Perception of Older Adults towards Smartwatch Technology for Assessing Pain and Related Patient Reported Outcomes: A Pilot Study

Abstract

Background: Chronic pain, including arthritis, affects about 100 million adults in the United States. Complexity and diversity of pain experience across time and people and its fluctuations across and within days show the need for valid pain reports that do not rely on patient's long-term recall capability. Smartwatches can be used as digital ecological momentary assessment (EMA) tools for real-time collection of pain scores. Smartwatches are generally less expensive than a smartphone, are highly portable, and have a simpler user interface, providing an excellent medium for continuous data collection and enabling a higher compliance rate.

Objective: The aim of this study was to explore the attitudes and perceptions of older adults towards smartwatch technology for measuring patient report outcomes (PRO) as an EMA tool.

Methods: A focus group session was conducted to explore the perception of participants towards smartwatch technology and its utility for PRO assessment. Participants included older adults (age > 65), with uniliateral or bilateral symptomatic knee Osteoaethritis (OA). A preliminary user interface with server communication capability was developed and deployed on 10 Samsung Gear S3 smartwatches and provided to the users during the focus group. Pain was designated as the main PRO, while fatigue, mood, and sleep quality were included as auxiliary PROs. Pre-planned topics included participants' attitude towards the smartwatch technology, usability of the custom-designed app interface, and suitability of the smartwatch technology for PRO assessment. Discussions were transcribed and content analysis with theme characterization was performed to identify and code the major themes.

Results: Twenty participants (age 65+) were recruited and consented to take part in the focus group study. The overall attitude of the participants towards the smartwatch technology was positive, and they showed interest in the direct phone call capability, availability of extra apps such as the weather apps, and sensors for tracking health and wellness such as accelerometer and heart rate sensor; with 74% of the participants showing willingness to participate in a 1-year study to wear the watch daily. Concerns were raised regarding usability, including accessibility (larger icons), notification customization, and intuitive interface design (unambiguous icons and assessment scales). Participants expresses interest in using smartwatch technology for PRO assessment and availability of methods for sharing data with healthcare providers.

Conclusions: All participants had overall positive views of the smartwatch technology for measuring OPROs to facilitate patient-provider communications, and to provide more targeted treatments and interventions in the future. Usability concerns were the major issues that will require special considerations in future smartwatch PRO user interface design, especially accessibility issues, notification design, and use of intuitive assessment scales.

Keywords: Smartwatch; Focus Group; Ecological Momentary Assessment (EMA); Patient Reported Outcomes (PRO).

Introduction

About 100 million adults in the United States are affected by chronic pain, including arthritis, costing $560 to $635 billion annually (1). Pain is a complex experience (2) that varies across time and people(3, 4). Recent research on pain in arthritis patients has shown that pain fluctuates significantly both across and within days (3). Traditionally, researchers and practitioners have relied on patient's recall to assess pain, as well as to track and evaluate pain management routines(5). While still a convenient method, many recent studies point to memory errors and distortions that impact pain recall (6, 7). For example, the "peak-end effect" causes the more recent experiences to have an especially strong influence on recall(8), and the "duration neglect" results in a tendency to ignore periods without pain(9). To provide valid pain PROs that do not rely on patient's long-term recall capability, researchers have used various EMA approaches such as paper-and-pencil and electronic diaries (7, 10), Twitter feeds (11), and smartphone apps(12, 13). These approaches can provide finer-resolution and possibly more valid assessments, while also providing the ability to examine the fluctuations and variation of pain over time. The use of digital EMA tools can be especially important for enhancing the accuracy of assessments in older adults, who are more likely than younger adults to experience memory lapses (14).

While smartphones are increasingly becoming popular as convenient digital EMA tools for real time assessments(12, 13), 70% of older adults still do not own a smartphone(15), and may lack the requisite knowledge and skills for effectively using a smartphone for this purpose. Moreover, due to their size, smartphones may not be optimally convenient for EMA purposes. As an alternative to using a smartphone, in this study we examined the perception and attitude of older adults towards smartwatch technology for capturing pain PROs. We specifically used the Samsung Gear S3 smartwatch. It is less expensive compared to a smartphone, highly portable, and highly discrete due to its sleek design resembling a regular watch. These factors could promote higher compliance. A smartwatch also has a much simpler user interface compared to a smartphone, and due to their enhanced portability, smartwatches provide an excellent medium for continuous data collection.

We hypothesize that since a smartwatch can be worn all day, potentially this will result in a higher compliance rate compared to a smartphone. A smartwatch, coupled with the embedded sensors including accelerometer, GPS (Global

Positioning Systems), UV (Ultraviolet), and heart rate sensor, can provide additional information such as physical activity intensity and duration, location, UV exposure, and heart rate. Previous EMA interventions based on basic watch-type computers for assessing fatigue have been reported to be successful at characterizing the temporal changes of fatigue(16), demonstrating the potential for momentary assessments. We assessed the attitudes older adults towards smartwatch technology for capturing pain PRO measures in a focus group, to guide hardware and software development and our long-term future studies. A preliminary version of the PROMPT[1] app was developed, along with the server infrastructure, which were provided to the participants during a demo session. The focus group discussions and suggestions were summarized and analyzed to assess the potential of smartwatch technology for PRO assessment and to guide future developments for use in older adults.

Methods

Study Population

Notice that the first subheading immediately follows the last heading. Subheadings under subheadings are also possible (see Statistical Analysis). We recruited 20 older adults aged 65-89 years (see for participants' characteristics), with 19 participating in the focus group. The inclusion criteria include age > 65 years and diagnosis of unilateral or bilateral symptomatic knee Osteoarthritis (OA). Some of the exclusion criteria include failure or inability to provide informed consent, significant cognitive impairment, defined as a known diagnosis of dementia, and being unable to communicate because of severe hearing loss or speech disorder (see supplemental material for complete list of eligibility criteria). A convenience sample of older adults was identified through posting flyers at University of Florida's Institute on Aging research and patient clinics, and direct mailings to age-eligible participants through approved registries. Each participant received a $50 gift card in compensation. The focus group protocol was approved by the Institutional Review Board (IRB) of the University of Florida.

Smartwatch App and Server Framework

The PROMPT framework is comprised of two components: the (1) server software and the (2) smartwatch app. This integrated framework is designed and developed to perform several tasks including remote data collection, storage, retrieval, and analysis.

The PROMPT smartwatch app, custom-built for Samsung Gear S3, collects self-report and sensor data, carries out the initial preprocessing, and transmits the preprocessed data to the server. The sensor data include accelerometer data collected at 10 Hz frequency, and heart rate and Global Positioning System (GPS) data collected every hour. The smartwatch app is developed in Tizen, a Linux-based operating system. It runs in a Webkit-based browser environment driven by Google V8 JavaScript engine, and its data storage is implemented using the IndexedDB JavaScript library.

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1 PROMPT=Patient Reported Outcome of Mood, Pain, and faTigue

The server provides several capabilities including remote smartwatch configuration, receiving collected data, and storing received data in a database for further analysis (Figure 1). Data are stored using the Apache Spark infrastructure and PostgreSQL database to ensure scalability to many smartwatches simultaneously deployed in the field. A web portal frontend also allows for remote monitoring of the smartwatches in the field and other administrative tasks, such as assigning study participants to specific smartwatch IDs.

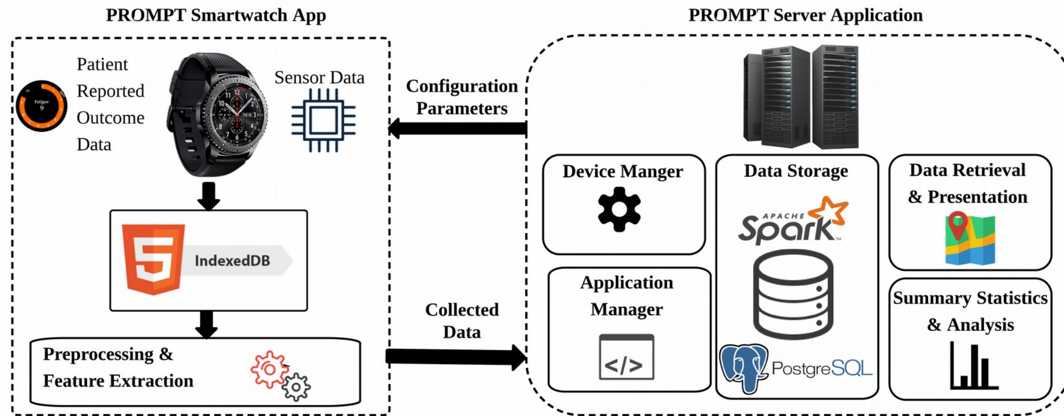


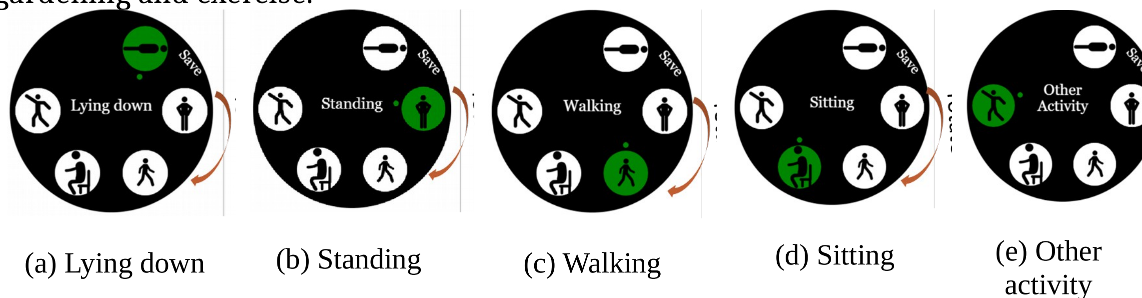
Figure 1: PROMPT framework comprises of the smartwatch app and the server application.

The PROMPT app was developed to show assessment notification every 4 hours, by asking the users to enter their current pain, fatigue, and mood assessments. Sleep quality is programmed to be assessed every morning with a prompt randomly provided between 8 am – 12 pm. Using the PROMPT interface, the assessment ratings can be easily entered by rotating a bezel (Figure 2b), and can be saved by pressing a button located on top of the bezel (Figure 2e). While we only have presented the pain assessment screen (Figure 2), similar screens have been developed for assessing fatigue, mood, and sleep quality. We use the Numerical Pain Rating Scale (NRS)(17) for pain assessment by showing pain intensity on a scale of 0-10. Other auxiliary PROs including mood, fatigue, and sleep are shown similarly using a numerical scale of 0-10(18, 19). All these scales except for the sleep quality designate 10 as the worst possible outcome (i.e. highest pain level, highest fatigue level, or the most negative mood).

(a) Samsung Gear S3 (b) Bezel rotation (c) Rating pain scores (d) Changing color schema (e) Saving the ratings

Figure 2: (a) The Samsung Gear S smartwatch used in the PROMPT study. (b) Ratings are entered by rotating the bezel to select pain ratings, as seen in (c)-(d). The color schema will also change as the ratings are increased or decreased. (e) Ratings can be saved by pressing the top button (physical button), located on top of the bezel.

The same bezel rotation and saving mechanism is also used to capture current user activities (Figure 3). Our current list of activities includes: lying down, standing, walking, sitting, and *other activities* representing other possible activities such as gardening and exercise.



(a) Lying down (b) Standing (c) Walking (d) Sitting (e) Other activity

Figure 3: Users can choose activities by rotating the bezel.

Focus Group Setup

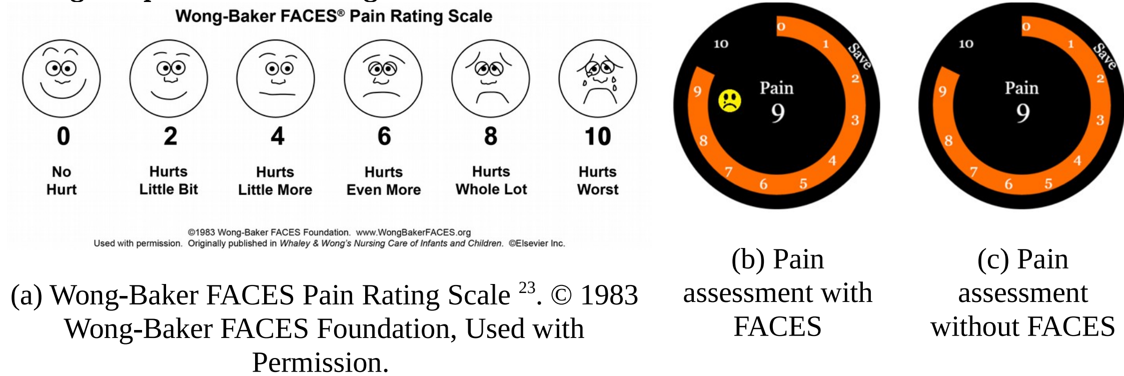
The focus group was conducted by a team consisting of a moderator and two assistant moderators. The focus group formation and content analysis was guided by memo writing, qualitative sampling, and metacoding.(20-22). The moderator used a semi-structured interview approach to presenting the information with a goal of promoting uninhibited dialogue and non-judgmental feedback. Research assistants took notes in form of verbatim quotes. They also observed and documented participants' expressions and reactions – no audio recording was performed for privacy reasons and to provide a more inviting discussion atmosphere. Both assistant moderators participated in facilitating the discussions. One of the assistants took notes on a large-sized easel pad, clearly visible to all participants, while also posting participants' notes on the easel using post-it notes provided to the participants at the beginning of the session. The other assistant moderator took notes on a laptop computer, and tallied the number of participants discussing each topic.

The first 30 minutes of the focus group was dedicated to introducing the smartwatch technology, explaining the rationale of the study, and showing screenshots of the interface. Then the participants were provided with 10 Gear S3 smartwatches preloaded with the PROMPT app. They were assisted in using the PROMPT app, as necessary. The watch configuration was changed to show notifications every 5 minutes to better allow for exploration of the app in a timely manner. Lastly, to better capture design preferences, the participants were asked to sketch their own smartwatch face design.

Focus Group Orientation and Questions

The focus group was designed to be an open-ended forum, starting with several directed questions. We asked 12 questions that related to the impression of the

smartwatch technology, different aspects of the PROMPT user interface, using a smartwatch for PRO assessment, long-term study logistics, and potential future improvements. These questions were designed to have direct responses, but allowed for open-ended answers (Table 1). Most of the questions related to the user interface were based on current PROMPT interface implementation to identify necessary improvements. Alternative scenarios, such as using emoticons on the assessment screens using the Wong-Baker FACES Pain Rating Scale (23) were shown during the presentation (Figure 4).



(a) Wong-Baker FACES Pain Rating Scale [23]. © 1983 Wong-Baker FACES Foundation, Used with Permission.

(b) Pain assessment with FACES

(c) Pain assessment without FACES

Figure 4: PRO assessment with and without emoticons.

Table 1: Focus group questions are summarized according to their topic.

Topic	Questions
a. Smartwatch Impression	
	a.1 What is your opinion about watch size and its accessory bands?
	a.2 What is your first impression of the watch itself?
b. PROMPT Interface	
	b.1 Do you like the PROMPT color schema for PRO assessment?
	b.2 Do you like the app flow? Any need for a back button?
	b.3 Would you like to add emoticons to the assessment screen?
	b.4 Do you like the activity icons? Would you prefer icons or text?
	b.5 What type of notification do you prefer to receive, and why?
	b.6 Is the text large enough to read?
c. PRO Assessment	
	c.1 How many times per day would be too burdensome to ask you?
	c.2 Other issues you like the researchers and doctors to know?

d. Study Logistics	
	d.1 How likely are you to participate in a one-year research study asking you to wear the smartwatch daily for up to a year?
	d.2 What other options would help you to participate?

Analysis

Following the focus group, the notes were compiled and summarized by the assistant moderators. Major topics were identified across the discussions by the assistant moderators, and were grouped based on the underlying themes.

Results

User Statistics

Out of the 20 consented participants, 19 attended and participated in the focus group study. The session lasted about 90 minutes. (Table 2) depicts the demographics information of participants.

Table 2: Characteristics of the focus group participants are presented. N = 19.

	Total	Female	Male
Number of Participants			
	19	14 (73.6%)	5 (26.3%)
Age			
	72.7 ± 6.1	72.0 ± 6.7	75.5 ± 5.8
Access to Wi-Fi			
	17 (89.4%)	-	-
Own a smartphone			
	14 (73.6%)	-	-
Own a smartwatch			
	1 (5.2%)	1 (7.1%)	0 (0.0%)
Active in water			
	4 (21.0%)	-	-

Content Analysis

The content analysis revealed several major sub-topics and theme under each major topic in (Table 1), as shown in Table 3-6. 109 verbatim quotes from participants were coded, where nine quotes were considered as irrelevant. The themes emerged under the four groups of questions (smartwatch impression, PROMPT user interface, PRO assessment, and study logistics). We identified 13 major themes and 48 detailed sub-themes.

Table 3: Themes and sub-themes are reported by the focus group participants. Numbers in front of each sub-theme indicate N (%) of participants reporting each theme, with % rounded to nearest integer. Number in front of each theme shows the % reported with respect to all the other themes.

Topic	Themes	Sub-Themes
Smartwatch Impression *(25%)*		
	Function *(32%)*	Time Display *1(5%)*, Apps *3(16%)*, Water Resistance *1(5%)*, Backlight *1(5%)*, Security *1(5%)*
	Apps *(27%)*	Weather *3(16%)*, Email *1(5%)*, Phone *2(11%)*
	Appearance *(32%)*	Heavy *2(11%)*, Accessory Bands *4(21%)*, Band Durability *1(5.2%)*
	Sensors *(9%)*	Step Count, Heart Rate, GPS *2(11%)*
PROMPT User Interface *(54%)*		
	Color Schema *(12.5%)*	Color-blindness *2(11%)*, Customized color schema *3(16%)*, Mapping colors to mental states *3(16%)*
	Icons *(18.7%)*	Icon Ambiguity *2(11%)*, Expanded list of activities *1(5%)*, Customized list of activities *1(5%)*, Activity intensity *1(5%)*, Emoticons *4(21%)*
	Notifications *(33.3%)*	Notification preferences *3(16%)*, Disruptive notifications *2(11%)*, Notification customization *1(5%)*, Context-dependent notifications *1(5%)*, Silent mode *1(5%)*, Number of notifications *7(37%)*, Start time customization *1(5%)*
	Usability and Accessibility *(27.0%)*	Easy setup *4(21%)*, Automatic prompts *1(5%)*, Speech input *1(5%)*, Large font size *3(16%)*, Large icons *3(16%)*, Notification customization for visually or hearing impaired *1(5%)*
	Assessment Scales *(6.25%)*	Scale direction *2(11%)*, Neutral value *1(5%)*
	Flow *(2.0%)*	Back button *1(5%)*
PRO Assessment *(18%)*		
	Capturing	Fluctuation and intermittent pain *2(11%)*,

	Pain *(50%)*	Activity dependent *1(5%)*, Pain location *1(5%)*, Weekly or daily summary *1(5%)*, Medication use *3(16%)*
	Other PROs *(50%)*	Stiffness *1(5%)*, Positive feedback instead of negative *4(21%)*, Tracking sleep *3(16%)*
Study Logistics *(2%)*		
	Study Participation *(100%)*	Use during travel *1(5.2%)*, Frequent clinic visit, Impact on personal data plan *1(5.2%)*

Theme percentages do not include the tally questions. Some discussion items were included under multiple themes. The discussion on user interface options was the most comprehensive (54% of all the topics discussed), spanning issues from accessibility for visually impaired users to specific details of design. The participants expressed a desire for customization, e.g. to choose how to be notified when it is time to enter the PRO assessments (sound, vibration, and music), or to customize the list of activities or medications. Initially most participants showed interest in using emoticons like the Wong-Baker FACES Pain Rating Scale (23) to guide them during assessment, but after working with the app on the watch, they felt there was no need for emoticons, given the color change during rating.

Table 4: Selected participants' quotes on discussed themes grouped according to topic.

Topic	Sub-Topic	Example Quotes
Smartwatch Impression		
	Function	*"Can you download its apps like on a smart phone?"*
	Apps	*"I would wear it as it is, it is excellent, but the more apps, the better"*
	Appearance	*"I like the extra band, lighter"*
	Sensors	*"Can its GPS be used to track if I am at gym?"*
PROMPT User Interface		
	Color Schema	*"when it shows my good mood as green, I don't like it, not my mental model of happiness"*
	Icons	*"standing can represent both washing dishes or cooking"*
	Notifications	*"my hearing is bad and I might be active and might not see it*
	Usability & Accessibility	*"voice activated recording might be helpful to record details of activities"*

	Assessment Scales	*"For feeling down, is the scale going up or down?"*
	Flow	*"I would like an erase or back button when I make a mistake"*
PRO Assessment		
	Capturing Pain	*"I have intermittent pain, walking for 5 minutes, then no pain, coming and going"*
	Other PROs	*"It is important to emphasis when you are feeling good, feeling up. To emphasis fatigue, it is negative and it is going to be measured in a negative way"*
Study Logistics		
	Study Participation	*"How would the watch affect my data plan usage?"*

The participants were asked about several issues regarding the RPOMPT app user interface, including the need for emoticons on PRO scales, the use of back button, font size, and displaying additional information such as heart rate or step count (Figure 5).

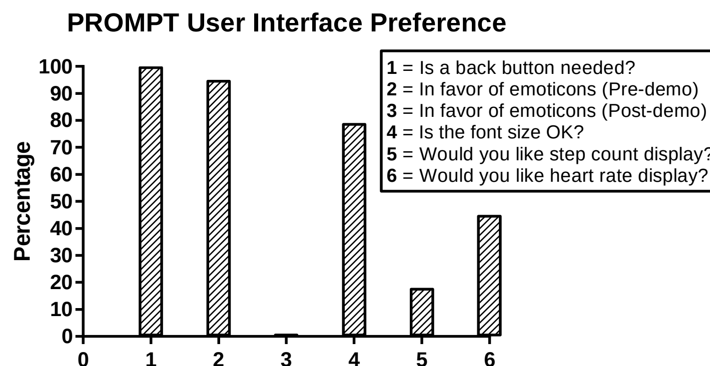
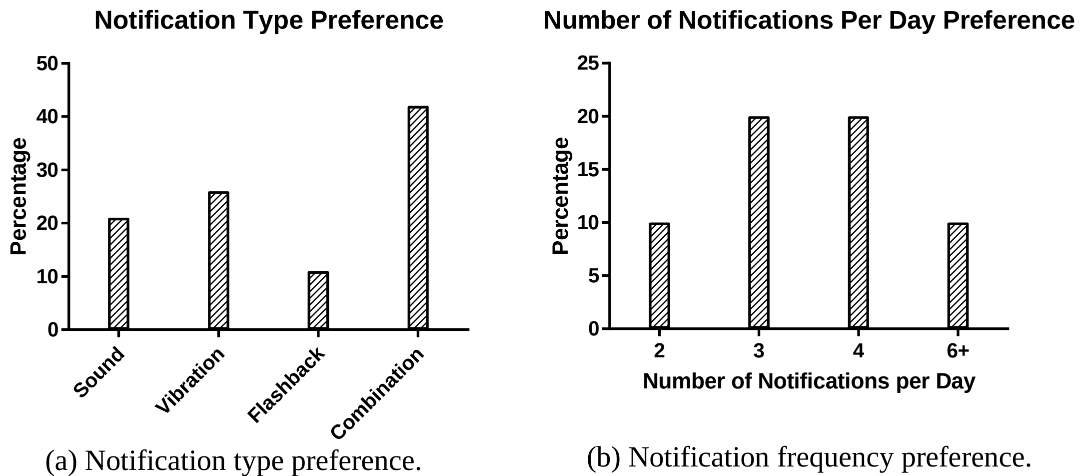


Figure 5: Participants' preference on various user interface issues related to PROMPT. The bars indicate the percentage of the users who responded 'Yes'.

The participants were asked about their notification method of choice (Figure 6a), and whether they would prefer sound, vibration, flashing light, or a combination of all. The participants were also asked about preferred number of notifications per day (Figure 6b). The PRO assessment discussions led to the fact that also EMA might not be able to capture the max pain experience during the day, if sampled at certain times. It was concluded that instead of prompting for PRO assessments 4 times a day, it might be better to prompt 3 times, while asking for a summary assessment at the end of the day to better capture the daily fluctuations. Additionally, 74% of the participants mentioned that they will be willing to participate in a 1-year study to wear the watch daily.



(a) Notification type preference.

(b) Notification frequency preference.

Figure 6: Participants' preference on notifications type and frequency.

Discussion

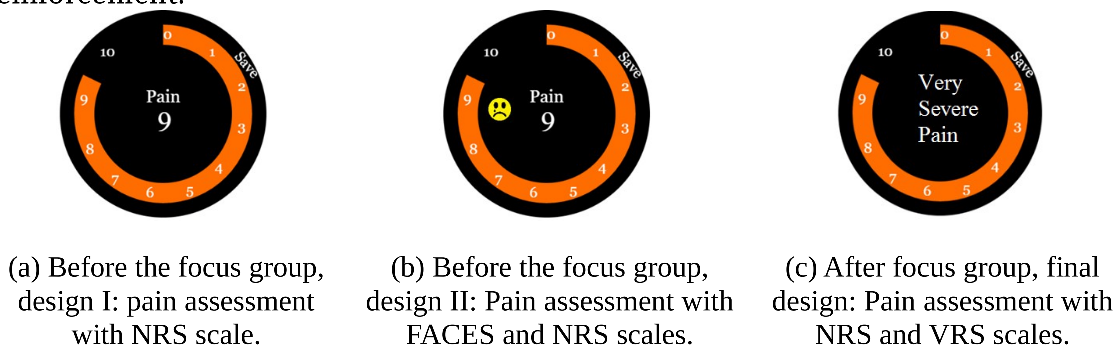
A review of the literature shows the lack of systematic evaluation of smartwatch technology among older adults. While several recent studies have developed smartwatch apps for fall detection(24), mood assessment(25), or gait estimation(26), there has been limited research (25) on using smartwatch technology for PRO assessment in general population, and more specifically among older adults.

This study allowed us to explore the attitudes and perceptions of older adults towards smartwatch technology, specifically for PRO assessment. Most participants in our study expressed enthusiasm for wearing the smartwatch, despite its weight and lacking several desired features. In general, while it has been shown that older adults are less likely to use new technology compared with younger adults(27), there is ample evidence that they also desire interaction with new technologies to remain active and engaged with society(28). In a recent framework, Lee and Coughlin identified 10 factors that affect how technology is adopted by older adults, including: perceived value, usability, affordability, accessibility, technical support, social support, emotion, independence, experience, and confidence(29). Our results are consistent with these factors and with other previous studies on the use of technology among older adults (30, 31), indicating an interest towards adopting new technology given perceived usefulness and potential benefits.

Several previous studies also have found that anxiety is positively correlated with age while self-efficacy is negatively correlated, resulting in lower self-confidence and higher anxiety in older adults when facing new technology(27, 32). As Lee and Coughlin point out(33), it is important to build an intuitive design to enhance self-confidence among older adults. Our focus group results point to the fact that a smartwatch provides a sufficient degree of familiarity by resembling a regular watch, thus facilitating knowledge transfer and overcoming the learning barriers, possibly building confidence in older adults' ability to use this new technology(33). In general, the participants perceived the smartwatch technology and its use for PRO assessment as an empowering tool as it allows them to provide real-world

symptomology to care givers. This is particularly true for chronic pain that is often highly variable.(34) They also indicated that a simple interface, technical support, and clear instructions are needed to tackle the technological barriers, consistent with other studies (29, 35). App interface customization was also a recurring theme across the focus group discussions, to tailor the app to individual needs and preferences of the users, and to accommodate hearing and visual impairment, further underlining the need for usability and accessibility.

We found that participants' mental models of assessment scales can greatly impact how they assess their outcomes (*"For feeling down, is the scale going up or down?"*). For example, initially we used NRS (17) for pain assessment by representing pain intensity on a scale 0-10 (Figure 7a). Based on our focus group discussion, we changed our design to reflect a combination of NRS and the Verbal Pain Rating Scale (VRS) (36)(Figure 7c), to avoid confusion and to better allow the participants to map the smartwatch scale to their mental scale. As discussed before, interestingly, the participants did not think it was necessary to use the Wong-Baker FACES Pain Rating Scale (23) to guide them during rating (Figure 7b). Similar verbal scales are used in our refined design for mood, fatigue and sleep assessment. We adopted existing verbal scales such as a modified version of the Visual Analogue Mood Scale (VAMS) (37)for mood assessment. We also changed some of the wording such as *feeling down* to *mood* reflect a more neutral sentiment and to avoid negative thought reinforcement.



(a) Before the focus group, design I: pain assessment with NRS scale.

(b) Before the focus group, design II: Pain assessment with FACES and NRS scales.

(c) After focus group, final design: Pain assessment with NRS and VRS scales.

Figure 7: Different pain assessment scales used before and after the focus group.

We also found that in general the touchscreen interface on the smartwatch was difficult to operate by some older adults due to the small size of icons, as well as their decreased motor resolution and coordination, as observed in previous studies on older adults with smartphones(38). Most participants preferred using the bezel rotation and the physical button pressing, thus our re-designed app only employs these mechanisms for interacting with the app.

The participants also expressed interest in several future features, most notably the capability to keep their healthcare provider in the loop through a healthcare provider portal or through Electronic Health Records (EHR) integration. They also showed interest in a patient Web portal for viewing their collected data in more detail on a larger screen device. Connectivity to other smart devices such as smart scales also was discussed by participants. Finally, an emergency option was on top of their future desired features, to be able to call 911 or relatives in case of emergency.

Though our results point to interesting insights, our study had several limitations. Our focus group participants were locally recruited and might not represent the broader population of older adults. The results are also based on a single focus group session following limited interaction with the technology, and different results could emerge if feedback were obtained after wearing and using the device for an extended period. Finally, it should be noted that we studied the smartwatch technology primarily in the context of pain assessment and participants reporting knee pain. These results might differ if the focus group is conducted on the use of smartwatch for different applications or when targeting populations with different medical histories. Nonetheless, these results point to the feasibility of using smartwatches for PRO assessment in older adults, and offer invaluable insights for improving the current interface and technology.

Conclusions

Our study confirms the feasibility and acceptability for using smartwatch technology as a PRO assessment in older adults. Usability and intuitive design, personalization, and accessibility were found to be important for adopting and using PROMPT smartwatch technology. The choice of different PRO assessment methods (e.g. visual versus verbal scales) was also found to impact how older adults use smartwatch technology for reporting their pain, mood, fatigue, and sleep quality. Finally, the participants expressed interest in the ability to observe these assessments in more detail on a Web portal and to be able to share them with their healthcare providers. These findings can be used to guide the future smartwatch software design, as well as to guide developing new EMA methods for PRO assessment.

Abbreviations

EMA: ecological momentary assessment
GPS: Global Positioning System
NRS: Numerical Pain Rating Scale
OA: osteoarthritis
PRO: patient reported outcome
PROMPT: patient reported outcome of mood, pain, and fatigue
UA: Ultraviolet
VRS: Verbal Pain Rating Scale

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