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Cell Phone Application to Monitor Pain and Quality of Life in Neurogenic Pain Patients

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Summary: Management of postoperative pain is a challenge for healthcare providers in all surgical fields, especially in the context of the current opioid epidemic. We developed a cell phone application to monitor pain, medication use, and relevant quality of life domains (eg, mood, mobility, return to work, and sleep) in patients with neurogenic pain, including those with limb loss. A literature review was conducted to define application length and design parameters. The final application includes 12 questions for patients with limb loss and 8 for patients with neurogenic pain without limb loss. Pilot testing with 21 participants demonstrates acceptable time to complete the application (mean = 158 seconds, SD = 81 seconds) and usability, based on the mHealth App Usability Questionnaire. We aim for our application to serve as an outcome measure for evaluation of an evolving group of peripheral nerve procedures, including targeted muscle reinnervation. In addition, the application could be adapted for clinical use in patients undergoing these procedures for neurogenic pain and thus serve as a tool to monitor and manage pain medication use. *(Plast Reconstr Surg Glob Open 2020;8:e2732; doi: 10.1097/GOX.0000000000002732; Published online 29 April 2020.)*

INTRODUCTION

Management of postoperative pain is a clinical challenge that has become increasingly relevant in the context of the current opioid epidemic. Accurate measurement of pain is an important step toward safe, optimal treatment, and cell phone applications have emerged as a platform for real-time pain monitoring and management.[1,2] For example, cell phone applications are being used to manage postoperative pain medication use and recovery after day surgery.[3,4] We developed a cell phone application to monitor pain and medication use in patients with neurogenic pain, including patients with limb loss. In this article, we describe the development of domains and questions, the structure of the application, pilot usability testing, and the application's planned and potential future uses.

METHODS

Application Length and Structure

The authors conducted a literature review of reported applications used to measure pain and quality of life. The search terms "electronic," "pain," "diary," "smartphone," and "application" were used to search titles and abstracts of articles in PubMed. Because previous systematic literature reviews have been conducted on mobile pain applications, we aimed to review a convenience sample of articles reporting usability and compliance properties of mobile applications designed to measure pain-related self-report outcomes.[1,2] Seven articles were reviewed, and the following data were extracted: domain measured, patient population, study design, number of items, average completion time, frequency of monitoring, and compliance rates (**see table, Supplemental Digital Content 1**, which summarizes the results of the literature review to guide application length and design parameters, http://links.lww.com/PRSGO/B354).

Domains and Questions

Six domains of interest were identified. Primary domains were (1) pain and (2) pain medication (opioid and non-narcotic) use, and secondary domains were (3)

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Table 1. mHealth App Usabililty Questionnaire (MAUQ) Questions[15] Used in Pilot Test

MAUQ ease of use module	
Question	**Response options**
1. The app was easy to use	Disagree → Agree N/A 1 2 3 4 5 6 7
2. It was easy for me to learn to use the app	N/A 1 2 3 4 5 6 7
3. The navigation was consistent when moving between screens	N/A 1 2 3 4 5 6 7
4. The interface of the app allowed me to use all the functions (such as entering information, responding to reminders, viewing information) offered by the app.	N/A 1 2 3 4 5 6 7
5. Whenever I made a mistake using the app, I could recover easily and quickly.	N/A 1 2 3 4 5 6 7
MAUQ interface and satisfaction module	
Question	**Response options**
6. I like the interface of the app	Disagree → Agree N/A 1 2 3 4 5 6 7
7. The information in the app was well organized, so I could easily find the information I needed.	N/A 1 2 3 4 5 6 7
8. The app adequately acknowledged and provided information to let me know the progress of my action.	N/A 1 2 3 4 5 6 7
9. I feel comfortable using the app in social settings.	N/A 1 2 3 4 5 6 7
10. The amount of time involved in using this app has been fitting for me.	N/A 1 2 3 4 5 6 7
11. I would use this app again.	N/A 1 2 3 4 5 6 7
12. Overall, I am satisfied with this app.	N/A 1 2 3 4 5 6 7

Table 2. Final Domains and Questions for Application

Domain	Questions
Pain	Regarding your residual limb pain in the past 7 days: How intense was your pain at its worst? (0-10) How intense was your average pain? (0-10) What is your level of pain right now? (0-10) Regarding your phantom pain, in the past 7 days: How intense was your pain at its worst? (0-10) How intense was your average pain? (0-10) What is your level of pain right now? (0-10) Regarding your nerve pain, in the past 7 days: How intense was your pain at its worst? (0-10) How intense was your average pain? (0-10) What is your level of pain right now? (0-10)
Medication use	Please enter the medication name, dosage, and frequency for each medication you are taking for pain.
Mood	How much emotional upset have you experienced in the past week? Depression (0-10) Anxiety (0-10)
Mobility	How much do you use your prosthesis when you are awake, as an approximate percent of time? (0% - 100%)
Return to work	Are you currently: • Working full time (including full-time student or running the home)? • Working part time? • Retired? • Retraining for alternative employment or looking for work? • Unable to work?
Sleep	In the past 7 days, my sleep quality was (0-10)

mood, (4) mobility, (5) return to work, and (6) sleep. Regarding the choice of secondary domains: depressive symptoms have been found to be a predictor of intensity and bothersomeness of phantom limb pain, residual limb pain, and back pain in patients with limb loss.[5] Increased mobility, often through the use of prosthesis, is associated with faster return to work and improved quality of life for these patients.[6] In addition, patients with neurogenic pain are at higher risk of sleep disturbance, which is a risk factor for diabetes, obesity, hypertension, and mortality.[7]

Cell phone applications have been shown to be a reliable, valid, and acceptable modality to measure a variety of metrics when compared with traditional paper- or computer-based administration.[8] Therefore, items under each domain were adapted from existing, validated questionnaires, when available, and created when not. Questions to elicit the intensity of pain were based on the Patient-Reported Outcomes Measurement Information System (PROMIS) Pain Intensity Short Form version 1.0. PROMIS is a validated toolbox of patient-reported outcome measures developed with modern psychometric techniques to allow for use across conditions and patient populations.[9]

The PROMIS Sleep Disturbance Short Form 8b was used to measure sleep quality. Literature review revealed the Emotion Thermometers—a set of visual analog scales that measure distress, anxiety, depression, anger, and need for help.[10] The Anxiety and Depression Thermometers were chosen because of the prevalence and association with pain intensity of these mood disorders in the limb loss population.[5] The diagnostic validity of the Emotion Thermometers to detect anxiety and depression has been demonstrated in patients with cancer[11] and cardiovascular disease[12] through comparison to clinically utilized measures (eg, the Generalized Anxiety Disorder 7-item scale and the Patient Health Questionnaire 9). Multiple mobility scales were reviewed, and a single question was adapted from the Houghton Scale.[13] The Houghton Scale was chosen for its acceptable reliability and validity when compared with other self-report mobility measures and its demonstrated convergent validity with the timed up and go test, an in-person measure of mobility validated in patients with limb loss. To assess a patient's ability to return to work, we reviewed employment questionnaires that have previously been used to assess employment status in people with limb loss. We adapted a question from work by Fisher and colleagues[14] that serially assessed a person's ability to return to work.

Pilot Testing

Pilot testing for usability was performed with the mHealth App Usability Questionnaire "Ease of Use" and "Interface and Satisfaction" modules.[15] Twelve questions ask about a standalone cell phone application's navigation and interface and about the user's satisfaction on a 0 to 7 Likert scale (Table 1). The range of possible scores is 5–35 for Ease of Use and 7–49 for Interface and Satisfaction. A higher score indicates higher usability. Patients with lower extremity limb loss and patients with neurogenic pain were approached in the Northwestern Memorial Hospital vascular and plastic surgery clinics. Verbal consent was obtained. Participants completed the survey portion of

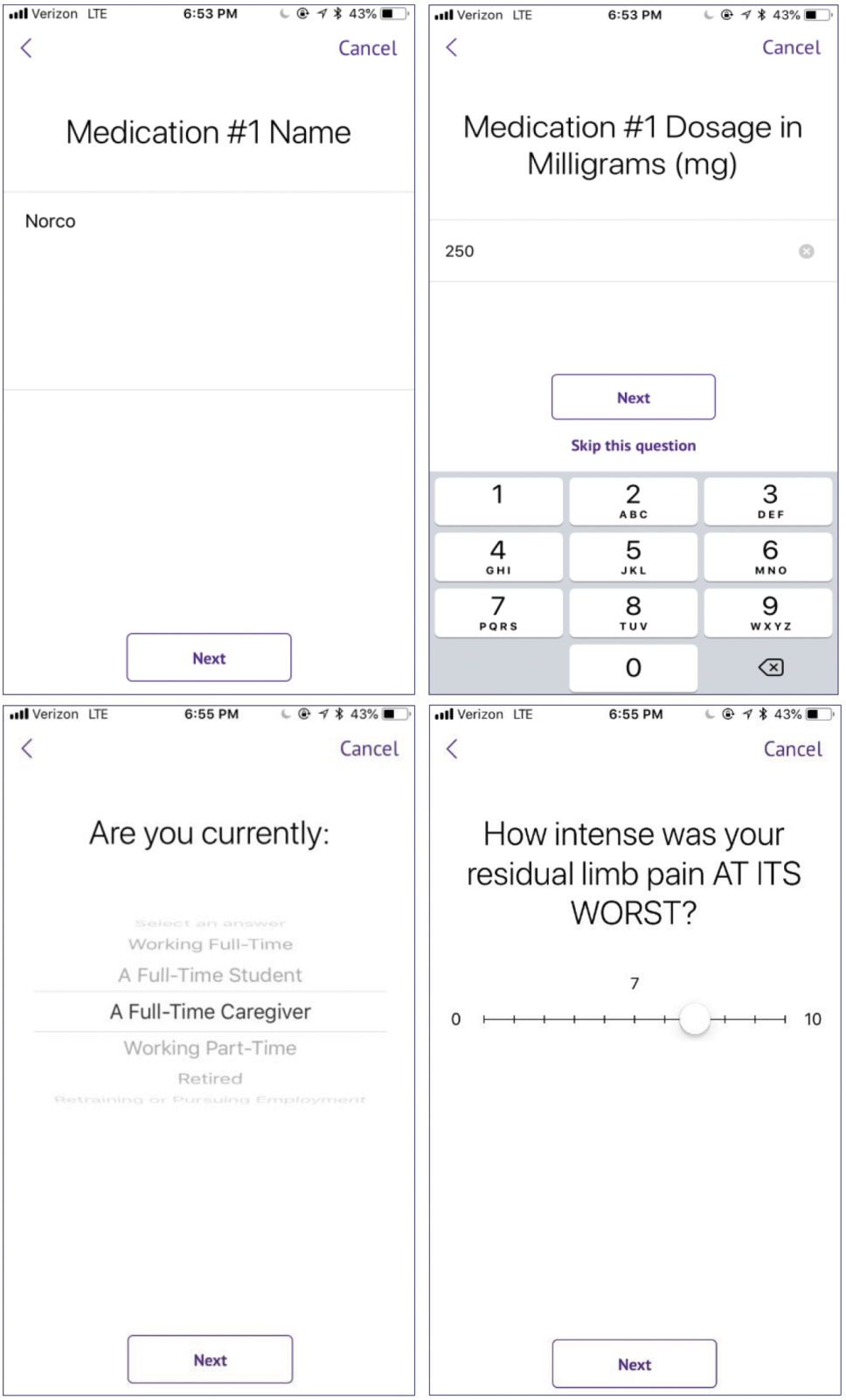

Fig. 1. Preliminary design of cell phone application. These screenshots show the preliminary design of the application. This design was used in the pilot to test usability and time to complete the application questions for patients with limb loss and patients with neurogenic pain not related to limb loss. Minor changes will be made to the design of the final application to respond to user feedback from the pilot trial.

Table 3. Time to Complete Application and Usability Data

	Age (Mean [SD])	Gender (n)	Time to complete survey in seconds (Mean [SD])	MAUQ Ease of Use Scale score (5-35) (Mean [SD])	MAUQ Interface and Satisfaction Scale score (7-49) (Mean [SD])
Patients with limb loss (n = 8)	64 (12)	Male 7 Female 1	175 (62)	32 (3)	47 (2)
Patients seen for neurogenic pain (n = 11)	58 (15)	Male 3 Female 8	128 (91)	28 (5)	38 (11)

the cell phone application on a study coordinator's cell phone, while the same study coordinator timed the participant. Each participant then completed the mHealth App Usability Questionnaire modules in Qualtrics (Provo, Utah). This pilot study was deemed not human research by the Northwestern Institutional Review Board.

RESULTS

In the 7 articles reviewed, electronic diaries ranged from 1 to 25 questions in length and reported compliance in pilot testing ranging from 45% to 100%. A single study reported time to complete the application—average 3.97 minutes (SD = 3.3 minutes) for 5 questions, with 96% compliance in pilot testing (**see table, Supplemental Digital Content 1**, which summarizes the results of the literature review to guide application length and design parameters, http://links.lww.com/PRSGO/B354).

Our final application design included 12 questions for patients with limb loss (6 regarding pain, a free-text question on pain medication and dosage, 2 regarding mood, 1 regarding mobility, 1 regarding return to work, and 1 regarding sleep) and 8 questions for patients without limb loss (3 regarding pain, a free-text question on pain medication and dosage, 2 regarding mood, 1 regarding return to work, and 1 regarding sleep) (Table 2). The application interface uses an esthetically consistent visual analog sliding scale (Fig. 1), autopopulates previously entered medications, includes a user-activated alarm, and integrates with the intrinsic smartphone step-counter and sleep-monitoring functions.

Eleven patients with neurogenic pain 10 patients with limb loss completed pilot testing of the application. Mean time to complete the survey once was 2 minutes and 8 seconds for neurogenic pain patients and 3 minutes and 11 seconds for patients with limb loss. Participants reported acceptable ease of use (mean = 32 [SD = 4]) and interface and satisfaction (mean = 45 [SD = 6]) scores (Table 3).

DISCUSSION

The final application questions and design adhere to the length parameters defined by the literature review, capture pain and clinically relevant domains, and prioritize usability. Pilot data demonstrate that a sample of the patient population intended to use the application is satisfied with the usability and interface of the application.

There has been a paradigm shift in the surgical treatment of peripheral nerve pain, with new, innovative techniques emerging to actively manage disorganized axonal growth in injured nerves.[16] These techniques include targeted muscle reinnervation and regenerative peripheral nerve interfaces, among others. However, the lack of a standard outcome measure has limited comparison among available techniques.[17] This application could be used in multicenter registries and trials to compare the variety of emerging peripheral nerve pain management procedures, demonstrate the extent of their benefit, and aid in widespread adoption.

Our team plans to use the application in prospective cohort studies of lower extremity limb loss patients to compare outcomes in those who undergo targeted muscle reinnervation at the time of amputation versus not. We will also assess the validity and reliability of this application as an outcome measure by comparing electronic results with in-person data from validated, self-report questionnaires (e.g. the Defense and Veterans Pain Rating Scale) and tests (e.g., the timed up and go test).

Finally, this application also has potential for the monitoring of neurogenic pain in clinical settings. The application questions and design could be synchronized with electronic medical record systems and allow for real-time notification of changes in patient pain status, creating opportunities to monitor opioid prescribing.

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