Questionnaire on the Safety and Satisfaction of the P/SA-QST Toolkit: The same questionnaire employed in study 1 was used for study 2. The questionnaire was based on the theoretical framework of acceptability was administered. It consisted of 10 items spanning seven domains (affective attitude, burden, perceived effectiveness, intervention coherence, opportunity costs, self-efficacy, and ethicality), with Likert scales ranging from 1 to 5, leading to a maximum score of 50. Higher scores represented greater acceptability. Participants were encouraged to provide comments on the P/SA-QST toolkit regarding different domains of acceptability.

Statistical Analysis

The data from both studies were analyzed using Microsoft Excel. Descriptive statistics summarized demographic and clinical characteristics of the study populations.

The primary analyses assessed the association of proxy- or self-administered QST (P/SA-QST) compared to laboratory-based QST (L-QST) using correlation coefficients. Bland-Altman plots evaluated agreement between P/SA-QST and L-QST measures. For within-subject comparisons, paired t-tests were performed based on data normality, with statistical significance set at $p < 0.05$. Linear models were developed to examine the relationship between L-QST and P/SA-QST when conducted by the patient versus the parent/proxy. Additionally, linear models were used to compare different time points when parents/proxy administered P-QST.

Personal Contributions

As part of this research, I played a pivotal role in patient recruitment, data collection, and analysis. My key contributions included:

- 1. Participant Recruitment and Consent:** Collaborated with Dr. Don Daniel Ocaj to identify eligible participants, facilitated recruitment, and obtained informed consent from parents and guardians.
- 2. Quantitative Sensory Testing (QST) Administration:** Conducted the walkthrough for the proxy/self-administered-based QST assessments, ensuring adherence to protocol and participant comfort.
- 3. Data Management and Quality Control:** Collected, organized, and cleaned study data to maintain accuracy and consistency. Managed data entry into REDCap and performed quality control checks.

- 4. Statistical Analysis:** Conducted preliminary statistical analyses, including reliability metrics, Bland-Altman plots, and regression modeling.

Through active participation in these aspects, I developed a strong understanding of QST methodologies, statistical analyses, and pediatric pain assessment. My contributions enhanced the study's execution and provided valuable experience in clinical research and data-driven decision-making.

CHAPTER THREE

Results

Demographics

Upon writing this thesis (end of February 2025), we have approached a total of 12 patients with SCD and 68 patients scheduled to undergo orthopedic procedures with regional anesthesia. To date, we have consented 2 patients with SCD and 24 patients who underwent orthopedic surgery. The results of this thesis will focus on the 15 patients who underwent orthopedic surgery with regional anesthesia and mechanical QST. One participant declined to finish the study after the second time point. Sample characteristics are summarized in **Table 1**. The duration of the L-QST averaged to be 11 minutes \pm 3.26 minutes for all participants, whereas the duration of the P/SA-QST toolkit conducted by the patients averaged to be 7 minutes \pm 2.19 minutes. The duration of the P/SA-QST toolkit conducted by the parents on the patients averaged to 10 minutes \pm 4.81 minutes at T2 in the PACU, 9 minutes \pm 4.10 minutes at T3 postoperative day 1, 8 minutes \pm 3.47 minutes at T4 postoperative day 2, and 7 minutes \pm 3.40 minutes at T5 postoperative day 3.

Table 1. Sample Characteristics	
Characteristic	Total sample (n=15)
Age (years, mean \pm SD)	18.4 \pm 3.7
Gender, n (%)	
Cisgender man	9 (60%)
Cisgender woman	6 (40%)

Race, n (%)	
White	15.0 (100%)
Black/African American	2.0 (13.3%)
Asian	1.0 (6.67%)
Native American / Alaskan Native	0
Native Hawaiian / Other Pacific Islander	0
Other	0
Interracial	3.0 (20%)
Dominant hand, n (%)	
Left	1 (6.67%)
Right	14 (93.33%)

Table 1. Demographic Characteristics, data is presented as mean \pm standard deviation unless otherwise stated

Agreement and associations between proxy/self-administered and laboratory- based quantitative sensory testing

Agreement between P/SA-QST and L-QST scores with similar scales were analyzed using Bland-Altman analysis and presented in **Table 2 & Figure 3**. Overall, acceptable agreement was observed across most possible comparisons between the H-QST and L-QST. There was a significant association between the pain intensity reported after stimulation from the round tip of the Neurotip from only P-QST with the pain intensity reported after 1 stimulation from the 128 mN pinprick during L-QST ($P=0.021$). The

vibration detection threshold recorded from L-QST significantly correlated with the vibration detection threshold recorded from the patient during SA-QST ($P= 0.029$), and by the parent during P-QST ($P= 0.001$). Moreover, the pressure pain threshold recorded from L-QST using the pressure algometer significantly correlated with the pressure pain threshold recorded from the patient during SA-QST ($P= 0.025$), and by the parent during P-QST ($P= 0.018$) using the blocked syringe.

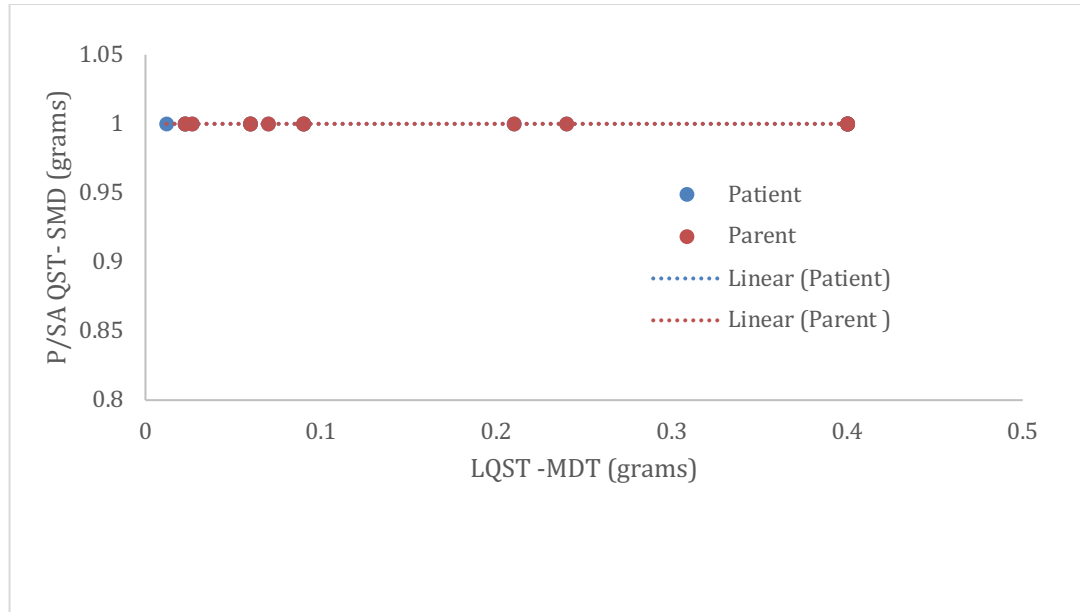
Comparison (P/SA-QST vs L-QST)	Mean difference (95% CI)	Adjusted limits of agreement	Correlation coefficient (p)	P-value
H-SMD (rotating filament wheel) vs L-MDT (von Frey filaments)- patient control area T1	0.781 (0.643, 0.919)	0.422 to 0.992	NA	
H-SMD (rotating filament wheel) vs L-MDT (von Frey filaments)- parent control area T2	0.719 (0.548, 0.889)	0.276 to 0.992	NA	
<i>H-SMA vs L-One 128 mN pinprick stimulation</i>				
Neurotip: round tip- patient control area T1	-0.646 (-1.666, 0.375)	-2.000 to 2.00	-0.006	0.982

Neurotip: round tip- parent control area T2	-1.021 (-1.875, - 0.167)	-2.000 to 2.00	0.609	0.021
<i>H-SMA vs L-DMA (Somedic brush)</i>				
Neurotip: round tip- patient control area T1	0.6 (0.158, 1.042)	-0.966 to 2		
Neurotip: round tip- parent control area T2	0.2 (0.047, 0.353)	-0.341 to 0.741		
<i>H-DMA vs L-DMA (Somedic brush)</i>				
Q-tip- patient control area T1	-0.022 (-0.070, 0.025)	-0.191 to 0.147	NA	
Q-tip- parent control area T2	-0.022 (-0.070, 0.025)	-0.191 to 0.147	NA	
<i>H-vibration sensitivity vs LDT vibrometer</i>				
H-VDT (Ryder-Seiffer tuning fork)- patient control area T1	0.033 (-0.235, 0.302)	-0.917 to 0.983	0.562	0.029

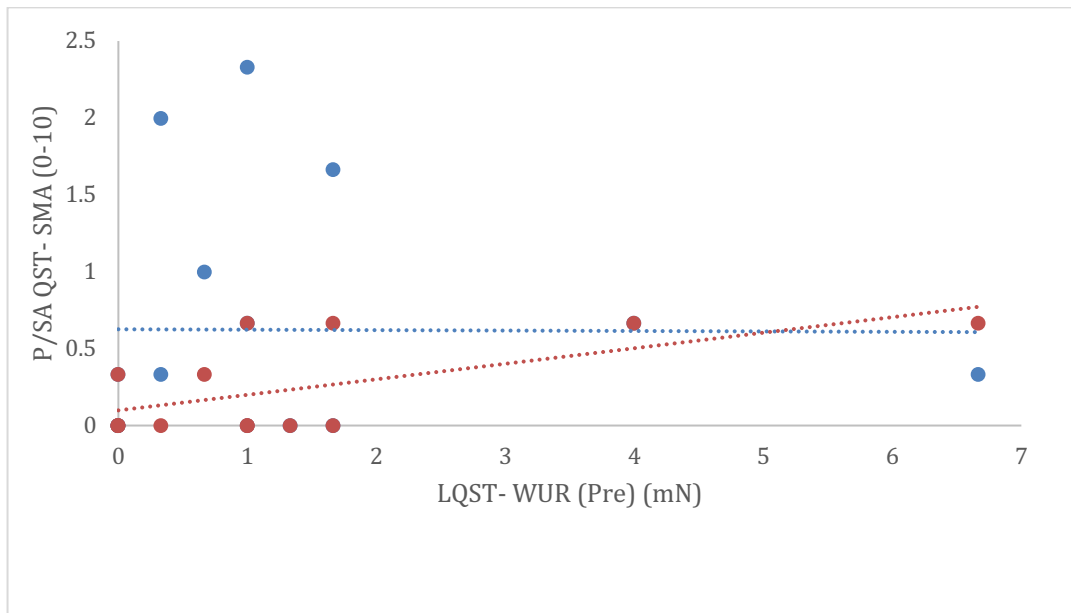
H-VDT (Ryder-Seiffer tuning fork)- parent control area T2	0.202 (0.055, 0.349)	-0.297 to 0.702	0.772	0.001
<i>H-PinPS (Neurotip- sharp tip) vs L-MPT (weighted pinpricks)</i>				
Neurotip: sharp tip- patient control T1			-0.374	0.17
Neurotip: sharp tip- parent control T2			-0.300	0.277
<i>H- PinPS (Neurotip-sharp tip) vs L-WUR (128 mN pinprick)</i>				
Neurotip: sharp tip- patient control T1			0.179	0.524
Neurotip: sharp tip- parent control T2			0.457	0.087
<i>H- PinPS (Neurotip-sharp tip) vs L-One 128 mN pinprick stimulation</i>				

Neurotip: sharp tip- patient control T1	0.438 (-0.691, 1.566)	-3.713 to 4.588	0.164	0.56
Neurotip: sharp tip- parent control T2	-0.25 (-1.456, 0.956)	-4.684 to 4.184	0.097	0.732
<i>H-Pressure sensitivity (air filled syringe) vs PPT (algometer)</i>				
H-PPT- patient control T1			-0.575	0.025
H-PPT- parent control T2			-0.618	0.018
H-PrePS- patient control T1			-0.489	0.064
H-PrePS- parent control T2			-0.309	0.263

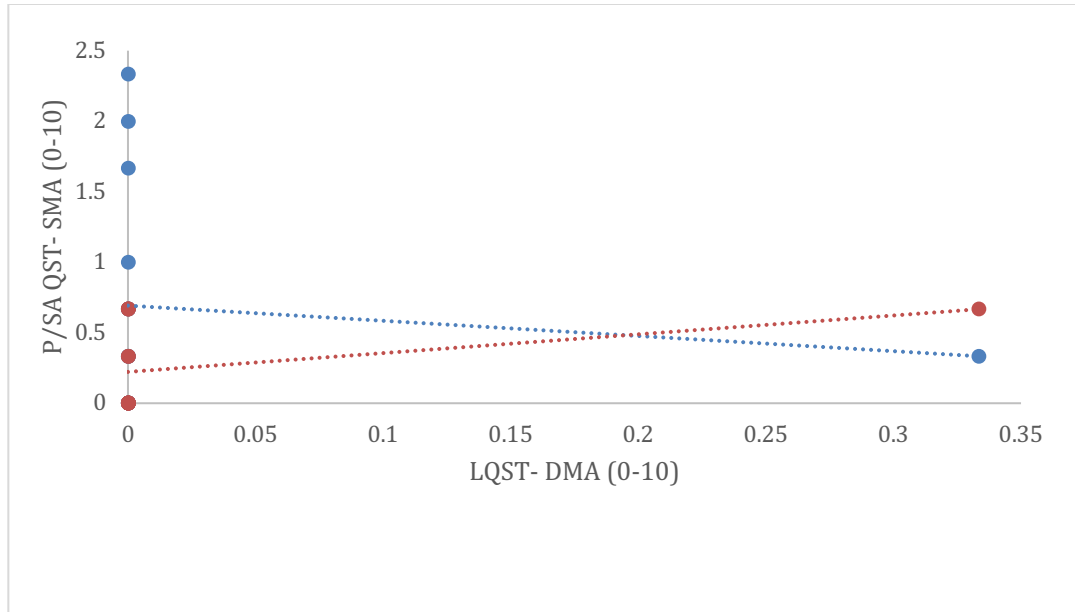
Table 2. Bland-Altman Analysis, Agreement and Association between Proxy/Self-Administered and Laboratory-based Quantitative Sensory Testing



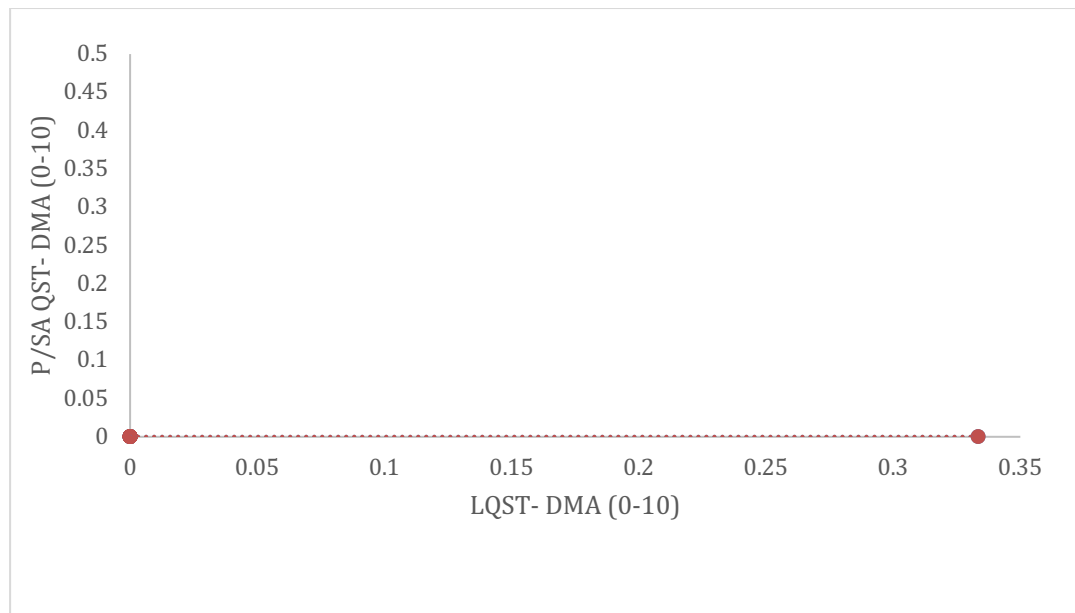
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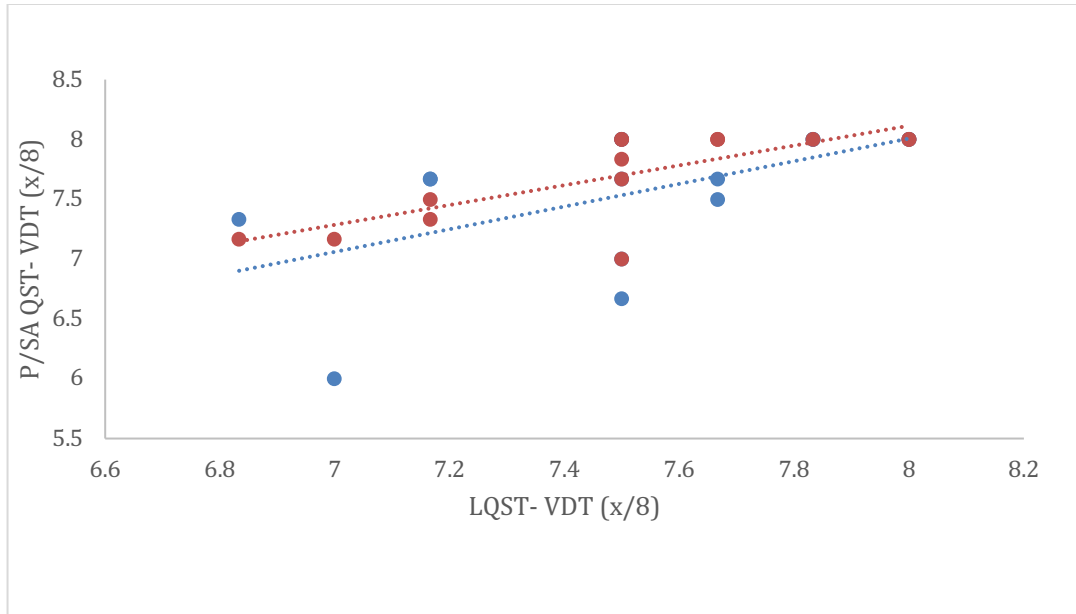
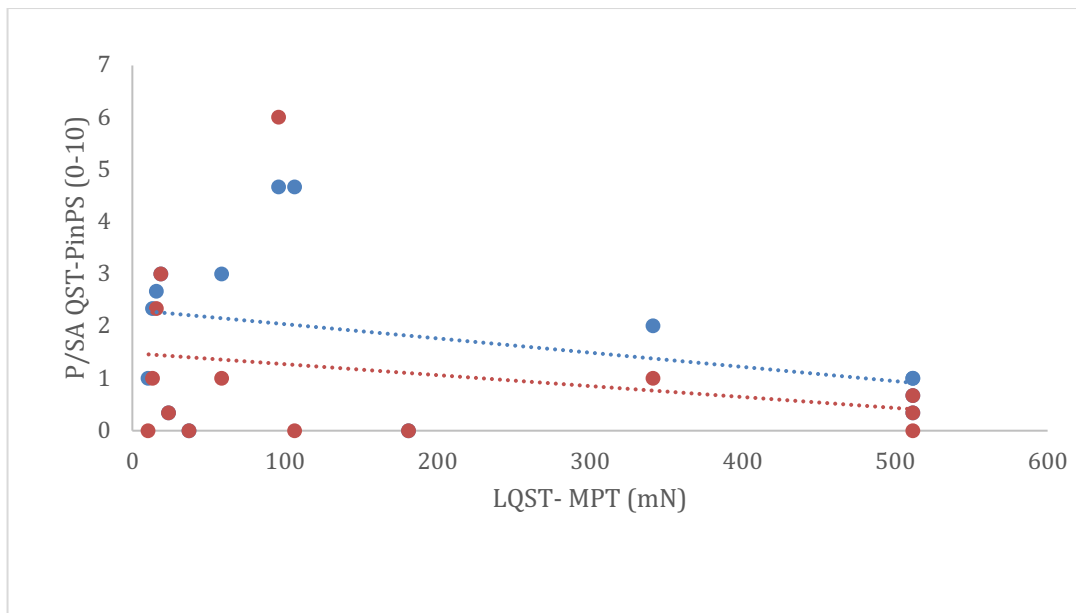
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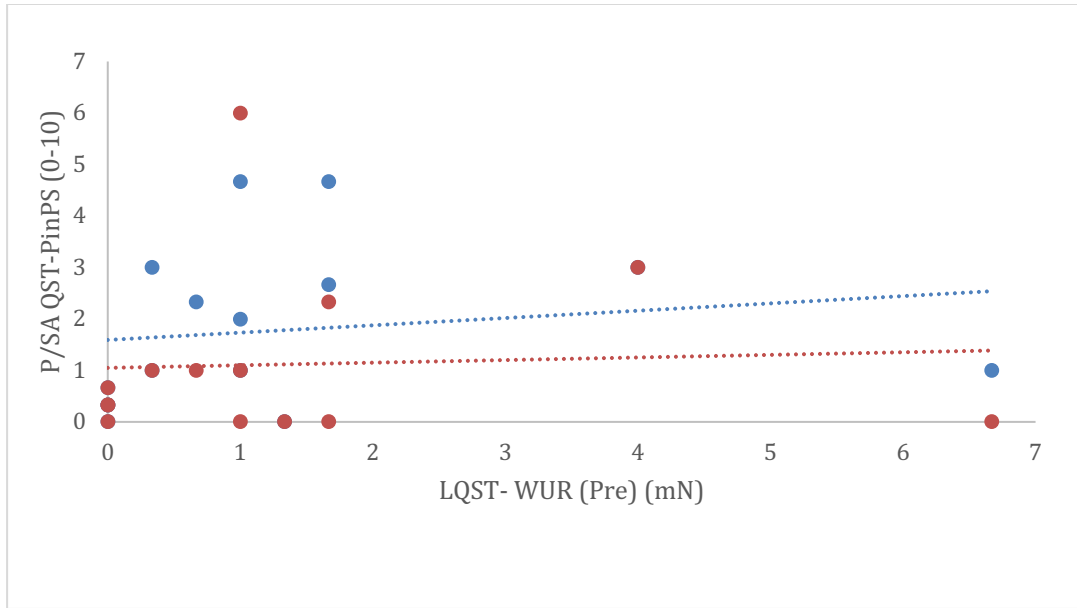


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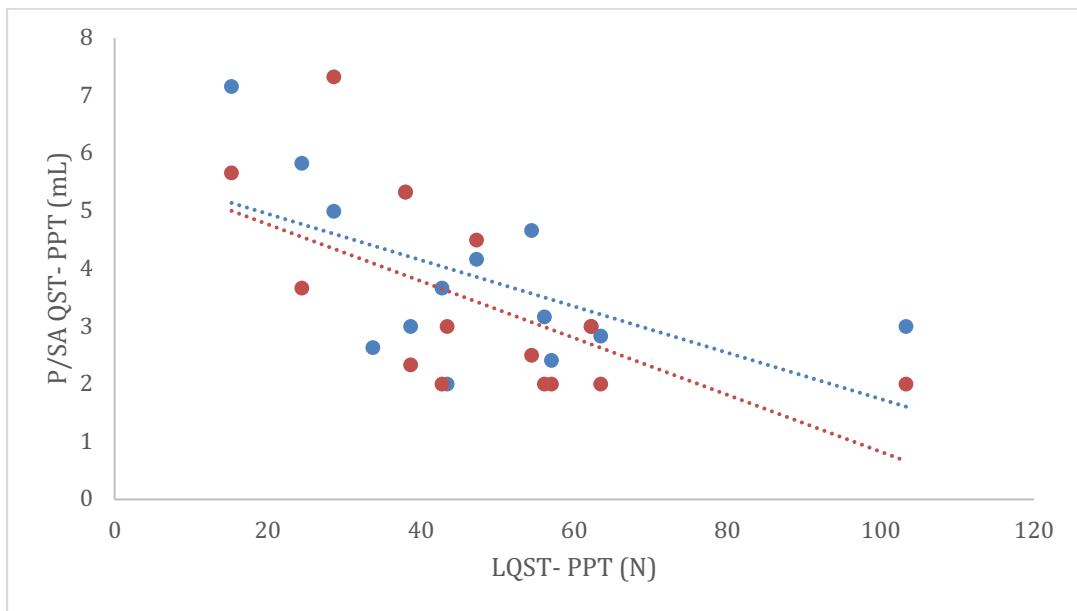


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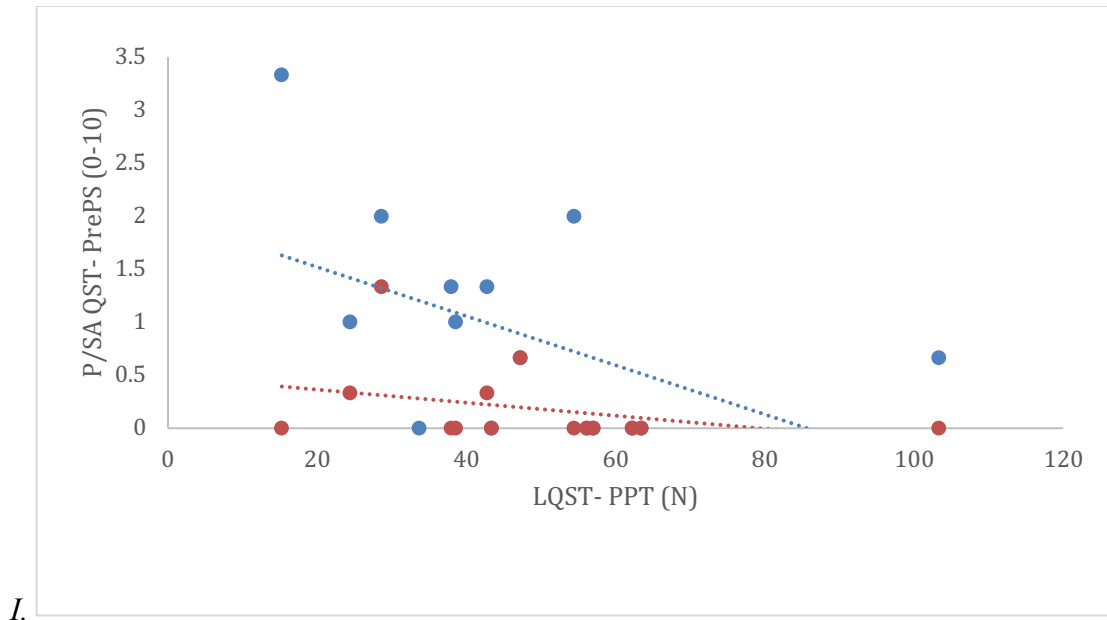
*E.**F.*



G.



H.



I.

Figure 3. Comparing the P/SA-QST scores for each specific test with its counterpart L-QST average. A) L-QST von Frey filaments vs P/SA-QST rotating filament wheel. B) L-QST 128 mN pinprick vs P/SA-QST neurotip round end pain intensity on the NRS-11 scale. C) L-QST Somedic brush vs P/SA-QST neurotip round end pain intensity on the NRS-11 scale. D) L-QST Somedic brush vs P/SA-QST Q-tip pain intensity on the NRS-11 scale. E) L-QST tuning fork vs P/SA-QST Rydel-Seiffer tuning fork vibration detection. F) L-QST 128 mN pinprick stimulation (mN) vs P/SA-QST neurotip sharp tip pain intensity on the NRS-11 scale. G) L-QST 128 mN pinprick vs P/SA-QST neurotip sharp tip pain intensity on the NRS-11 scale. H) L-QST pressure algometer (N) vs P/SA-QST mL of compressed air in the syringe. I) L-QST pressure algometer (N) vs P/SA-QST air filled syringe pain intensity on the NRS-11 scale. P/SA-QST represents proxy- or self-administered quantitative sensory testing; L-QST, laboratory-based quantitative

sensory testing; SMD, static mechanical detection; MDT, mechanical detection threshold; SMA, static mechanical allodynia; WUR, wind up ratio; DMA, dynamic mechanical allodynia; VDT, vibration detection threshold; PinPS, pinprick sensitivity; MPT, mechanical pressure threshold; PPT, pressure pain threshold; PrePS, pressure pain sensitivity.

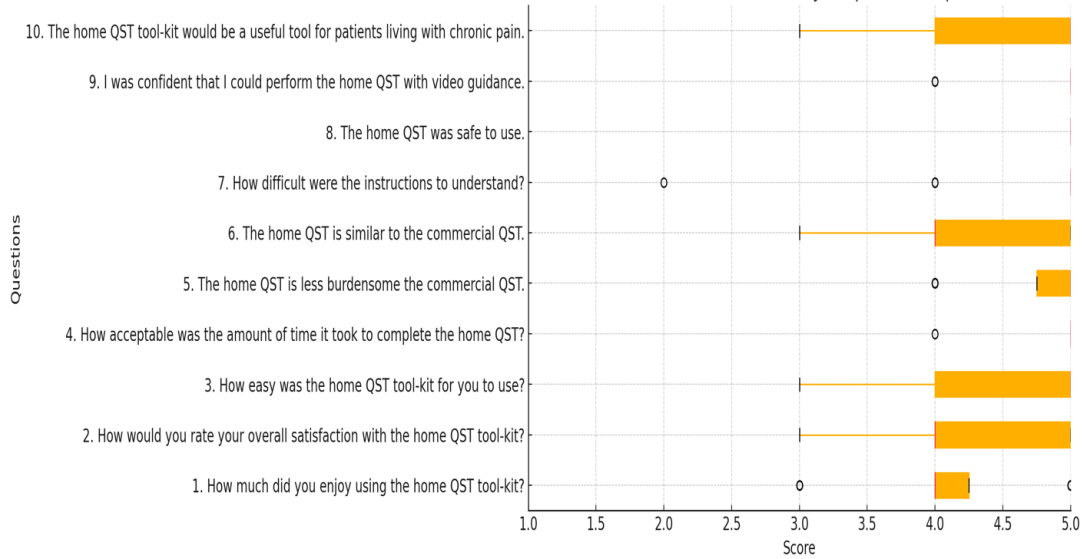
Safety and Tolerability

No adverse events relating to P/SA-QST toolkit were reported. The P/SA-QST toolkit did not evoke visible signs of skin injury. Three participants reported their pain intensity equal to or greater than 5/10 during the pinprick sensitivity test in the control area using the sharp end of the Neurotip. One of those 3 participants reported their pain intensity equal to or greater than 5/10 during the pinprick sensitivity test in the control area using the sharp end of the Neurotip on all timepoints when the parent conducted the P/SA-QST. None of the patients reported a pain intensity equal to or greater than 5/10 during the pressure pain threshold using the blocked syringe.

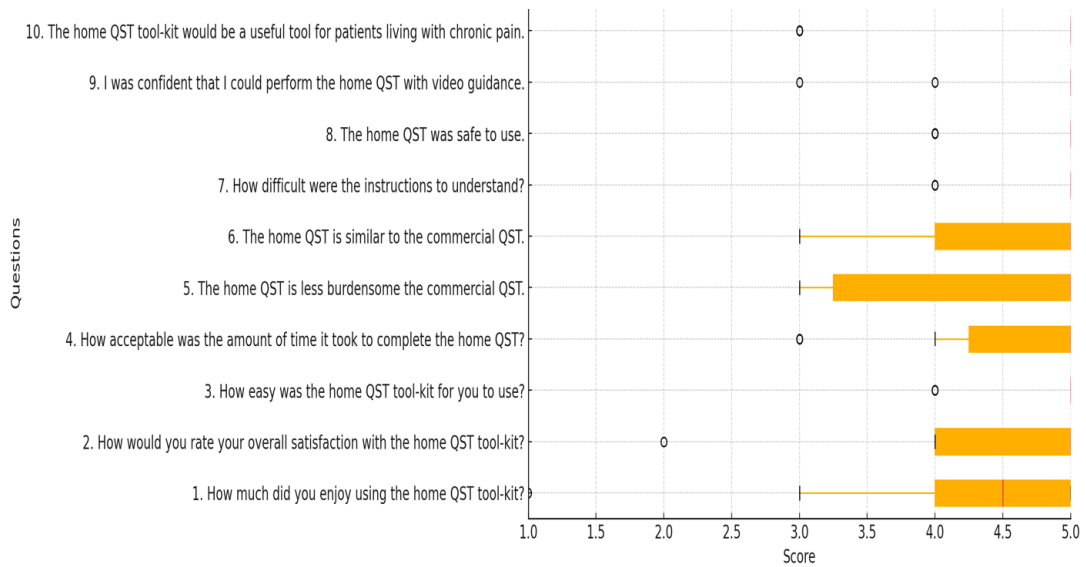
Participants' Comments

The overall acceptability of the P/SA-QST toolkit was high with an average score of 45/50 with a standard deviation of ± 4.72 on our questionnaire (Figure 4). Qualitative analysis of the comments extracted from the questionnaire lead to multiple themes identified across 4 domains.

A. Preoperative



B. PACU



C. Postoperative day 3

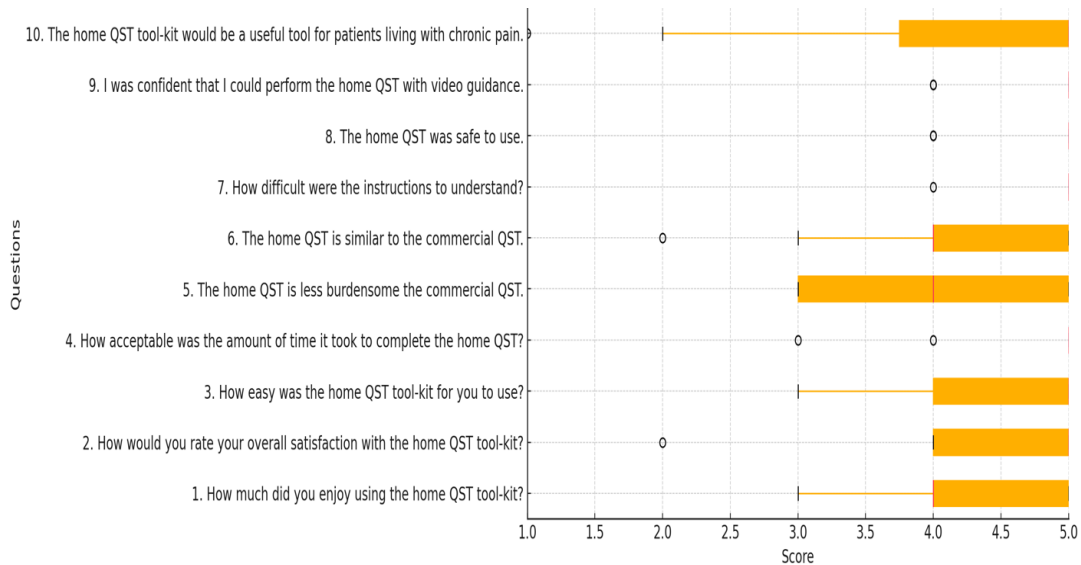


Figure 4. P/SA-QST Satisfaction Survey Responses

A) Preoperatively by the patients, B) in PACU by the proxy, and C) on Postoperative day 3 by the proxy with or without the input from the patient. Each question score was ranked with Likert scales ranging from 1 to 5, with higher scores representing greater acceptability.

Of the 18 comments on how participants felt about the P/SA-QST toolkit, 10 participants primarily wrote comments attributed to a positive attitude towards the toolkit, whereas 6 participants primarily wrote comments attributed to a negative attitude towards the P/SA-QST toolkit. The negative comments were mainly on the tools used, such as

participants found that “There were some small objects that may be easily lost” or they found “The syringe was a bit difficult to push down past a certain point”.

Of the 9 comments on whether the participants found the P/SA-QST less burdensome than the L-QST, 6 participants found that it was a lot easier to use than the L-QST. One participant specifically stated that “the thing that makes the home kit a lot easier than the commercial is the fact that it eliminates travel to the office.” 2 participants primarily wrote comments attributed to a negative attitude towards specific tests in the P/SA toolkit, such as “The syringe was a bit difficult for me personally (I have some systemic weakness.”

Of the 10 comments on how difficult the instructions were to understand for the participants, 6 participants highlighted the ease of use of the P/SA-QST whereas, the 2 negative comments were attributed primarily to wanting more instruction on how properly use the P/SA-QST toolkit with participants noting that “maybe a printed sheet to explain what the tests are and how to do them”.

Of the 9 comments on how similar the P/SA-QST toolkit is to the L-QST toolkit, 3 participants primarily reported that they felt the P/SA-QST toolkit was just as effective as the L-QST toolkit. 5 participants noted the differences they found in the between the toolkits such as “The varying sizes of the dull needle tips (commercial kit) is the only difference that stuck out to me between the home kit and the commercial kit” or that “I think the pain and pressure were quite different.”

Most participants found the P/SA-QST toolkit to be very safe, however 1 participant raised some safety concerns stating that “The small items may be a risk to

small children or those with pets in their home, but if kept in a good place this will be resolved.” They also recommended creating a “a case to keep small objects organized”.

Of the 4 comments on the participants’ confidence that they can perform the P/SA-QST could be attributed as the P/SA-QST was easy to follow with video guidance.

Of the 4 comments on the extent to which the P/SA-QST would be a useful tool for patients living with chronic pain could be attributed as the P/SA-QST would be a useful tool.

Ability to detect changes in sensory and pain processing

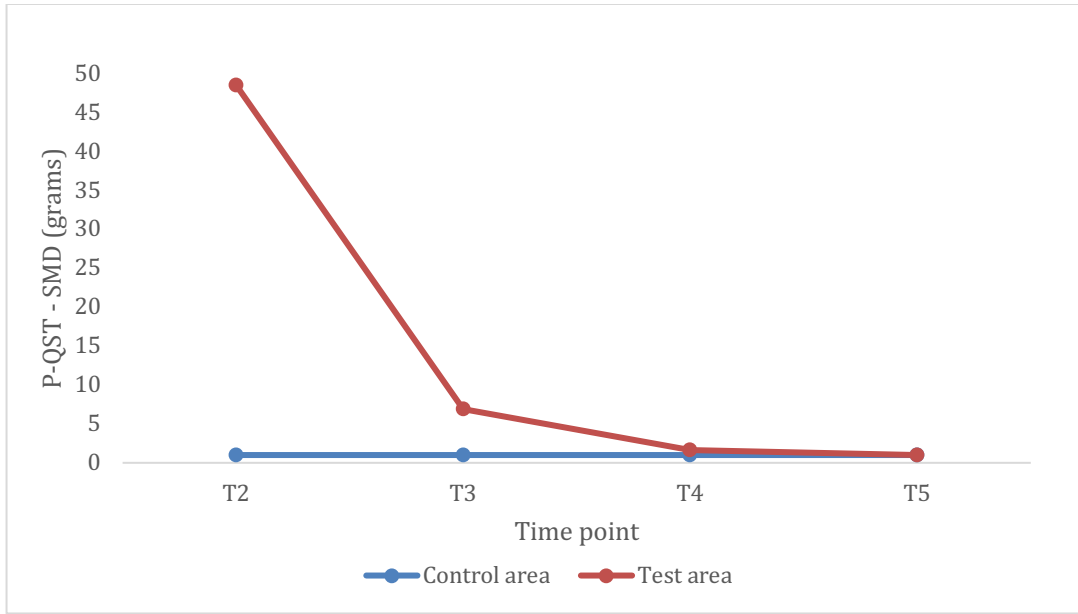
Upon testing of the rotating filament wheel on the participants control and test areas, a significant difference of static mechanical detection was observed in PACU, however no difference was observed from postoperative day 1 to day 3 (**Table 3 & Figure 5**). A significant loss of function was observed in their vibration detection threshold using the Rydel-Seiffer tuning fork from PACU to postoperative day 2. A significant gain in function was observed in their pressure pain threshold during postoperative day 3. There was also a significant gain of function observed in their pinprick sensitivity using the Neurotip sharp tip on postoperative day 2 and 3.

Table 3. Paired T-tests for the P/SA-QST postoperatively conducted by proxy		
Comparison (control vs test)	T-statistic	P-value
SMD (rotating filament wheel)		

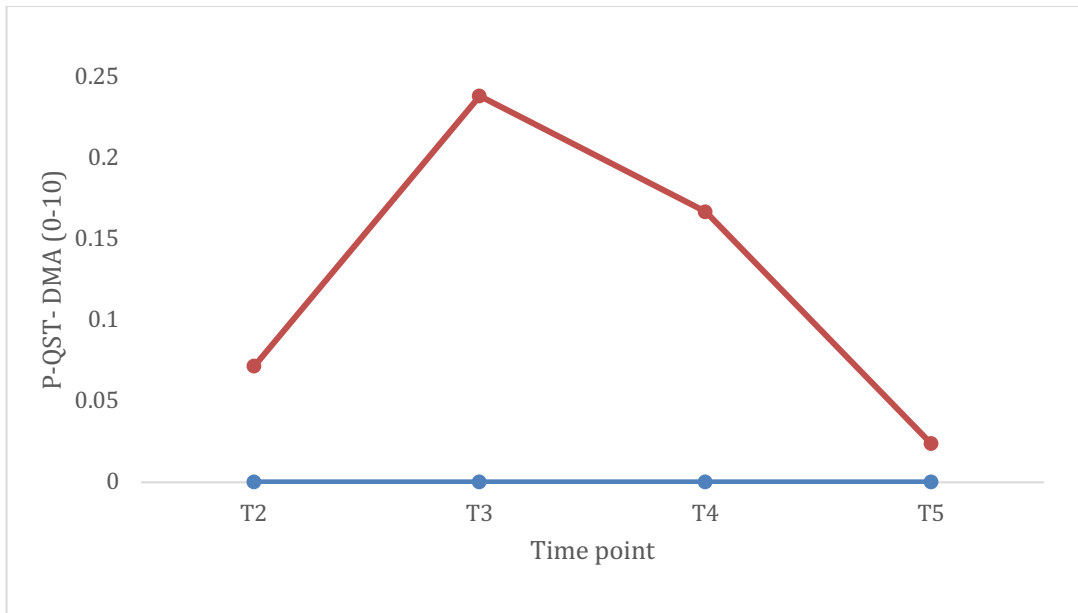
PACU	-3	0.01496
POD1	-1.12	0.2814
POD2	-1	0.3356
POD3	N/A	N/A
SMA Neurotip: round tip		
PACU	-0.3764	0.7127
POD1	-1.35	0.2012
POD2	-1.65	0.1233
POD3	-2.01	0.0659
DMA Q-tip		
PACU	-1	0.3356
POD1	-1.41	0.1827
POD2	-1.34	0.2045
POD3	-1	0.3356
VDT (Ryder-Seiffer tuning fork)		
PACU	2.55	0.0243
POD1	2.79	0.0154
POD2	3.01	0.0101
POD3	0.78	0.4474
PinPS Neurotip: sharp tip		
PACU	1.24	0.2381

POD1	-0.143	0.8884
POD2	-3.22	0.0067
POD3	-3.99	0.0015
PPT (air filled syringe)		
PACU	0.878	0.3989
POD1	-1.4	0.185
POD2	-1.52	0.1536
POD3	-1.94	0.0743
PrePS (air filled syringe)		
PACU	-1.02	0.3276
POD1	-1.2	0.2509
POD2	-2.09	0.0568
POD3	-3.41	0.0046

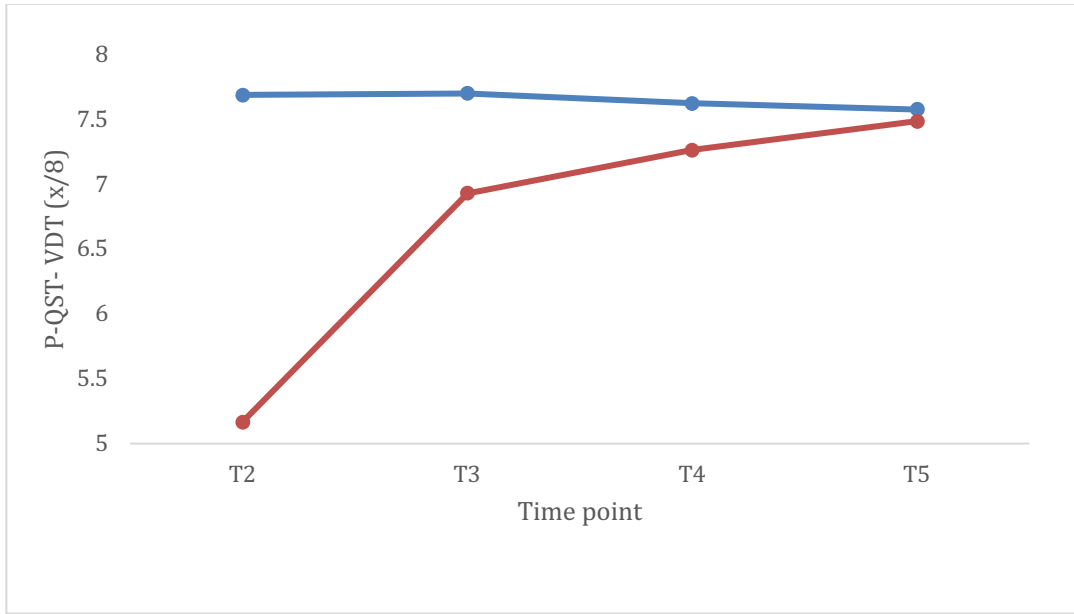
Table 3. Paired comparisons between control and test Areas. PACU represents post-anesthesia care unit; POD, postoperative day; SMD, static mechanical detection; SMA, static mechanical allodynia; DMA, dynamic mechanical allodynia; VDT, vibration detection threshold; PinPS, pinprick sensitivity; PPT, pressure pain threshold; PrePS, pressure pain sensitivity.



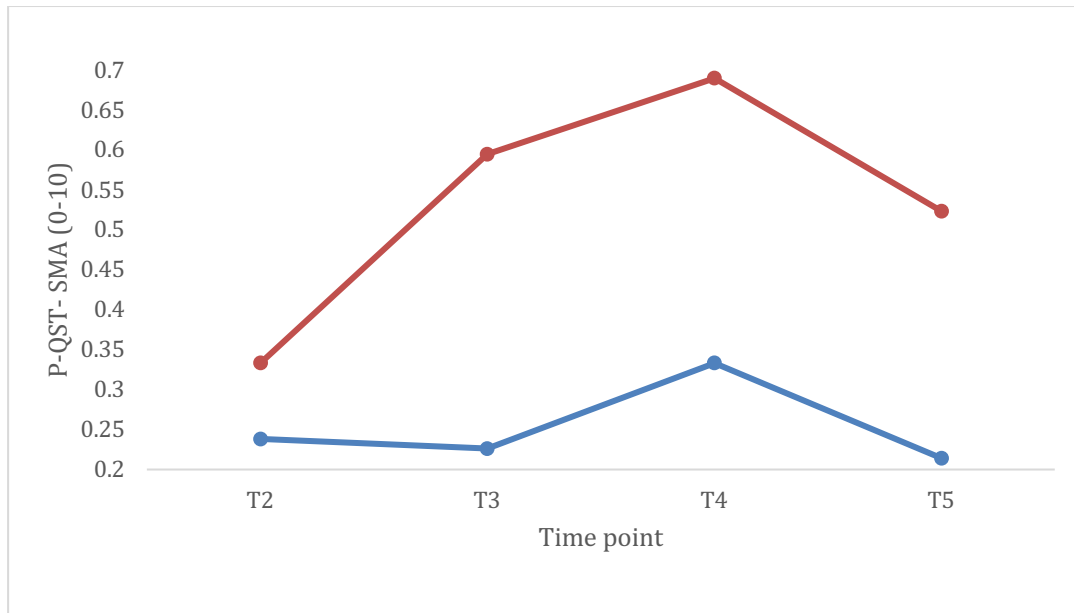
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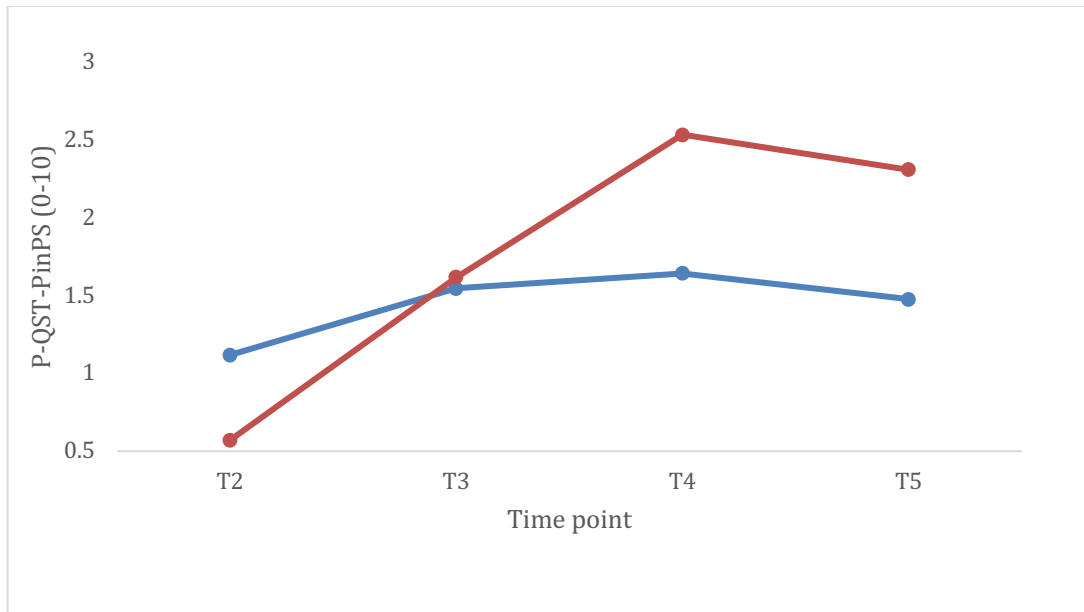
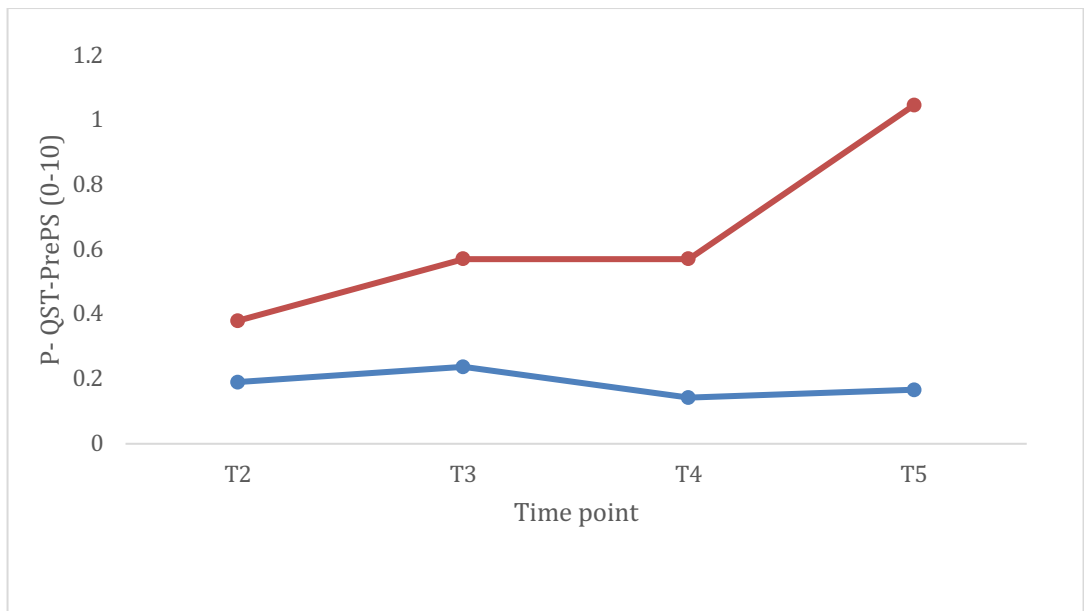
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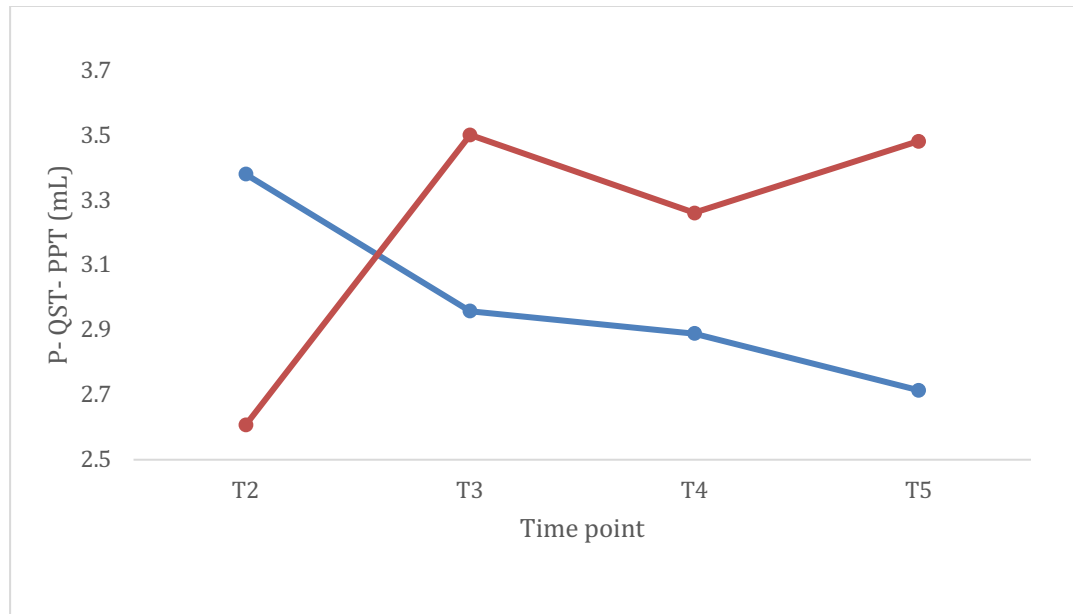


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Figure 5. Comparing the P -QST of the control and test area results for each specific test per timepoint. T2= PACU, T3= postoperative day 1, T4= postoperative day 2, T5= postoperative day 3.

A) Rotating filament wheel application. **B)** Q-tip pain intensity on the NRS-11 scale. **C)** Rydel-Seiffer tuning fork vibration detection threshold. **D)** Neurotip round end pain intensity on the NRS-11 scale. **E)** Neurotip sharp tip pain intensity on the NRS-11 scale. **F)** Air filled syringe pain intensity on the NRS-11 scale when compressed to 4mL. **G)** mL of compressed air in the syringe. P-QST represents proxy-administered quantitative sensory testing; SMD, static mechanical detection; DMA, dynamic mechanical allodynia; VDT, vibration detection threshold; SMA, static mechanical allodynia; PinPS, pinprick sensitivity; PrePS, pressure pain sensitivity; PPT, pressure pain threshold.

CHAPTER FOUR

Discussion

Background/rationale

The preliminary results demonstrated significant weak-to-moderate associations between specific Proxy/Self-Administered Quantitative Sensory Testing (P/SA-QST) and Laboratory-Based Quantitative Sensory Testing (L-QST) results. The preliminary findings support the potential of the P/SA-QST toolkit in assessing changes in sensory and pain processing postoperatively in patients receiving regional anesthesia. Importantly, no adverse events related to the use of the P/SA-QST toolkit were reported, and participants expressed high acceptability of the toolkit.

Quantitative sensory testing (QST) may contribute to individualized and evidence-based pain management strategies. The preliminary results of this study align with previous research supporting the role of QST as a diagnostic, prognostic, predictive, and pharmacodynamic biomarker (Smith et al., 2017). However, standardization of these assessments is still necessary to ensure consistency across clinical and research applications. Despite the advantages of laboratory-based QST, including precision and controlled settings, limitations such as cost, complexity, training requirements, lack of portability, and prolonged testing time restrict its broader implementation. The P/SA-QST toolkit may provide an alternative that extends QST accessibility to home environments.

Comparability of the P/SA-QST to L-QST

The P/SA-QST required less time for administration compared to L-QST. The self-administered QST in one area, guided by instructions, was on average four minutes shorter than the L-QST. Proxy-administered testing in two areas had a testing time about one minute shorter than L-QST in one area. Expectedly, acceptable agreement was observed between P/SA-QST static mechanical detection and L-QST mechanical detection thresholds. Significant correlations between P/SA-QST and L-QST were observed in the neurotip round tip and 128 mN pinprick stimulation assessments, but only when administered by the parent. However, there were no correlation observed for the neurotip sharp tip pinprick stimulation.

Self-administered testing did not yield significant correlations, likely due to participant expectations affecting pain perception. Given this, we recommend that testing using a noxious stimuli be conducted by another individual rather than being self-administered to enhance reliability. Significant correlations were observed in vibration detection threshold assessments using the Ryder-Seiffer tuning fork when conducted by both the patient and a proxy. Some participants, however, reported difficulty in inducing vibration but not in perceiving it, suggesting a need for improved instructions on proper tuning fork usage. Pressure pain threshold assessments also revealed significant correlations between laboratory-based and P/SA-QST results. Unlike L-QST, which is often conducted in patients between painful episodes, the P/SA-QST allows for repeatable assessments, facilitating investigations into both hypoalgesia and hyperalgesia during non-painful and painful periods. While the P/SA-QST is not identical to L-QST, it

provides valuable complementary information, particularly for repeatable testing over time. Additionally, an important advantage of the P/SA-QST toolkit is its facilitation of patient participation in sensory testing, encouraging active involvement in their own evaluation and care (Smith, 2017).

Safety, convenience and ease of use of P/SA-QST

Participants reported high acceptability of the P/SA-QST toolkit, though some concerns regarding safety and differences from L-QST were noted. As L-QST was conducted before P/SA-QST, potential carryover effects must be considered. However, this sequencing was intentional to allow participants to provide comparative feedback. Video guidance with verbal instructions was found to be beneficial, though some participants expressed a preference for additional guidance, suggesting that a complementary written manual may improve usability.

Participants also recommended clearer differentiation between L-QST and P/SA-QST expectations to avoid confusion. Specific tools, such as the tuning fork and syringe, presented challenges, highlighting the need for more detailed practice instructions or potential design modifications. A larger syringe may enhance pressure sensitivity testing accuracy, as participants struggled to push beyond a certain point. Safety concerns regarding smaller tools suggest the provision of a protective case should be considered.

P/SA-QST ability to assess changes in sensory and pain processing after regional anesthesia

Regional anesthesia is known to reduce acute postoperative pain and sensation (Rivat et al., 2013). The P/SA-QST toolkit successfully detected sensory changes

following regional anesthesia, with significant reductions in static mechanical detection observed immediately postoperatively in the Post Anesthesia Care Unit (PACU) and on postoperative day one. This reduced sensitivity in the PACU highlights the efficacy of the regional anesthesia, with sensations normalizing by the time patients returned home.

The toolkit also detected significant reductions in vibration detection thresholds for up to two days postoperatively, with no significant changes by day three. Similarly, pressure pain thresholds showed significant changes only on the last postoperative testing day, consistent with the gradual resolution of regional anesthesia effects with the presence of hyperalgesia at the surgical location. Furthermore, significant reductions in pinprick sensitivity were observed on postoperative days two and three, aligning with expectations as the anesthesia effects diminished. Future studies should compare L-QST results under similar postoperative conditions to validate these findings further. Despite these limitations, our results suggest that the P/SA-QST toolkit can detect significant changes in hypoalgesia and hyperalgesia following regional anesthesia.

Limitations

Several limitations should be considered when interpreting the findings of this study. The main limitation is the study's focus on pediatric patients, meaning the acceptability and effectiveness of the P/SA-QST toolkit cannot be generalized to adult clinical populations. Further research is needed to evaluate its applicability across different age groups. Additionally, as noted, difficulties in using certain toolkit components, such as the tuning fork and syringe, suggest that modifications and improved instructional materials are needed for enhanced usability. Moreover, another

limitation is that the patients in this study only conducted mechanical QST. The complete burden of including thermal QST cannot be extensively evaluated.

Future directions

Our team is continuously improving the toolkit and working to address some of the limitations mentioned. We are currently working to complete recruitment of the rest of the regional anesthesia patients, with expected completion in spring 2025. We are hoping to have the rest of the patients undergo thermal QST. Recruitment of participants, particularly those with sickle cell disease, proved challenging, as parents were often reluctant to enroll their children due to the time demands of hospital visits. However, we are still recruiting sickle cell disease patients to the study and hoping to continue administering sensory testing on this population.

Conclusion

Despite these challenges, the findings highlight the potential of the P/SA-QST toolkit as a cost-effective method for collecting clinically relevant sensory and pain data. Our research team is committed to refining the toolkit based on these findings to improve its usability and reliability. Future studies should focus on assessing its long-term reliability and validity in diverse patient populations, including adult cohorts.

APPENDIX

P/SA-QST toolkit evaluation form

Validating a home toolkit to assess changes in sensory and pain processing – a pilot study in children and adolescents undergoing regional anesthesia for orthopedic procedures

The following questionnaire was developed for the purpose of eliciting feedback about the usefulness and value of the home QST toolkit.

Study ID:

Date of evaluation:

Affective attitude (How you feel about the home QST toolkit)

1. How much did you enjoy using the home QST toolkit?

1 Not at all	2	3	4	5 Very much
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2. How would you rate your overall satisfaction with the home QST toolkit?

1 Very dissatisfied	2	3	4	5 Very satisfied
------------------------	---	---	---	---------------------

Comments (if any):

Burden (Your perceived effort required to undergo the home QST)

3. How easy was the home QST toolkit for you to use?

1 Very difficult	2	3	4	5 Very easy
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4. How acceptable was the amount of time it took to complete the home QST?

1 Very unacceptable	2	3	4	5 Very acceptable
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5. The home QST is less burdensome the commercial QST.

1 Strongly disagree	2	3	4	5 Strongly agree
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Comments (if any):

Perceived effectiveness (Whether the QST toolkit achieved its purpose)

6. The home QST is similar to the commercial QST.

1 Strongly disagree	2	3	4	5 Strongly agree
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Comments (if any):

Intervention coherence (Did you understand the home QST toolkit and how it works)

7. How difficult were the instructions to understand?

1 Very difficult	2	3	4	5 Very easy
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Comments (if any):

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Opportunity costs (The risks and/or benefits to undergo the home QST)

8. The home QST was safe to use.

1 Strongly disagree	2	3	4	5 Strongly agree
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Comments (if any):

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Self-efficacy (Your confidence that you can perform the home QST)

9. I was confident that I could perform the home QST with video guidance.

1 Strongly disagree	2	3	4	5 Strongly agree
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Comments (if any):

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Ethicality (The extent to which the home QST was a good fit with your values)

10. The home QST toolkit would be a useful tool for patients.

1 Strongly disagree	2	3	4	5 Strongly agree
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Comments (if any):**References:**

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CURRICULUM VITAE

