

# Development of a mHealth Real-Time Pain Self-Management App for Adolescents With Cancer: An Iterative Usability Testing Study

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## Abstract

**Purpose:** A user-centered design approach was used to refine the mHealth *Pain Squad+* real-time pain self-management app for adolescents with cancer for its usability (defined as being easy to use, easy to understand, efficient to complete, and acceptable). **Method:** Three iterative usability testing cycles involving adolescent observation and interview were used to achieve this objective. During each cycle, adolescents used the app while “thinking aloud” about issues encountered. Observed difficulties and errors were recorded and a semistructured interview about the experience was conducted. Using a qualitative conventional content analysis approach, themes related to app usability were identified. **Results:** Participants required an average of 4.3 minutes to complete the pain assessment component of *Pain Squad+*. Overall, the app was acceptable. Problematic issues related to software malfunction, interface design flaws, and confusing text. Software revisions were made to address each issue. **Conclusion:** The multifaceted usability approach used provided insight into how a real-time app can be made acceptable to adolescents with cancer and succeeded in developing a *Pain Squad+* app that is fit for future effectiveness testing.

## Keywords

adolescent with cancer, pain self-management, mHealth, smartphone, usability

## Introduction

Adolescents with cancer can experience pain related to the cancer and its therapies both during treatment and for years following (Fortier et al., 2012; Lu et al., 2011; Stinson, Jibb, et al., 2015). Pain management can be complex, involving the patient, family, and health care team and can require dynamic combinations of interventions to provide the best possible quality of life to young people with cancer. The impact of cancer-related pain on adolescents can be negative and long lasting. Known sequelae of cancer-related pain include impediments to disease recovery (Shepherd, Woodgate, & Sawatzky, 2010), impaired sleep (Baggott, Cooper, Marina, Matthay, & Miaskowski, 2012), distress and fear (Hedén, von Essen, Frykholm, & Ljungman, 2009; Walker, Gedaly-Duff, Miaskowski, & Nail, 2010; Windich-Biermeier, Sjoberg, Dale, Eshelman, & Guzzetta, 2007), functional limitations (Varni et al., 2010), parental anxiety (Link & Fortier, 2016), and poorer overall quality of life (Klassen et al.,

2008; Stinson, Jibb, et al., 2015; Sung et al., 2009). Despite the increasing breadth of knowledge related to the etiology, prevalence, severity, and impact of pain, pain in adolescents with cancer continues to be poorly managed (Ameringer, 2010; Baggott et al., 2010; Jacob, Hesselgrave, Sambuco, & Hockenberry, 2007; Zernikow et al., 2012).

Self-management represents one strategy to improve cancer pain outcomes for adolescents (Cowie et al., 2013). Self-management involves a patient’s ability to monitor his or her condition and employ cognitive, behavioral, and

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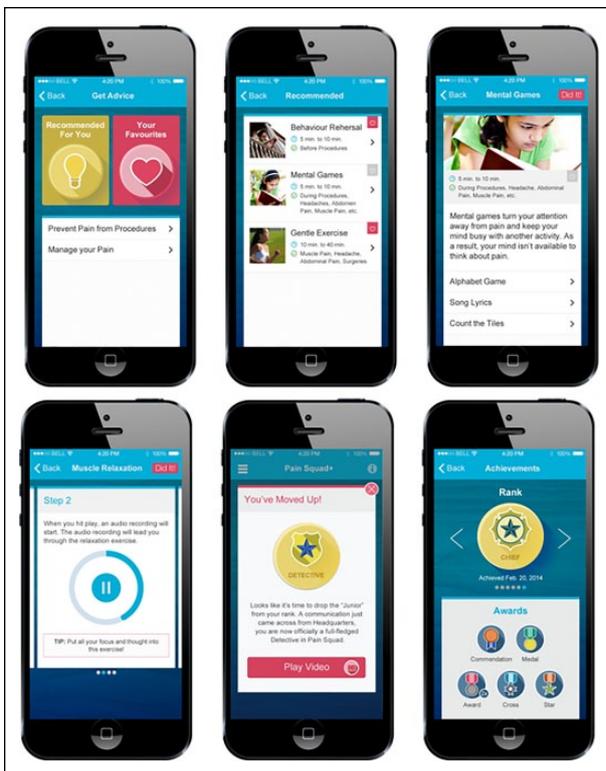
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emotional strategies to maintain a satisfactory quality of life (Barlow, Wright, Sheasby, Turner, & Hainsworth, 2002). At present, several studies have shown positive physical and emotional outcomes in adolescents engaged in self-management interventions when compared with adolescents receiving medical care alone (Barlow & Ellard, 2004; Cafazzo, Casselman, Hamming, Katzman, & Palmert, 2012; Stinson et al., 2010; Stinson, Wilson, Gill, Yamada, & Holt, 2009).

Smartphones may be especially useful in supporting pain self-management in all of an adolescent's natural environments (eg, home, school, hospital), because of the ability of these devices to deliver real-time support. Smartphone-based real-time support to guide treatment decisions can provide patients with the ability to self-manage symptoms the moment they occur. Additionally, adolescents with cancer have cited a desire to develop practical skills to manage their disease (Stinson et al., 2012), which may be realized through this real-time decision support.

In response, we developed the *Pain Squad+* mHealth real-time pain management app. *Pain Squad+* is a web-based smartphone application that has been developed in a phased research approach that has involved adolescents with cancer throughout the process (Jibb et al., 2014; Stinson et al., 2012). The app prompts adolescents with cancer to complete the valid and reliable multidimensional 22-item pain questionnaire from the publically available *Pain Squad* app (Stinson, Jibb, et al., 2015) each morning and evening. If an adolescent experiences pain anytime between these scheduled assessments, a truncated 8-item pain questionnaire can be completed. The truncated questionnaire includes a sample of questions from the 22-item questionnaire that were selected as important by clinical experts in pediatric pain and oncology and is designed to minimize the response burden for adolescents (Jibb et al., 2014). All questionnaire data are sent to a secure hospital server and, in response to pain, adolescents are instantly provided with algorithm-based real-time pain management advice (Jibb et al., 2014, 2015). The advice may be pharmacological, psychological, and/or physical in nature and includes strategies such as using "mental games" or audio-recorded muscle relaxation-based mindfulness sessions. When a recommendation is made, the app alerts adolescents to complete a pain reassessment 1-hour later and offers additional advice as appropriate. Measurement parameters for moderate to severe adolescent pain have been determined as pain intensity ratings  $>3/10$  (Hirschfeld & Zernikow, 2013). Using these parameters in *Pain Squad+*, 3 consecutive adolescent reports of current pain intensity  $>3/10$  result in an email alert being sent to an oncology-trained registered nurse. The nurse then contacts the adolescent and their primary oncologist to discuss the case and initiate



**Figure 1.** *Pain Squad+* mHealth pain management app screenshots.

Note. Top row, left to right: (a) pain management screen, (b) sample of pain self-management recommendations, and (c) detailed view of "Mental Games" self-management advice for pain. Bottom row, left to right: (d) detailed view of audio-recorded "Muscle Relaxation Mindfulness" self-management advice for pain, (e) sample of reward for continued expertise (ie, advancement through law-enforcement ranks and receipt of videotaped acknowledgements related to app interaction), and (f) "point and levelling system" used to inform the user of their level of familiarity with the app.

provider-driven intervention (eg, adjusting a prescribed medication regime). The app is also "gamified" with adolescents who use the app playing the role of law-enforcement officers investigating pain cases. Specifically, adolescents acquire "badges" in response to meeting achievement goals (eg, completing 5 consecutive scheduled pain assessments) and participate in a "point and levelling system" that rewards continued expertise (ie, advancement through law-enforcement ranks and receipt of videotaped acknowledgements related to app interaction). For the purposes of this study, all testing occurred using iPhone 6 devices, which were loaned to participants for the usability testing session. Figure 1 shows screenshots of various *Pain Squad+* app modules.

The focus of this study, which represents the next phase of app development, is usability testing. Any potential health care value of an intervention such as *Pain Squad+* can be realized only if the intervention is effectively used by end-users. A user-centered approach to the

development and design of mHealth interventions should therefore be employed to ensure that the resultant interventions are user-friendly, amenable, and perceived as helpful to particular end-users (McCurdie et al., 2012). Usability testing is a widely used user-centered design methodology that incorporates an iterative process of testing an intervention's user-interface and then applying the results to redesign the prototype to meet user needs. The objective of this research was to refine the *Pain Squad+* mHealth real-time pain self-management app through usability testing such that it was found to be easy to use, easy to understand, efficient to complete, and acceptable to adolescents with cancer.

## Methods

### *Design, Setting, and Participants*

Prior to commencing the study, a prototype smartphone interface was created by a software development firm in Toronto, Canada. Governed by a user-centered design approach, iterative cycles of usability testing and interviews with adolescents with cancer were then used to refine this *Pain Squad+* prototype. This study was conducted in a single hematology/oncology division of a university-affiliated pediatric tertiary care center in Canada. A purposive sampling method was employed where maximum variation selection was used in an effort to produce a study sample that varied in terms of age, sex, and cancer diagnosis. Adolescents meeting the following criteria were eligible for participation: aged 12 to 18 years, able to speak and read English, undergoing cancer treatment on an in- or out-patient basis, at least 3 months from diagnosis, and having self-reported pain of any intensity in the week immediately prior to recruitment. Adolescents were ineligible for participation if they had 1 or more major comorbid (medical or psychiatric) condition and/or were receiving palliative end-of-life care.

### *Sample Size*

As this study employed an iterative testing approach to app development, the final sample size was determined by (a) the number of testing cycles needed to sufficiently refine the app prototype and (b) the number of participants *per* testing cycle needed to reach data saturation. Review of the literature and previously conducted usability testing studies indicates that prototype refinement is typically achieved within 2 to 3 cycles of testing (Macefield, 2009; Molich, 2010; Stinson et al., 2013). Additionally, data saturation can usually be reached with samples as small as 5 to 7 participants per usability cycle (Kushniruk & Patel, 2004). Therefore, we aimed to recruit 10 to 21 adolescents between the ages of 12 and

18 years for 2 to 3 cycles of usability testing. The final sample size included in this study was 16 adolescents across 3 testing cycles.

### *Procedure*

The research ethics boards at the Hospital for Sick Children and University of Toronto approved this study, and informed consent was obtained from each participant prior to commencing testing. Demographic and disease data, as well as data on comfort level with smartphone devices, were collected from each participant. The usability testing session then began and the remainder of the study procedure was digitally audio-recorded. Whenever possible, 2 trained observers was present for usability testing sessions, providing the ability for a peer debrief after the session and enhancing the credibility of study results.

Adolescents were asked to complete the app while "thinking aloud" about perceptions related to *Pain Squad+* and any difficulties encountered. The time taken to complete the pain assessment component of the app was recorded. Once the adolescent had worked through the app, a brief semi-structured interview related to the app was conducted. Field notes were taken during the usability testing session to record any observed technical difficulties encountered, ease of use, and learning as well as nonverbal behaviors related to acceptability. Usability testing sessions continued until no data were generated that had not already been categorized (ie, data saturation). At this point, all usability issues from a single iterative cycle were considered to have been identified (Macefield, 2009; Molich, 2010). Software developers made revisions to the app according to instructions from the research team that were based on usability-related themes.

### *Data Analysis*

Demographic data were analyzed descriptively using Microsoft Excel software. Qualitative data analysis began once the first usability session was conducted ensuring that issues identified in early sessions could inform later sessions using constant comparative analyses (Bowen, 2008; Lingard, Albert, & Levinson, 2008). Two investigators (LJ and CN) conducted data analyses. Immediately after each usability session, these investigators discussed themes that emerged during the session with reference to field note data. Audio-recorded data were referred to as necessary. Discrepancies in opinion regarding themes were to be resolved using group discussion with a third party once the third party had reviewed the session audio-recording; however, no discrepancies occurred. A conventional qualitative content analysis approach was used to code data (Hsieh & Shannon, 2005). Specifically, both

**Table 1.** Characteristics of Study Participants.

Characteristic	Cycle 1 (n = 4)	Cycle 2 (n = 6)	Cycle 3 (n = 6)
Mean age in years (SD)	15.3 (2.6)	15.5 (1.6)	13.7 (1.9)
Sex, n (%)			
Female	3 (75)	4 (67)	2 (33)
Male	1 (25)	2 (33)	4 (67)
Race/ethnicity, n (%)			
Black	0	1 (17)	1 (17)
Latin American	0	1 (17)	2 (33)
South Asian	0	1 (17)	1 (17)
South East Asian	1 (25)	1 (17)	0
White	3 (75)	2 (33)	2 (33)
Cancer diagnosis, n (%)			
Acute lymphoblastic leukemia			2 (33)
Acute myeloid leukemia		1 (17)	1 (17)
Adrenocortical carcinoma	1 (25)		
Osteosarcoma			2 (33)
Ewing sarcoma	1 (25)	1 (17)	
Lymphoma	1 (25)	2 (33)	1 (17)
Neuroblastoma	1 (25)		
Posttransplant lymphoproliferative disorder		1 (17)	
Triton tumor		1 (17)	
Mean duration of illness in years (SD)	0.4 (0.3)	0.4 (0.3)	1.0 (1.8)
Diagnosed with relapsed cancer, n (%)	1 (25)	0	1 (17)
Treatment modality, n (%) <sup>a</sup>			
Chemotherapy	3 (75)	6 (100)	6 (100)
Radiation	3 (75)	0	1 (17)
Surgery	1 (25)	2 (33)	1 (17)
Stem cell transplant	0	0	1 (17)

<sup>a</sup>More than 1 response option possible per participant.

LJ and CN independently made notes of impressions and thoughts on usability issues that arose during a given testing session based on the study objectives. These impressions and thoughts were considered as codes, which were then grouped into meaningful categories based on the relationships between codes. Categories were generated until all data from the usability session were catalogued under existing categories (Patton, 2002; Sandelowski, 2010). Categories were then grouped into usability themes.

## Results

### Sample Selection and Participant Characteristics

In total, 18 eligible adolescents with cancer were approached to participate from September 29, 2014, to January 30, 2015. Two adolescents (11%) declined to participate—one felt too ill and the other was preoccupied with another activity. Adolescents ranged in age from 12 to 18 years (mean = 14.8; SD = 2.1), and 9 (56%)

were female. Adolescents were most commonly diagnosed with lymphoma (4; 25%). The frequencies, percentages, means, and SDs for demographic and disease-related characteristics are shown in Table 1. The majority of participants (11; 69%) reported owning a smartphone and 15 participants (94%) reported using a smartphone (either their own phone or that of a friend or family member) at least once per day. Participants were either comfortable (3; 18%) or very comfortable (13; 81%) using smartphones. Details related to adolescent smartphone use are shown in Table 2.

### Usability Testing of the Pain Squad+ App

Three iterative cycles of usability testing were conducted to refine the *Pain Squad+* app. The time from the completion of a single usability testing cycle to the implementation of app revisions by the software developers was 19 days for each of Cycle 1 and 2 changes. Below, the data from all cycles of app testing have been categorized according to the study objectives: ease of use, ease of understanding, efficiency, and acceptability.

**Table 2.** Smartphone-Associated Information for Study Participants.

Characteristic	Cycle 1 (n = 4)	Cycle 2 (n = 6)	Cycle 3 (n = 6)
Smartphone ownership, n (%)			
No	0	0	3 (50)
Yes	4 (100)	6 (100)	3 (50)
Times smartphone used per day, n (%)			
Never	0	0	1 (17)
1-3 times	1 (25)	0	2 (33)
4-6 times	1 (25)	1 (17)	2 (33)
7-10 times	0	1 (17)	0
>10 times	2 (50)	4 (67)	1 (17)
Purpose of smartphone use, n (%) <sup>a</sup>			
App use	3 (75)	5 (83)	3 (50)
Calling	1 (25)	4 (67)	2 (33)
Emailing	1 (25)	2 (33)	2 (33)
Game playing	3 (75)	4 (67)	5 (83)
Music listening	2 (50)	4 (67)	2 (33)
Texting	4 (100)	5 (83)	4 (67)
Not applicable	0	0	1 (17)
Comfort using smartphone, n (%)			
Not at all	0	0	0
A little	0	0	0
Comfortable	1 (25)	1 (17)	1 (17)
Very comfortable	3 (75)	5 (83)	5 (83)

<sup>a</sup>More than 1 response option possible per participant.

### Ease of Use

All participants but one were able to complete testing of the pain assessment, pain management, and gamification mechanics (ie, badge acquisition, point, and leveling system) of *Pain Squad+* app in a single session. Minimal assistance was required from the study team. A technical issue with the app software that caused the app to crash during the first usability testing cycle was the reason for the single participant's inability to complete the session. Participants across all testing cycles stated that *Pain Squad+* was easy to use. All participants intuitively knew how to launch the app and begin a pain assessment. One adolescent stated, "Well, I felt it was easy enough. Easy to read. Very straightforward, which is what most people are looking for" (male, 16 years).

Ease of use was negatively affected in the first testing cycle by technical malfunctioning of the app. Three out of 4 participants experienced difficulties completing the *Pain Squad+* pain assessment due to the app unexpectedly relaunching the assessment midway through the questionnaire. Highlighting this issue, one participant stated, "Oh ok! I got to like the 5th question and it shot me back to number 2" (female, 13 years). Because of participant frustration related to having to repeatedly re-start the pain assessment, Cycle 1 was stopped after 4 testing sessions. In response to this issue, the software development team reprogrammed

the app and tested it internally to ensure all pain assessment questions could be answered in sequence. No further malfunctions occurred after the reprogramming.

In Cycle 2, half of the participants experienced difficulties with the responsiveness of the app. For example, an adolescent stated after the session that, "The only thing I can possibly think of, and it's not actually a really big thing, but . . . is that the buttons are annoying. Like they don't seem to want to work" (female, 18 years). To correct the issue, software developers increased the "clickable" surface area corresponding to the app buttons and cursors.

Following the implementation of these changes, there were no issues related to *Pain Squad+* ease of use identified in Cycle 3. Participants commented that, "It was really a very simple process. So the basics, all the instructions, helps you just . . . go" (male, 13 years) and "It was pretty easy, because everything's explained. Like, it's there and it tells you where to go for advice and stuff and you don't have to like look around" (female, 16 years).

### Ease of Understanding

All adolescents endorsed the *Pain Squad+* app as simple to comprehend: "All the questions in the app were easy to understand and it was very helpful" (female, 15 years). However, some difficulties with understanding certain

text-based aspects of the app were noted. In Cycle 1, confusion associated with the question related to how much control the adolescent felt they had over their pain was noted. One participant noted, "When I use medicine and it takes away my pain, I feel like I have control. But when it comes back, that's when I don't [feel I can control my pain]. So I don't know [how to answer this question]" (female, 13 years). Three of the 4 adolescents in Cycle 1 did not understand the meaning of the phrase "pharmacological pain management." To correct these misunderstandings, the wording of the "pain control" question was changed to "How well do you think you were able to manage your pain since your last case?" and the "pharmacological pain management" wording was changed to "medicines to treat pain." Following these revisions, no issues related to ease of understanding were uncovered in Cycles 2 or 3.

### Efficiency

The time to complete the pain assessment component of the app across all iterative cycles was  $4.3 \pm 3.5$  minutes ( $M \pm SD$ ; range = 1.9-14.3 minutes), excluding the single adolescent that did not complete testing due to technical difficulties with the app. All participants except for one were able to complete the assessment in 6.4 minutes or less. The participant who required 14.3 minutes was very emotional during the testing process due to reasons unrelated to *Pain Squad+* use. This participant paused testing several times, but was keen to complete the assessment. Regarding the time required to complete the assessment and review pain management strategies plus allotted rewards, participants reported, "It was fine" (female, 13 years) and "If I timed [the app notifications] for the right times [in my day], it would be ok" (male, 12 years).

### Acceptability

Data related to *Pain Squad+* acceptability were categorized as "likes" and "dislikes" related to the app design, content, navigation, utility, and customizability. All participants across the 3 cycles were satisfied with the *Pain Squad+* app, with adolescents referring to app as a whole as "pretty neat" (male, 12 years) and "cool" (female, 17 years).

**Design and Engagement Enhancing Features.** Across all testing cycles, adolescents liked the design as well as the badge acquisition and point and leveling system of the app. Endorsement of the design and gamification mechanics was ubiquitous across adolescent age and sex. Adolescents remarked that the app was visually appealing, several times stating specifically that they liked the color scheme and detective theme of the app: "It was cute how

you have the whole rookie thing added to it. So at the same time as someone is trying to get rid of their pain, they're also enjoying themselves" (female, 17 years). The videotaped acknowledgements of adherence to pain reporting were also an appreciated feature:

I like that it had the little videos. It tells a story. Like telling [adolescents] that they are leveling up and stuff. I think that was cool. [The app] would stop what it was doing and like show me this video, and I was like, "Ok cool, I leveled up." (Male, 18 years)

Because no negative feedback about aesthetics was received during usability testing, no changes to the overall design or the gamification mechanics of the app were made.

**Content.** Participants provided generally positive feedback regarding the pain assessment and management content in the app. Participants particularly liked having multiple options to describe and manage their pain and the detail provided with regard to pain management advice:

It has so many options for [describing] the pain. Like they say, "How is it feeling?" and they have so many options you can choose [affective elements and descriptors of pain]. You can choose so many of them instead of being like, "Oh it's this one." (Male, 13 years)

Yeah, I like them [pieces of pain management advice]. I liked when it gave step-by-step instructions on how to do it. Because just saying, "Relax" doesn't help you relax. (Female, 16 years)

In Cycle 2, 3 participants (50%) mentioned that the content of the different pain assessment questions seemed similar. For instance, an adolescent stated,

Well I thought some of the questions were just repetitive. I don't know . . . because it said, "from your last case how was your worst, average, least amount of pain." It was asking the same thing but with a different wording. That's what I felt. (Male, 16 years)

In response to this issue, one adolescent suggested: "Maybe you could put the words in different colors" (female, 15 years). To allow adolescents to clearly and quickly distinguish the meaning of the various pain assessment questions, key words were bolded and underlined. No further modifications to app content were required in Cycle 3.

**Navigation.** Participants valued the ability to easily operate the *Pain Squad+* app. This finding was apparent in Cycle 1, when 1 adolescent (25%) stated,

I like how underneath the questions the app was asking, they gave a description of what they meant, so you didn't get confused or anything. So it said, "Tap here" and told you when you could click multiple choices. That was a good idea. (Female, 17 years)

The same participant also made a recommendation to streamline navigation through the app by minimizing the number of steps and time required to move from 1 app module to the next: "It kind of takes a few clicks to go back [out of the pain management section] though. If someone's in pain and they want advice, they'll probably just want to get to it. They'll be impatient" (female, 17 years). This recommended change was made and no additional changes were needed in Cycles 2 or 3.

**Utility.** Participants across all 3 cycles endorsed the utility of *Pain Squad+*. The app was considered a useful adjunct to the usual pain care adolescents with cancer received, especially because of its ability to provide real-time support. For instance, related to a question on the utility of the app an adolescent responded:

Yeah because it just gave you stuff you could do on the spot and advice you could do anywhere. When I was in pain, I was looking for everything to help it go away. Like I looked at everything. All night. I'd look at every website and I couldn't really find anything, so I feel like this would be really helpful. (Female, 17 years)

Participants specifically noted the utility of the app as it pertained to providing access to pain management "at night or when someone wasn't around" (male, 18 years) as well as "at home . . . because I can't get advice from the nurses and stuff" (female, 16 years).

Adolescents in all cycles also stated that they would be likely to use the app daily for a sustained period of time because of its perceived value in guiding pain self-management. This finding is highlighted in the following quotation: "I think they'll use it as long as they need it. If they're in pain and they need something, pretty sure they'll go on it" (female, 17 years).

**Customizability.** Across all usability testing cycles, adolescents described liking the ability to customize the app to their preferences. To do so, adolescents could select pieces of pain management advice that they enjoyed and thought were effective and these items were preferentially offered by the app to adolescents on future pain reports.

## Discussion

This study explored the usability issues and perceptions of adolescents with cancer related to the *Pain Squad+* real-time smartphone-based pain management app. Whereas

many pain management apps are currently available (Laloo, Jibb, Rivera, Agarwal, & Stinson, 2015), an app that provides adolescents with cancer with comprehensive, expert-vetted, and age-appropriate pain self-management advice has not been developed to date (Jibb et al., 2014). Formal evaluation of the usability of the prototype *Pain Squad+* app for adolescents with cancer allowed for identification of software malfunction, interface design flaws (ie, responsiveness of interactive elements, burdensome number of "clicks" required to navigate app), and confusing text (ie, meaning of the concepts "control over pain" and "pharmacological pain management"). Additionally, the refinement of the app in a user-centered manner provided evidence that *Pain Squad+* is easy to use and understand, efficient, and acceptable to adolescents, including in terms of its design, content, and utility. Both positive and negative feedback from study participants regarding the design, content, organization, and utility of the app also provided insight into app function and interface principles that may be transferable to the development of other real-time self-management interventions, especially those that target the adolescent developmental stage.

Over the course of 3 usability-testing cycles, the *Pain Squad+* app was refined for both ease of use and ease of understanding. All adolescent participants were either "comfortable" or "very comfortable" using a device and 81% owned their own smartphone. These observations are reflective of much larger national reports showing that 75% of adolescents have or have access to a smartphone (Lenhart, 2015). It might be expected then that ease of use issues, particularly those related to using basic app functions such as clicking and swiping, would be minimal. Indeed, adolescents in this study intuitively understood how to launch and use *Pain Squad+*.

Ease of use was negatively impacted by software malfunction (ie, app "crashing") in the first cycle of testing. The malfunction prevented adolescents from adequately completing the "think-aloud" usability task assigned and therefore testing was halted after 4 participants. Software malfunction is a leading reason for wasted time and user frustration with various electronic systems and results in decreased user engagement (Ceaparu, Lazar, Bessiere, Robinson, & Shneiderman, 2010). Poor responsiveness of interactive app elements also inhibited ease of use and is a known factor associated with decreased mHealth user engagement and associated meaningful behavior change (Danaher, Brendryen, Seeley, Tyler, & Woolley, 2015). Rectifying these issues refined the app such that it was considered sufficiently easy for adolescents with cancer.

Issues negatively affecting ease of understanding related to adolescents' inability to comprehend the text content of the app. Similar issues have been demonstrated in previous usability testing studies focused on this age group (Murphy, Sawczyn, & Quinn, 2012; Stinson et al.,

2006). In instances where poor understandability was problematic, including those identified in this study, revising the text to be simpler succeeded in improving the readability by the intended audience.

Evaluated objectively, *Pain Squad+*, the app was quick to complete. In addition, subjective reports from adolescents regarding the time required to use the app indicated that this was considered satisfactory. This finding further supported the usability of *Pain Squad+* as the ability for end-users to use a technology in a timely matter is considered a cornerstone of good app development (Brown, Yen, Rojas, & Schnall, 2013).

In general, *Pain Squad+* was considered acceptable to adolescents with cancer. This favorable result agrees with other studies that evaluated the acceptability of electronic symptom assessment and management apps for adolescents with cancer. These studies have demonstrated that pediatric oncology patients aged 9 to 21 years and diagnosed with a variety of disease types found the use of such apps to be satisfactory (Baggott, Gibson, et al., 2012; Macpherson et al., 2014; Rodgers, Krance, Street, & Hockenberry, 2013; Stinson, Jibb, et al., 2015; Tomlinson et al., 2014). mHealth apps therefore appear to represent a viable means to support cancer symptom assessment and management by adolescents during cancer therapy.

Particular components of *Pain Squad+* that were deemed acceptable to adolescents included the app design, which was resoundingly endorsed. Published literature has also shown adolescents to like mHealth and other Internet-based interventions that include colorful, age-appropriate graphics, and videos (Schneider et al., 2016; Stinson, Gupta, et al., 2015). It may be important to consider the use of these design elements when developing mHealth apps for this age group as these elements are expected to improve intervention engagement (Danaher et al., 2015).

The content included in the app was also well-endorsed by adolescents. Adolescents specifically liked having multiple available options to describe and manage their pain, and detailed information on how to implement management interventions. Studies of adult cancer patients have likewise shown that 87% of patients surveyed desired as much information as possible about their disease and treatment (Eysenbach, 2015). Despite this desire for cancer-related information by patients, a review of electronically available cancer information showed a lack of high-quality content targeted at the adolescent reading level (Stinson et al., 2011). Therefore, there is an opportunity for the development of mHealth interventions, such as *Pain Squad+*, to offer reputable and effective real-time pain management advice to young cancer patients.

Concerning the acceptability of navigation within the *Pain Squad+* app, adolescents with cancer were displeased with the excessive number of steps required to

complete a function. The desire to minimize complexity and maximize the convenience of mHealth interventions has been previously shown in adolescents with anaphylactic allergies (Anderson & Wallace, 2015) and asthma (Schneider et al., 2016). Furthermore, "difficult to find" features of mHealth interventions have been a leading cause of user frustration and therefore may limit user interaction (Ceaparu et al., 2010). The constrained screen size of smartphones, which can diminish the capacity of a user to interact with the device, further supports the need to streamlined navigation (Danaher et al., 2015). In the present study, following Cycle 1 of testing, the navigation path through the app was simplified successfully and no problems related to navigation were noted during subsequent testing.

Adolescents' endorsement of the utility of *Pain Squad+* is comparable with recent studies of other mHealth interventions (Anderson & Wallace, 2015; Jibb et al., 2014; Ly et al., 2015; Maguire et al., 2015; Stinson et al., 2013). These studies have shown that mHealth interventions are consistently considered useful and valuable adjuvants to routine clinical care. This study adds to this research by indicating that adolescents with cancer expect that they will use mHealth interventions such as *Pain Squad+* over a prolonged period whenever they experience symptoms and especially in circumstances of limited access to other clinical support. This finding is particularly important in the case of adolescent cancer because recent electronic diary research has shown 95.3% of 8- to 18-year-olds with cancer experience pain at least daily, including when not in the hospital (Stinson, Jibb, et al., 2015). Therefore smartphone-based means to support consistent adolescent pain management in all naturalistic settings (eg, home, school, hospital) have potential cancer care value.

The ability for adolescents to customize *Pain Squad+* to their preferences represented the final app acceptability theme. Participants valued the capacity to personalize the pain advice that was recommended to them. A customizability capacity is in keeping with previous clinical and theoretical usability research with adolescents with health conditions (Anderson & Wallace, 2015; Brown et al., 2013). These studies indicate that customizability may be a valuable app usability asset because it allows users to operate a system as preferred and may therefore improve satisfaction.

The strengths of this study include the user-centered and iterative design approach to the refinement of the *Pain Squad+* app. In addition, the credibility of the results was enhanced by triangulation of findings across data sources (ie, observation and interviews). Still, several research limitations must be highlighted. First, this study was conducted at a single tertiary pediatric center using a relatively small number of adolescents who were generally newly diagnosed with cancer, which could represent

a threat to the generalizability of the results. Second, the usability of *Pain Squad+* in adolescent environments other than the hospital (eg, home and school) and longitudinally was not assessed. Because components of an app's usability, such as technical difficulties and acceptability, may differ across testing environments and with repeated testing, it is recommended to test interventions under the various circumstances within which they will be used (Brown et al., 2013; Kushniruk & Patel, 2004; McCurdie et al., 2012). Subsequent phases of *Pain Squad+* testing will address this issue. Last, potential cognitive biases may have been introduced into the findings. Experimenter bias may have been introduced as the same team members who conducted the usability testing observation and interviews, also conducted the analyses. However, because 2 independent observers endeavored to be present at all testing sessions and debriefed about the session afterwards and a bracketing protocol was used, this bias is expected to have been limited. Social desirability response bias, or the tendency to obtain approval by responding in a culturally and socially acceptable manner (Logan, Claar, & Scharff, 2008), may also have impacted our findings. In an effort to provide a socially desirable response and "look good," children and adolescents may deny negative thoughts and feelings (Paulhus & Reid, 1991). In this study, because adolescents used the app in the presence of the research team and then provided feedback to the team, there is potential for the responses we received to be biased in a favorable direction. To minimize this effect, at testing onset all adolescents were encouraged to use the app naturally and were told that both positive and negative feedback were equally important. In addition, we used field notes to record observations of nonverbal behavior related to ease of use and acceptability, which has also been shown to reveal hidden app design flaws (McCurdie et al., 2012).

Although the primary objective of this study was to refine *Pain Squad+* for usability, implications for pediatric oncology nursing practice have emerged. If shown to be effective, *Pain Squad+* has the potential to act as a useful tool to support real-time pain assessment and management in a cancer patient population increasingly treated on an out-patient basis (Fortier et al., 2012). In this regard, health care professionals, including those responsible for introducing clinical quality improvement initiatives, will be imperative in translating knowledge generated by this research directly into practice. This study also has broad implications for the use of innovative methods, such as *Pain Squad+*, in pediatric oncology practice. As demonstrated presently, the use of Internet- and mobile-based technologies by adolescents is both acceptable and commonplace. Health interventions grounded in technologically based modalities therefore may represent a viable, useful, and potentially cost-effective means to improve the

health of adolescents with cancer and their use in routine practice should be considered.

In conclusion, engagement of end-users early and throughout mHealth development is highly recommended to ensure that interventions meet the explicit needs of the target group (McCurdie et al., 2012; Wootten et al., 2014). In the present study, findings from usability testing cycles with adolescents with cancer were successfully used to refine the *Pain Squad+* app for ease of use, ease of understanding, efficiency, and acceptability. Next research steps will include piloting *Pain Squad+* longitudinally with adolescents in their naturalistic settings before testing app effectiveness in a future multicenter study. If effective in improving pain outcomes for adolescents with cancer, the *Pain Squad+* app may represent a viable means to offer patients real-time self-management support related to a number of physical and psychosocial cancer symptoms. Future research will also focus on the translation and cultural adaptation of *Pain Squad+* such that it is appropriate to adolescents with cancer across a range of cultural contexts. Finally, a usable *Pain Squad+* app may act as a template for the remote real-time self-management of a variety of chronic and life-limiting conditions, although additional usability testing with these user groups is recommended.

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