Title: Quality and usability of arthritic pain self-management Apps for older adults: a systematic review.

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Abstract

Objective: To appraise the quality and usability of currently available pain applications that could be used by community dwelling older adults to self-manage their arthritic pain.

Methods: A systematic review. Searches were conducted in App Store and Google play to identify pain self-management apps relevant to arthritic pain management. English language pain management apps providing pain assessment and documentation function, and pain management education were considered for inclusion. A quality evaluation audit tool based on the Stanford Arthritis Self-Management Program was developed *a priori* to evaluate app content quality. The usability of included apps was assessed using an established usability evaluation tool. .

Results: Out of the 373 apps that were identified, four met the inclusion criteria. The included apps all included a pain assessment and documentation function; and instructions on: medication use, communication with health professionals, cognitive behavioural therapy based pain management, and physical exercise. Management of mood, depression, anxiety and sleep were featured in most apps (n=3). Three quarters (n=3) of the apps fell below the acceptable moderate usability score (≥3), while one app obtained a moderate score (3.2).

Conclusion: Few of the currently available pain apps offer a comprehensive pain self-management approach incorporating evidence-based strategies in accordance with the Stanford Arthritis Self-Management Program. The moderate level usability across the included apps indicates a need to consider the usability needs of older population in future pain self-management app development endeavors.

Keywords: Older Adults, Pain Management, Arthritis, Smartphone, Apps, Usability, Technology.

BACKGROUND

Population aging is a global phenomenon. By 2050, 1.5 billion of the world's population will be older than 65 years ('older adults') [1], with most living in the community [2-4]. Between 20-46% of all community dwelling older adults live with comorbid conditions that cause varying levels of disability and symptoms, including unrelieved pain [5]. For 70% of older adults, arthritis [6] is a major cause of chronic, unrelieved pain [7]. Across the developed world arthritic conditions cost between 1% and 2.5% of the gross national product [8].

While, osteoarthritis is the most common joint disease of old age, rheumatoid arthritis affects all ages but is more prevalent among older adults [9, 10]. Despite different pharmacological treatment approaches, the recommended rheumatoid and osteoarthritis pain self-management strategies tend to be similar [11, 12]. Both arthritic conditions require the patient to assess and interpret their pain (symptom awareness) and to apply adaptive coping strategies (symptom management) such as analgesic adjustment, or lifestyle modification on a regular basis [13]. An additional but important element of the self-management approach is the integration of a shared decision-making model where clinicians work closely with patients to build their self-management capabilities by provisioning appropriate instruction, education and support [14-16]. All of these elements are integral to the Stanford Arthritis Self-Management Program ('Stanford Program').

The Stanford Program is a well-established pain self-management program [17, 18] found to be consistently effective in improving patient's self-efficacy by increasing physical exercise, adoption of healthier eating and pain-coping strategies, and better medication adherence [19, 20]. Delivered either face-to-face or via the Internet [18], the Stanford Program focuses on; i) patient education; ii) addressing other symptoms that commonly accompany pain; iii) Cognitive Behavioural Therapy (CBT) approaches to pain management; and iv) physical exercise regulation [19, 20]. For the purpose of this review, the Stanford Model was chosen

as the 'gold standard' self-management model as it has been empirically validated in a number of studies across a variety of formats (face-to-face, Internet delivery, expert patient delivery) and successfully applied to arthritic pain management with community dwelling older adults, the focus of the current review [17-20].

Mobile Technology and pain self-management

Significant advances in smartphone technology and a proliferation of app development has occurred since the release of the first Apple iPhone in 2007 [21]. There are currently over 300 pain self-management apps providing functions such as: pain assessment recording, pain related information, and pain self-management plans [22, 23]. These pain self-management apps could potentially be utilised by older adults to facilitate their pain self-management, especially as increasing numbers of older adults are now using the Internet (60%), smartphones (18%), and tablet computers (18%) in their daily lives [24]. There is also emerging evidence that a growing number of older adults are willing to use smartphones to better manage their pain [25-27] and that simpler designs, clearer instructions and features help compensate for older people's reduced sensory and motor skills [28, 29]. As, many of the currently available pain apps have been developed with minimal input from clinicians or consumers, and very few are based on scientific, theoretical or a conceptual foundation [22, 23, 30, 31], it is difficult to know whether any meet the specific self-management needs and expectations of older people with arthritic pain.

Several pain app systematic reviews have been undertaken but none have focused specifically on the needs of older people with arthritic pain. The evaluation and reporting approaches used in these systematic reviews varied widely, with some reviews only providing a descriptive account of the pain apps features [23, 31], while others provide details of an evidence based quality appraisal [22, 30, 32].However, these quality appraisals were limited because the review either: excluded arthritis pain apps [30]; appraisal focused on non-arthritic

literature [22], and/or was based only on CBT pain management literature [32]. Another limitation is that most reviews have not considered the needs of older users [33, 34] and/or utilized a quality assessment criteria based on an extensive arthritic pain self-management literature, leading to inconclusive results.

Usability

Although usability evaluations of health care applications have become increasingly prevalent in the recent years [35-38], there has been little research addressing usability evaluations of pain apps [30]. While usability of pain apps has been evaluated in a recent systematic review [30], it was limited to evaluation of only two pain apps, and was based on ratings of middle-aged raters in an author developed rating tool. No systematic evaluation of older adult specific usability of pain apps has been undertaken. As the vast proportion of the arthritic pain population is comprised of older adults, an evidence based quality and usability evaluation of pain apps considering older adults' technology specific needs is necessary to help users make informed choices.

OBJECTIVE:

To appraise the quality and usability of currently available pain applications that could be used by community dwelling older adults to self-manage their arthritic pain.

METHODS

Systematic review methodology informed by three frameworks namely:1) the World Health Organization [39] Innovative Care for Chronic Conditions (ICCC) (macro level); 2) the domains of chronic disease self-management (meso level) [40]; and 3) the elements of Stanford Program (micro level) [17, 18] was adopted to appraise the quality and usability of pain apps (Figure 1).

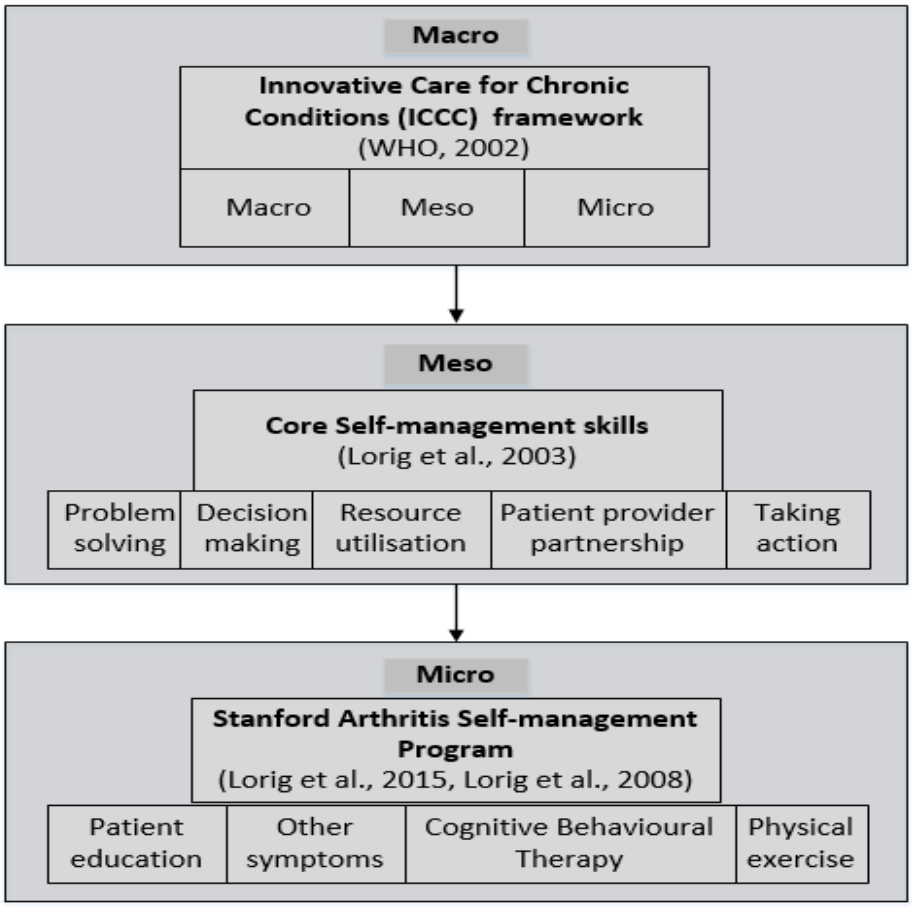

Figure 1 Guiding framework of this review

Inclusion criteria

English language pain self-management apps developed from 2007 onwards and including at least one symptom awareness function (i.e. pain assessment, pain recording, pain management recording; and/or recording other complaints) *and* one symptom management function (i.e. patient education; other symptoms; CBT approach; and/or physical exercise) were eligible for inclusion. An app with only one function (either symptom awareness or symptom management) was deemed unlikely to comprehensively assist with pain self-management activities and was therefore excluded. Apps focusing on migraine, dental, or gynecological pain were excluded as the management approaches of these conditions tend to be different than arthritic pain.

Searches were conducted between 1st and 30th May 2016 on two leading mobile operating systems which make up 99% of the global smartphone market [41] (App-store for Apple and Google Play for Android) using keywords: pain, arthritis, osteoarthritis, back pain, and iPain. A Google web search using the phrase "pain App" was also conducted to ensure adequate coverage. Resultant apps were screened based on their name and description. As the resultant app list was potentially endless (similar to a Google search), we utilized the approach used in a previous review [42] and carried out the screening process until twenty consecutive apps yielded no new potentially relevant app. These apps were downloaded to an iOS (Apple iPhone 5S) or an Android device (Samsung Galaxy S5) for assessment against the inclusion criteria. Multiplatform apps were downloaded to the Apple device. Three reviewers (PB, TNJ, and JLP) assessed the eligibility of the resultant apps against the inclusion criteria. Inter-rater reliability of included/excluded apps was determined by calculating Cohen's kappa statistic for the primary author's independent ratings (PB) against the two other authors (JP, TNJ). There was moderate to excellent agreement among raters ($k=.595 – 1.00$; $p < 0.001$) in the initial rating, and with subsequent discussion, full agreement was reached on all included/excluded apps. Apps meeting the inclusion criteria were saved for data extraction.

An app quality evaluation audit tool (Appendix 1) was developed *a priori* to evaluate app content quality. This audit tool was informed by: the Stanford Program [17, 43], Cochrane reviews [44, 45], established arthritic pain management guidelines [46, 47] and a Randomized Control Trial (RCT) [48] (Refer Table 1).Two key aspects of pain self-management: symptom monitoring (pain assessment and ability to document assessment findings), and symptom management (pain management concepts and strategies: promoted via education/instruction), were the focus of the quality evaluation. Each quality evaluation item in the quality evaluation tool was allocated one point if it was present ('Yes') and zero if not present ('No'). An aggregate score for each symptom monitoring and management sub-

section was calculated. Three reviewers (PB, JLP, and TNJ) independently rated each of the included app using this quality evaluation audit tool.

Table 1: overview of the App quality evaluation audit tool

Symptom awareness (Pain assessment and awareness function)
Pain Diary This section assessed if the App in question provided key functionalities expected in a pain diary, namely: a. Pain assessment recording, b. Pain management recording, and c. Recording of other symptoms and complaints These key components were derived from an earlier randomized trial study that developed and tested an electronic pain diary[48].
Symptom management (Pain management function)
Patient education This section assessed if the App in question included the following key-components of Stanford Program, namely: a. Education on important pain related topics, b. Management of symptoms that commonly accompany pain, c. CBT approach, and d. Physical activity These key-components were then developed as sections with corresponding sub-sections designed to collect information on how each App delivers the component to the user. The items in the sub-sections were compiled based on recommendations from Cochrane reviews[44, 45], established guidelines[46] [47], or from best practice evidence such as the Stanford program itself[43]. However not all of the items included within the sub-sections of each key-component have established evidence to support their efficacy in pain self-management.
Usability evaluation
This section assessed how usable the App in question is from the perspective of older users. The following components were assessed[36]: a. Comprehensibility b. Presentation (image and text) c. Usability, and d. General characteristics

The usability evaluation was carried out using the older adult specific usability evaluation tool used in an earlier evaluation of diabetes apps [36]. This tool ranks four functionality criteria, namely: comprehensibility, presentation, usability, and general characteristics using a 5-point Likert-scale [36]. An overall usability score is calculated by averaging the scores of

each of the functionality criteria (ranges 1- 5), with a score of ≥3.0 reflecting acceptable usability [36]. General information about each app was extracted onto a Microsoft Excel table. The quality and usability score for each app is reported as the mean of each rater's score.

RESULTS

Of the 433 apps identified only four met the inclusion criteria (Figure 2). All of the apps were available in the Apple (iOS) platform, however one (WebMD Pain Coach) [49] was downloaded to the Android device due to it repeatedly crashing on an Apple device. The Google web search yielded no additional apps.

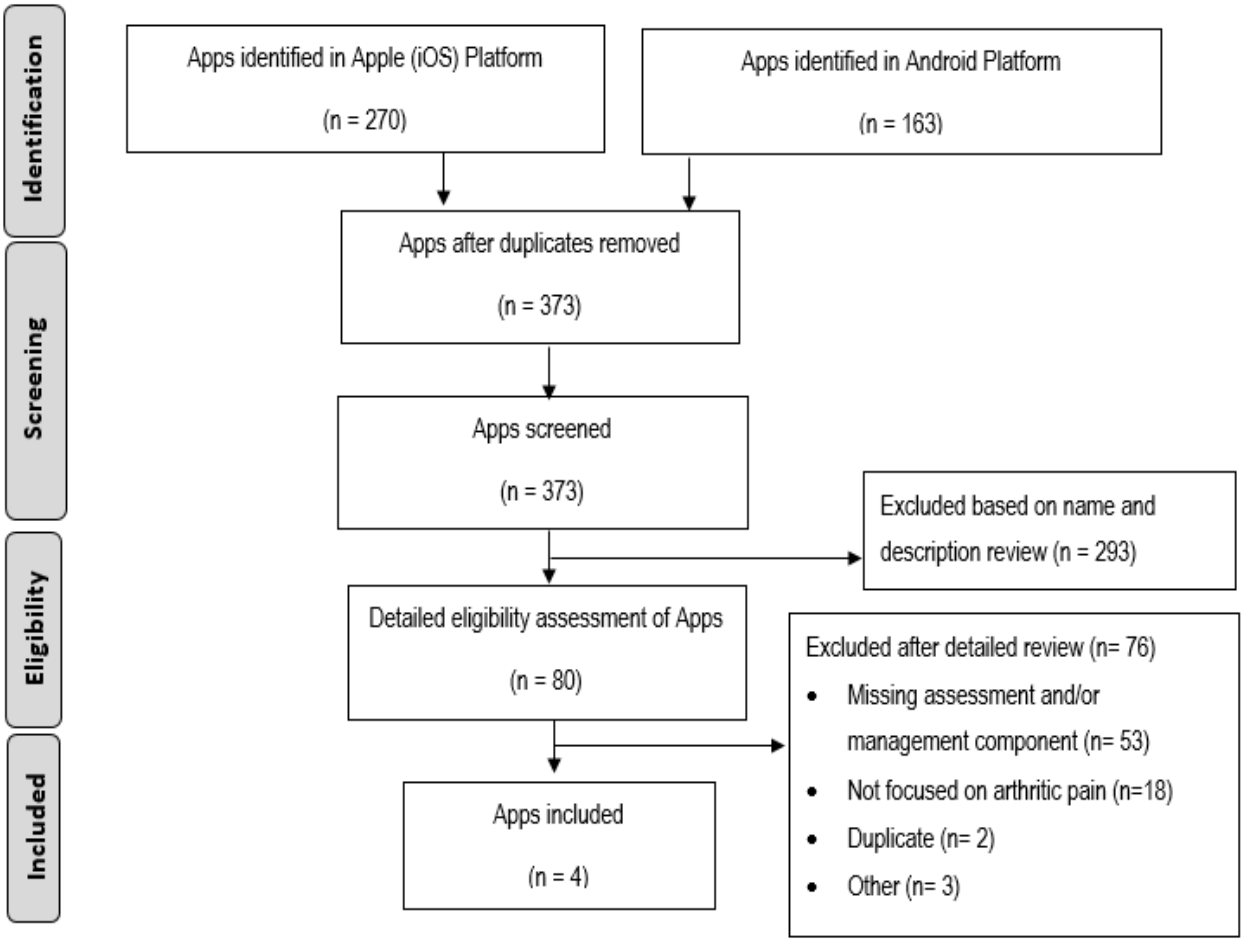

Figure 2: Flowchart of Apps from search to inclusion

App characteristics

The summary of included apps is provided in Table 2. All of the apps were developed in high-income countries: two in the United States (US) (Track + React, WebMD Pain Coach) [49, 50], one in the United Kingdom (UK) (Pain Toolkit) [51], and one in Ireland [Rheumatoid Arthritis, Information, Support and Education (RAISE)] [52]. All of the apps were developed in consultation with a health care authority or health professional. None of the apps required payment for download, however one app (Pain Toolkit) [51] required either a UK based GP provided token number or a payment of $7.99 (AUD) for full access.

Quality evaluation

The app quality evaluation summary is presented in Table 3 (Refer Appendix 2 for rater's scores). All of the apps included a pain assessment function [49-52]; three featured a Numeric Rating Scale (NRS) for pain intensity assessment that could be used as frequently as the user wished [49, 50, 52], whereas the fourth [51] included a body chart based assessment of pain location, pain impact assessment, and questions on pain type that was only completed as part of the initial assessment. Two apps also included an option for recording analgesic(s) taken and other accompanying symptoms and/or complaints [49, 50]. The Pain Toolkit [51] provided a free text option for users to enter information relating to their pain medication and the effect of non-pharmacological interventions employed.

All of apps provided education on topics such as pain self-management principles and medication use. [49-52]. However, the content is generic with no capacity to be tailored as per individual need or preference. In addition, all four apps [49-52] encouraged users to regularly communicate their pain concerns with their health professionals, and seek advice when contemplating new pain management approach. Disease related problem solving was covered by three apps [49-52]. None of the apps highlighted strategies to minimize or address pain related fear avoidance

Table 2: Summary of included Apps

App Name	Developer	Cost/ Pain type	Assessment and documentation function	Management function	Usability	Total Score [a]
WebMD Pain Coach [49]	WebMD	Free/ All type	At least daily assessment and recording of pain using 11 point NRS. Option to record the name of analgesic taken (time stamped). Option to record other symptoms and complaints as desired.	Provision of education on pain/ self-management process, medication use, communication with health professionals and pain related problem solving. Detailed information on sleep, nutrition, and psychological issues management. CBT based pain management instruction on relaxation, mindfulness and meditation, distraction, imagery, and goal setting. Customizable exercise plan, with detailed information on stretching, isotonic, aerobic and aqua exercises.	Average general features (1.9/5), and presentation (2.9/5), moderate usability (3.4), and high comprehensibility (4/5).	Quality= 27.7/39 Overall usability = 3.2//5
			**Score= 4.7/7*	**Score= 23/32*	**Score= 3.2/5*	
Track + React [50]	Arthritis Foundation US	Free/ Arthritis	At least daily assessment and recording of pain using 11 point NRS. Option to record the name of analgesic taken, nutrition, fitness, sleep, medication, overall feeling, fatigue, mood, stiffness, and joint function.	Education provision on pain/ self-management process, medication use, communication with health professionals and pain related problem solving. Information on management of fatigue, sleep, nutrition and affect. Inclusion of goal-setting function and information on activity-pacing. Customizable stretching, isotonic, aerobic and aqua exercise; warm-up, cool-down included.	Poor general features (1.1/5), average presentation (2.3/5), moderate usability (3.2/5), and comprehensibility (3.6/5)	Quality= 22.5/39 Overall usability = 2.7/5
			**Score= 4.5/7*	**Score= 18/32*	**Score = 2.7/5*	
RAISE [52]	St James Hospital + Arthritis Ireland	Free/ Rheumatoid Arthritis	At least daily assessment and recording of pain and activity level using 6-point (0-5) NRS. Pain management approach documentation not included.	Provision of education on pain/pain self-management process, medication use, communication with health professionals and pain related problem solving. Information on fatigue, sleep, and psychological issues management. CBT pain management instruction on relaxation, goal-setting, and activity pacing (20-30 minutes session). Videos of stretching, isotonic and aerobic exercise with warm-up and cool-down stages. Duration and frequency indicated.	Poor general features (1.2/5), average presentation (2.8/5), moderate usability (3/5), and comprehensibility (3.6/5)	Quality= 22.7/39 Overall usability = 2.9/5
			**Score= 1.2/7*	**Score= 21.5/32*	**Score= 2.9/5*	
Pain Toolkit [51]	Pain Sense	$7.99/ Chronic pain	One of assessment of pain type and location, no intensity reporting offered. Health needs and pain impact measuring option. Option to record medication on the diary function of the App. Assessment and recording of other complaints not prompted.	Provision of education on pain/pain self-management, medication use, communication with health professionals, and sleep management. CBT approach to pain management recommended via use of general relaxation, activity pacing and goal setting. Personalised approach recommended for stretching and aqua exercise	Poor general features (1.2/5), average presentation (2.5), and usability (2.7/5), and high comprehensibility (4.2/5)	Quality= 16.7/39 Overall usability = 2.8/5
			**Score= 2.7/7*	**Score= 14/32*	**Score= 2.8/5*	

Kev: * = mean scores of three rater

Information relating to the management of nutrition, general mood, depression, and anxiety were included in two apps [49, 52]. Additionally the RAISE [52] app also included information on fatigue management, and the WebMD Pain Coach [49] included comprehensive information on sleep management. The Track +React app [50] included information on management of sleep, fatigue, general mood and nutrition; whereas the Pain Toolkit [51] only included information on sleep management.

The WebMD Pain Coach [49] integrated a number of CBT based pain management approaches (5/8), including information on general relaxation, mindfulness meditation, distraction, imagery and goal setting. The RAISE [52] and Pain Toolkit [51] apps both included information on general relaxation, goal setting and activity pacing, with the Pain Toolkit [51] additionally including information on mindfulness meditation. The Track + React app [50] only covered goal setting and activity pacing.

While varying levels of physical exercise information was included in all of the apps the WebMD Pain Coach [49], and RAISE [52] Apps provide users with an option to create a personalized exercise program from a list of recommended stretching, isotonic, aerobic and aqua exercises. The RAISE app [52], in addition to detailing the WHO's recommendation for duration and frequency of exercise for adults [46], also included a series of warm-up and cool-down exercises. The Pain Toolkit [51] provided information on stretching and aqua exercises and highlighted the need for an exercise program to be personalised as per individualized needs and capabilities. Several elements of the quality evaluation were not found in any of the included apps such as education on fear-avoidance principles, biofeedback treatment, and operant conditioning.

Usability evaluation

WebMD Pain Coach [49] was the only app to obtain a moderate usability score of ≥3, while Track + React [50], RAISE [52], and Pain Toolkit [51] all fell just below the acceptable moderate usability score of ≤ three (Refer Table 2).

Table 3: Quality evaluation summary of included Apps as rated by two or more raters

	Quality components	WebMD Pain Coach [49]	Track + React [50]	RAISE [52]	Pain Toolkit [51]
Recording/ diary function [48]	Daily NRS	✓	✓	✓	×
	Pharmacological pain management	✓	✓	×	✓
	Non-pharmacological pain management	×	×	×	✓
Patient education [43]	Pain/pain Self-management	✓	✓	✓	✓
	Fear avoidance	×	×	×	×
	Medication use	✓	✓	✓	✓
	Communication with HP	✓	✓	✓	✓
	Problem solving	✓	✓	✓	×
Education on Other symptoms [43]	Fatigue	×	✓	✓	×
	Sleep	✓	✓	×	✓
	Nutrition	✓	✓	✓	×
	Affect	✓	✓	✓	×
	Depression	✓	×	✓	×
	Anxiety	✓	×	✓	×
CBT pain management techniques [43-45]	Relaxation	✓	×	✓	✓
	Mindfulness meditation	✓	×	×	✓
	Diversion distraction	✓	×	×	×
	Imagery	✓	×	×	×
	Goal setting	✓	✓	✓	✓
	Biofeedback	×	×	×	×
	Activity pacing	×	✓	✓	✓
	Operant treatment	×	×	×	×
Physical exercise [43, 46, 47]	Personalised	✓	✓	×	✓
	warm-up cool down	×	×	✓	×
	Stretching	✓	✓	✓	✓
	Isotonic	✓	✓	✓	×
	Isometric	×	×	×	×
	Aerobic	✓	✓	✓	×
	Aqua Exercise	✓	✓	×	✓
	Duration	×	×	✓	×
	Frequency	×	×	✓	×

DISCUSSION

This systematic review has demonstrated that a very small number of pain apps offer pain self-management strategies based on arthritic pain self-management literature. Additionally, there seems to be very little consideration of older adult specific usability in currently available pain apps. Although the resultant app numbers were small, some valuable insights have been generated about the quality and usability of pain self-management apps, particularly in relation to the elements of Stanford Program as detailed below:

Elements of Stanford Program

Recording Diary Function: Despite the abundance of pain apps, very few promoted pain self-management practices in accordance with the elements of Stanford Program [18, 40]. At a minimum, all of the included apps provided options to assess pain (pain intensity or pain type and location).While pain intensity assessment is noted to be one of the most common features of pain apps [30, 31],this measure is less relevant than pain impact in the context of chronic arthritic pain [53, 54]. Pain intensity scores are known to be poor indicator of clinically important pain [53], with little evidence of accuracy and effectiveness in improving delivery of care and outcome. Instead, pain impact assessment, which is a better indicator of chronic pain patient's treatment preferences, could be a more valuable addition to future pain apps with a potential to guide appropriate self-management strategies [54].

Although international guidelines recommend arthritic pain management plans to include both pharmacological and non-pharmacological approaches [55, 56], the latter seems to have received very little recognition among pain apps. While the recording of analgesic use was a prominent feature, the recording of non-pharmacological treatments as part of an active self-management plan is a noticeable gap in the majority of pain apps. By focusing disproportionately on analgesics, these apps may inadvertently lead to non-pharmacological strategies being under promoted. In addition, poor access and limited availability of non-pharmacological pain self-management

strategies such as mindfulness and tai-chi, together with limited promotion of such approaches by primary care clinicians [57] could further contribute towards the underutilization of these strategies among arthritic patients [58, 59]. *Patient education*: Pain education and self-management instructions were featured in all of the included apps. This approach adheres with the conceptual definition of persistent pain self-management process where older adults are expected to acquire knowledge and skills necessary to respond to and control their pain [60]. Furthermore, provision of information and skills necessary to attain mastery over the care of one's health condition is the foundation of patient empowerment process [61]; and is recommended in the self-management of chronic diseases such as diabetes [62].

It is interesting that the majority of the included pain apps provided information relating to nutrition management [49, 50, 52]. Although appropriate nutritional intake is an important component of healthy living among older adults [63], there is little evidence supporting a specific diet for pain self-management purposes. While nutritional interventions for older adults with reduced functionality may result in improved energy level, they fail to translate into improved functional outcomes [64].

Written learning content embedded within the majority of apps was the prime medium used to educate consumers. Only one of the apps integrated a different learning format in the form of providing supplemental audiovisual material [51]. Although written communication is a widely used passive health information dissemination strategy, the addition of audiovisual mode leads to relatively greater information recall [65]. Recall of health information is crucial if consumers are to effectively implement the recommended self-management instructions [66]. Optimizing learning opportunities in apps is crucial given many older adults have low health literacy levels [67]. People with poor health literacy not only lack the necessary skills to understand and use health related information [68], but are also known to have poorer recall

[69]. Moreover the cognitive and sensory changes that accompany the process of aging further amplifies the challenges associated with teaching older adults new learning content [70].

CBT Approach to pain management: Although a CBT based pain management approach is recommended for older adults as an adjunct, or a first-line therapy if the patient prefers [5], most of the included apps only alluded to CBT approaches in very basic form (e.g. written instruction on relaxation or activity pacing). This finding is consistent with a recent review of adult pain apps where features consistent with evidence based CBT principles were present in very few apps [32].

As behavioral goal-setting is an effective strategy supporting self-management behaviours [62], it was pleasing that CBT goal-setting approaches were incorporated within all of the included apps. This finding differs from earlier research which found that goal-setting was rarely included in pain apps [22, 32]. It is unclear if CBT features have been under-reported in previous app reviews or if this finding reflects recent advancement in technology that has led to increased inclusion of goal-setting feature. Goal-setting is prominently featured in physical-activity [71] and weight-loss [72] apps, with a corresponding indication from consumers of its desirability [73]. However, the role of goal-setting in pain apps and the views of consumers of this feature ought to be explored. There is also a need to explore the effectiveness of integrating CBT into Pain apps as a recent RCT of CBT based App for depression has demonstrated clinically significant improvements [74].

Physical Exercise: The inclusion of some form of physical exercise component in all of the included app reflects the established recommendation to incorporate physical exercise in pain management of older adults [5, 46]. The importance of regular exercise in older adults with chronic pain and arthritis is supported by high level evidence [46, 47], yet few if any pain self-management apps have included all of these physical exercise recommendations.

The exclusion of tailored physical exercise prescription, including duration and frequency of movements by the majority of apps is a notable gap that needs to be addressed in future pain self-management apps. A tailored physical exercise prescription adaptable which can be adapted according to the comorbidities, functionality and safety profile of an individual user may not only assist older users to better self-mage their pain, but also help prevent falls and injury [75, 76]. Additionally, providing information on the beneficial role of physical exercise in preventing falls may also encourage older users to engage effectively with their physical exercise prescription.

Usability

Overall, the older adult specific usability of pain self-management apps could be classified as moderate at best. Functions important to older users such as enlarging the app screen size or font was not provided in any of the apps, indicating that these apps were developed without consideration of the visual and motor impairment prevalent among older adults, the group that form the significant proportion of the pain population [77]. Consideration of the usability requirement of older adults is necessary in future pain app development endeavors; after all, provision of high quality information in an app may be of no benefit it the usability needs of the target users are not met [78].

Technological advances in future

Given the smartphones' high quality on-board sensors that can capture advance movement and sound based assessment data [79], there are opportunities to integrate these features into future apps. Apps capable of assessing and interpreting sensor-based data in the future may assist cognitively impaired older adults and/or carers to better manage their pain. While sensor-based features have been utilised in screening and monitoring apps for depression [80]and sleep disorders [79] none have the capacity for electronic health information exchange between the users and their treating health professional. Given the importance of the patient-clinician

partnership as technology advances, building electronic health information exchange capacity into future pain apps will strengthen their utility.

Patient recorded pain management data, if shared with clinicians, could not only assist with the development and/or refinement of an individualised pain management plan, but also facilitate technology use among older users [81]. However, as primary care clinicians will often be unable to deal with the large volumes of data generated by these technological interventions, caution should be exercised in data-sharing with clinicians to minimise data-overload [82]. While future pain apps should prioritise electronic health information exchange, clinicians should be involved in setting-up this process to ensure useful and practical presentation of the data [82].

Implications for practice

The lack of clinician's involvement in development of pain related apps and other healthcare apps has been noted previously indicating concerns of accountability, accuracy and reliability of the app contents; calling for increased regulatory oversight so as to safeguard patient's welfare [30, 31, 83, 84]. It is worth noting that all the apps included in this review (that had some merit based on the pain self-management literature) had some input from health care authority/professionals. Although there is not enough evidence to suggest that apps developed with a clinician's involvement are superior to those developed without their input; such collaboration has the potential to inform the self-management and patient education inclusions to be appropriately well-integrated and evidence based [23]. Involvement of pain experts should be considered in future pain app development endeavors.

Despite being considered an important inclusion in a pain self-management plan [44, 85, 86], operant treatment, biofeedback, and fear-avoidance education were not featured by any of the apps and were probably out of the scope of an app to deliver. This suggests that while apps may be helpful adjuncts in the pain self-management process, the creation of the expert patient

occurs when the patient is supported and empowered by their clinicians throughout the pain self-management journey [40]. Clinicians providing care to patients who utilise apps to facilitate their pain self-management process should be aware of the capabilities and limitations of the apps and provide appropriate support and education to these patients.

In addition, the inclusion of non-evidence based component such as nutrition management in the apps indicates that clinicians should exercise caution in recommending or 'prescribing' apps to their patients. There is a need for a health app rating system so that clinicians and consumers are able to easily appraise which app promotes the best available evidence for the purpose of pain self-management. Furthermore, a valid and reliable tool designed for quality and usability evaluation of pain self-management apps is necessary to further enhance this area of research.

Strengths and limitations

Some limitations should be considered in interpreting our review's result. Firstly, as our searches were conducted in Australia, apps exclusively available to App Stores of other countries could have been missed by our search. In addition, although searches were conducted in the two most popular app platforms (Apple store and Google Play), some apps hosted exclusively in websites may have been missed in this review. Secondly, although the tools used to evaluate the quality and usability of the apps were evidence-based, they are not validity and reliability tested; future work in testing the validity and reliability of these tools is warranted. Thirdly, this review did not involve any older adults in the quality appraisal and evaluation process thereby limiting the review's potential to provide views of older adults who are the end-users of the apps. Finally, although care was taken to rate the apps as objectively as possible, we acknowledge that some level of subjectivity or bias may have existed in rating the apps. Involvement of three raters and reporting of the mean scores of the quality criteria was done to minimize this issue.

Nevertheless, this review also has notable strengths. The development and utilization of an evidence-based app quality evaluation tool to appraise the merit of currently available pain apps (paid and free) has allowed this paper to offer an evidence based comparison of the capabilities of these apps. The quality evaluation tool can serve as a basic guide for future app development or existing app refinement process. To our knowledge this is the first review to investigate the older adult specific usability of pain apps.

CONCLUSION

Despite availability of a large number of pain apps, this review has revealed that few offer a comprehensive pain self-management approach aligned with established evidence. Although a very small number of apps did provide pain self-management function, the range of included strategies did not seem to be comprehensive. The moderate level older adult specific usability across the included apps also indicates a need to consider the usability needs of older population in future pain self-management app development endeavors.

Future work in the area of pain self-management should consider a collaborative venture between industry, health professionals and end-users where the app development process should include the question of "what features and qualities should this app possess to support an effective pain self-management for older users?" In addition, as the features of smartphones continue to advance, developers of future pain self-management apps should consider incorporating these advance functions in the pain self-management apps with an option of real-time data sharing with the user's health care provider.

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Appendix: 1: App Assessment Case Report From (CRF)

App Name	
Platform	
Date of download	
Developer	
Cost	
Target population	
Target pain type	

Reviewed by

Initial	
Date	

Quality evaluation tool

Pain assessment and documentation (Diary) aspect covered by the app [1]

Pain assessment/management recording	At least daily 11-point NRS Scale for pain	Pain management process documentation	Recording of other symptoms and complaints	Score
☐ Yes (Provide details in the next columns) ☐ No (Proceed to components listed below)	☐ Yes ☐ No (Proceed to next column)	**Approach** / Score Pharmacological Analgesic taken ☐ Yes ☐ No Administration time ☐ Yes ☐ No Effects of analgesics ☐ Yes ☐ No Non-pharmacological Effects of other therapies ☐ Yes ☐ No	☐ Yes ☐ No (Now proceed below to educational components)	
/1	/1	/4	/1	/7

Patient education components covered by the app [2-5]

Component 1
Important patient educational topics covered
☐ Yes (Provide details below)
☐ No (Proceed to next component)

Education topic		Score
Pain/pain self-management related education	☐ Yes ☐ No	
Pain related fear avoidance	☐ Yes ☐ No	
Medication use	☐ Yes ☐ No	
Communication with health professionals	☐ Yes ☐ No	
Disease related problem solving	☐ Yes ☐ No	

Other relevant details:

Component 2
Accompanying symptom management
☐ Yes (Provide details below)
☐ No (Proceed to next component)

Symptoms addressed

Symptoms		Score
Physical		
Fatigue	☐ Yes ☐ No	
Sleep	☐ Yes ☐ No	
Nutrition*	☐ Yes ☐ No	
Psychological		
Affect- anger frustration, hopelessness etc.	☐ Yes ☐ No	
Depression	☐ Yes ☐ No	
Anxiety	☐ Yes ☐ No	

Other relevant details:

Component 3
CBT based pain coping skills
☐ Yes (Provide details below)
☐ No (Proceed to next component)

CBT approaches included

Approaches		Score
Cognitive or Respondent treatment		
Relaxation (general)	☐ Yes ☐ No	
Mindfulness/ meditation	☐ Yes ☐ No	
Diversion/distraction	☐ Yes ☐ No	
Imagery	☐ Yes ☐ No	
Goal setting	☐ Yes ☐ No	
Biofeedback	☐ Yes ☐ No	
Activity pacing	☐ Yes ☐ No	
Operant treatment	☐ Yes ☐ No	

Other relevant details:

Component 4
Physical exercise
☐ Yes (Provide details below)
☐ No (Proceed to next component)

Exercise plan		Score
Personalised	☐ Yes ☐ No	
Involves warm up and cool down	☐ Yes ☐ No	

Type of physical activity

Exercise type		Score
Stretching	☐ Yes ☐ No	
Isotonic	☐ Yes ☐ No	
Isometric	☐ Yes ☐ No	
Aerobic	☐ Yes ☐ No	
Aqua exercise	☐ Yes ☐ No	
Total		/5

Duration and Frequency

Session Duration	Frequency per week	Score
20-30 minutes	3-4 days	
☐ Yes	☐ Yes	/2
☐ No	☐ No	0

Other relevant details:

/6	/7	/9	/10	/32

*Not evidence based but included in the Stanford Program based on no- low level evidence

Usability evaluation tool [6]

	Main Criteria	Sub-criteria	Assessment Criteria: Likert Scale (1 to 5)	Score
Comprehensibility	Use of understandable semantics		1 Does not apply at all / 2 / 3 / 4 / 5 Does fully apply 1 → 5	
		Avoidance of foreign language and technical terms		/5
		Use of generally intelligible symbols and terms		/5
		If necessary, provision of additional explanations		/5
	Simple comprehensibility and interpretability of displayed images and depictions		1 Does not apply at all / 2 / 3 / 4 / 5 Does fully apply 1 → 5	
		Self-explanatory images and depictions, understandable without further support and explanations		/5
	Simple, self-explanatory menu structures		1 Does not apply at all / 2 / 3 / 4 / 5 Does fully apply 1 → 5	
		Easily understandable and internally consistent menu structures		/5
		Avoidance of strong hierarchical menu structures and too many functionalities		/5
Presentation (Image and Text)	Sufficient color contrast		1 Does not apply at all / 2 / 3 / 4 / 5 Does fully apply 1 → 5	
		Clear, distinguishable colors for images and depictions or choice of color-neutral depictions		/5
		Avoidance of too glaring colors		/5
	Large size of operating elements		1 Does not apply at all / 2 / 3 / 4 / 5 Does fully apply 1 → 5	
		Sufficient size of screen as well as input and output fields		/5
	Ability to adapt the size of operating elements and displayed images		Applicable or Not applicable	
		Ability to adapt size of operating elements and displayed images according to individual needs, capabilities, and preferences	Applicable =1 Not applicable=0	/1
Usability	Instant and easily understandable feedback		1 Does not apply at all / 2 / 3 / 4 / 5 Does fully apply 1 → 5	
		Instant response to entered data, including easily understandable error		/5

		messages in case of erroneous data input		
	Intuitive usability		1 2 3 4 5 Does not apply at all … Does fully apply 1 → 5	
		Ability to use the application without prior knowledge		/5
		Ease of learning		/5
Usability		Fast achievement of a first feeling of success		/5
	Simple recognition of click-sensitive areas		1 2 3 4 5 Does not apply at all … Does fully apply 1 → 5	
		Simple distinction between click-sensitive and non-click- sensitive areas, also without prior knowledge of the features of the touchscreen technology.		/5
General Characteristics	High Fault tolerance/ efficient fault management		1 2 3 4 5 Does not apply at all … Does fully apply 1 → 5	
		Reducing probability of erroneous data input by limiting choice to meaningful values		/5
		Efficient proofreading mode and/or helpful user feedback, for example, in case of erroneous data input [27,30]		/5
	Password-protected services		Applicable or Not applicable	
		Avoidance of registration at online platforms (but partly contrary to data protection regulations)	Applicable =1 Not applicable=0	/1
Total score				/82

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Appendix: 2: App scoring summary illustrating the scores of three raters

	JLP	TNJ	PB	Mean
WebMD Pain Coach				
QUALITY				
Pain assessment and documentation	5/7	4/7	5/7	4.7/7
Pain management	23/32	23/32	23/32	23/32
USABILITY				
Overall usability	3.9/5	2.4/5	3.2/5	3.2/5
Track + React				
QUALITY				
Pain assessment and documentation	4.5/7	5/7	4/7	4.5/7
Pain management	17/32	21/32	17/32	18/32
USABILITY				
Overall usability	2.8/5	2.7/5	2.6/5	2.7/5
Raise				
QUALITY				
Pain assessment and documentation	1.5/7	1/7	1/7	1/7
Pain management	23.5/32	20/32	21/32	21.5/32
USABILITY				
Overall usability	3.0	3.2	2.5	2.9/5
Pain Toolkit				
QUALITY				
Pain assessment and documentation	2/7	4/7	2/7	2.7/7
Pain management	14/32	16/32	12/32	14/32
USABILITY				
Overall usability	2.8	2.9	2.6	2.8/5