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A Systematic Literature Review of the Pain Management Mobile Applications: Toward Building a Conceptual Model

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ABSTRACT In healthcare, mobile-based interventions support the improvement of clinical process and result in a positive behavioral change and improve the patients' health condition. This study aims at reviewing mobile applications documented for pain management in the scientific databases, to identify the key factors that are vital for pain management. In this research, a systematic literature review was conducted on the selected studies collected from five scientific databases: Medline, PubMed, EMBASE, Web of Science and Scopus. After applying the inclusion and exclusion criteria and performing the quality assessment, twenty-five studies were finalized. It has been observed that the apps were not all-inclusive in features to provide an effective pain self-management solution. As found from the review, the general features of the pain management mobile applications are pain information, pain coping strategy, social support, sub-goals and achievements, self-reporting, feedback, and patient report. Some apps involved psychological interventions. A prominent technique found was cognitive behavior therapy. This study has contributed to the body of knowledge by proposing a conceptual model in guiding the development of pain management mobile applications. The conceptual model was evaluated by a panel of experts to evaluate comprehensiveness, accuracy, and dependencies among the elements of the model, and the appropriateness of the proposed model. Experts recognized the importance of pain management and provided positive feedback to the proposed model.

INDEX TERMS Conceptual model, mobile applications, m-health, pain, self-management, systematic literature review.

I. INTRODUCTION

Informatics is an integral part of medicine providing storage and access to medical information. In the past two decades, due to the tremendous growth of technology and people are more receptive to the technology, it has brought forward the concept of e-health [1]. E-health is basically an overlapping domain comprised of medical informatics, public health, and business to improve and deliver healthcare services via information and communication technology [2].

The e-health revolution has digitized the medical world and updated information could be easily accessible from the electronic resources. Also, patients' records and medical references are stored electronically and accessible via the network. Next step in this evolution is to provide mobility, portability and convenient information retrieval [1]. M-health (mobile health) is a subset of e-health which covers the areas of information and communication technologies within the healthcare domain to proficiently and effectively deliver healthcare [3], [4]. Common features provided by mobile health apps include health tracking, involvement of a healthcare provider, social connectivity, health information, and reminder services.

Pain is one of the health conditions addressed by m-health. It has been found from the literature that every third person is nowadays suffering from chronic pain in some part of their life [5]. Due to increasing age factor, elders are more prone to chronic illness than young adults [6] and pain is a common problem in elderly. Patients suffering from pain faced various issues like mental and emotional disturbance, social fear and

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limited or restricted physical and social activities. It also has additional effects as fatigue and can cause anxiety, sleep and appetite disorders [7]. It also affects directly or indirectly, the economic situation of a pain sufferer or family [5].

Pain management involves pharmacological and non-pharmacological approaches [7]. Among various non-pharmacological approaches, like physiotherapy, cognitive behavioral therapy, and hypnosis etc., mobile applications for pain management play a supportive role. Mobile applications aid in the periodical assessment and provide self-management services. Electronic pain diaries, being easier to use, support recording of real-time pain data at regular intervals or when required with the help of careful self-monitoring of pain symptoms, associated factors of mood, sleep or activity disorder and use of medication [8].

Various studies have shown that acceptance and compliance rate of using electronic diaries are higher than paper-based assessment methods. This is because patients feel confident to answer questions privately in an anonymous environment. It is also because of the psychological effect that one question appears at a time on a screen, instead of a lengthy list of questions, thus facilitating the patient to focus on each question separately [9]. Analysis of the data recorded by the patient and the provision of results helps patients to analyze the change in pain rating and improvement with time. This information can also be used by the patients and clinicians to take effective decisions for change in the treatment plan or pain management [8]. The historical patient record can be used for knowledge sharing with other members of the healthcare providers' group [8].

There are hundreds of pain management apps to support patients and promote health care. The increased number of healthcare mobile apps come up with a new challenge of regulation and data security [10], [11] that must be addressed without creating hurdles in the progress of mobile phone technology [12]. The majority of the pain management apps available on the internet do not have any affiliation with any healthcare institute and charge for the services' provided. There is a lack of evidence for authenticity. Some free of cost apps are affiliated with non-profit organizations and are for awareness purpose only [13]. There is no regulatory body for the approval of the release of these apps. The FDA in the USA also highlights the need of having some guidelines for the smartphone apps [14]. These apps do not involve healthcare professionals in their development, thus there is a question of the validity of their content. Out of several quality control schemes available, there is no specific format for the quality check of health care apps. New medical mobile apps must be properly tested and evaluated according to the standard scientific process before its launch and it must be documented or published in the journals of medicine and mobile technology so that medical practitioners can have an idea of the new trends [1].

A study was conducted in the United Kingdom as early as in 2010 [12] when 111 pain management apps were evaluated from five famous smartphone platforms: iPhone, Android, Blackberry, Nokia / Symbian and Windows mobile. Apps were included for evaluation if they were patient-centered instead of being solely for healthcare providers and were related to the general condition of pain. It was concluded that though pain management apps provide counseling, yet unavailability of evidence of the authentic content and valuable input from medical practitioners may lead to the adverse effect on the health of desperate people who intend to find a solution for the relief of pain [12].

In 2012 an updated study was conducted on the generic pain management apps, sourced from two famous smartphone application platforms: iPhone and Android [15]. Apps were included if they are targeting the general pain type, patient-centric and allow recording of pain attributes and maintain history for future analysis. Apps were excluded if they were for some specific pain type. The contents of the selected apps were analyzed on the basis of pre-defined quality assessment criteria and two apps were selected for the usability testing. Content analysis revealed that apps varied to a large extent and did not have any involvement of health care providers during development. Usability testing showed the unawareness of participants on the pain management mobile apps before this study. Participants emphasized the improvement of the design of mobile applications in the context of color schemes and textual presentation.

Wallace and Dhingra [16] reviewed the apps of pain management that were available to download from the official platforms of Android, BlackBerry, and iPhone in the United States. They analyzed their cost, evidence of input via clinical participation as well as the app development, pain type targeted by the app, and the primary focus of the app. It was observed that no evidence of clinical input was recorded. Moreover, the majority of the apps (50%) were for general chronic pain and 25% of the apps were specific for neck or back pain. Very few apps (13%) served the purpose to provide both pain self-management and pain education. Also, there is a lack of evidence in the inclusion of pain management features.

Following the research, in this domain, another study was carried out in 2013 for the commercially available pain management mobile apps and the apps available in scientific databases [17]. It was found that the apps documented in the scientific journals were not available commercially to the public while the commercially available apps had no scientific base. One of the limitations of the research was that it was restricted to the apps of pain assessment and there was no detailed analysis of the apps documented in the scientific journals.

Another study was conducted by Lalloo *et al.* [18] to critically review the content and functionality of the pain management apps found on the smartphone applications' platforms. Analysis showed that no app involves health care professional and scientific evaluation for feasibility and effectiveness. Moreover, the reviewed apps presented a variation in functionality, ranged from pain self-care skill support being the most included feature (77.4%) to the social support and

goal setting features that had the least occurrences, i.e. 3.6% and 0.72% respectively. Pain education and self-monitoring features were involved on an average in the apps. None of the apps were comprised of ample integrated features to provide pain self-management. Majority of the apps were comprised of a single pain management function. The authors emphasized to develop evidence-based solutions to support the cause.

In [19], a search was conducted on the Apple and Google Play store platforms to screen and evaluate the apps for quality. This quality assessment was done based on the checklist formalized according to the cognitive behavioral therapy (CBT) guidelines. Only six apps fulfilled the criteria. The research was executed in continuation of a previous study [12] to assess the content of pain management apps and the extent to which they can support self-management. Its findings revealed similar results of a lack of theoretical content for pain self-management and social support. Also, very few apps support bio-physiological approaches, although such approaches prove to be significant in behavior change and pain management. It was recommended that apps must also be certified by some healthcare body to ensure patients have informed choices of solutions to select from. As this study was limited to the keyword 'pain' for the title-based screening and description of the app, it might have missed some other good quality apps. The assessment checklist was also formulated on the basis of previous systematic reviews, so it may not be a comprehensive list of content and quality evaluation. Also, user satisfaction was not highlighted in this research.

Alexander and Joshi performed a critical appraisal in [20] on pain management mobile applications. They bring forward the critique that such apps lack collaboration between developers and healthcare providers which affects the usefulness of the apps. The protocol for design and development of pain management apps could be found from peer-reviewed literature but validation studies for the functionality, specifically for the commercially available apps are not available. Majority of the apps are inadequate in the provision of bio-psychosocial support that may help in the effective treatment of pain.

Although there are some studies on the pain management apps, to the best of authors' knowledge, no systematic literature review is available for the pain management apps documented in the scientific journals to date, with respect to the functional requirements of pain management mobile applications, i.e. the features required to fulfill the users' needs. Upraised utility and high usability with a goal of increased patient engagement and empowerment will contribute to having a useful system. Hence, in the purview of pain self-management, this study aims at analyzing literature to identify and organize the key features that are important for the pain self-management and future development of pain self-management applications. Usability requirements of the pain management mobile applications were also examined in another study [21]. A conceptual model representing utility aspects of pain management mobile apps was proposed as the result of this systematic literature review and verified by doctors practicing pain management.

II. MATERIALS AND METHODS

This systematic literature review is conducted by following the approach of Kitchenham [22]. The quality of the review has been further evaluated as per PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) guidelines [23]. In this purview, research questions were defined; a strategy was formulated for searching in the identified electronic databases and keywords were specified for effective retrieval of relevant results. Further, inclusion and exclusion criteria were set to screen and select the studies for review. The selected studies were also analyzed for the quality of content in relevancy with the research questions. The finally selected studies were then went through the process of full-text review to extract necessary data for analysis. Fig. 1 shows the flow chart of the study selection procedure.

A. RESEARCH QUESTIONS

The principal research questions of this systematic review are listed below:

RQ1: What are the general features of the pain management mobile applications documented in the scientific journals?

RQ2: To what extent psychological interventions are involved in the pain management mobile applications?

B. SEARCH STRATEGY

This research is comprised of an electronic search conducted on five databases i.e. Medline, PubMed, EMBASE, Web of Science and Scopus to gather relevant data for the systematic literature review. The findings comprised results from the year 2005 to 2017, language limitation of 'English' and involve 'Human' as specie. There was no constraint of age. Relevant keywords were identified and articles were extracted from the above-mentioned databases on the basis of these search terms:

1. Pain Management AND (Information and Communication Technology OR Interactive Health Communication Applications OR Web-Based Applications OR Computer Aided Systems OR Monitoring Systems OR Information Storage and Retrieval OR Telemedicine OR Telehealth OR Telemonitoring OR Telecommunication).

2. Pain Management AND Assessment AND (Mobile Technology OR Mobile Devices OR Mobile Applications OR Embedded Systems OR Hand Held OR Personal Digital Assistant OR Electronic Diaries OR Data Collection).

C. INCLUSION AND EXCLUSION CRITERIA

In the process of searching the databases, first, the papers were screened on the basis of titles. Second, screening was performed to remove duplications from the datasets retrieved from the above-mentioned five databases and to choose the relevant ones by overviewing the abstracts. Potentially relevant papers were further extracted in the third screening by

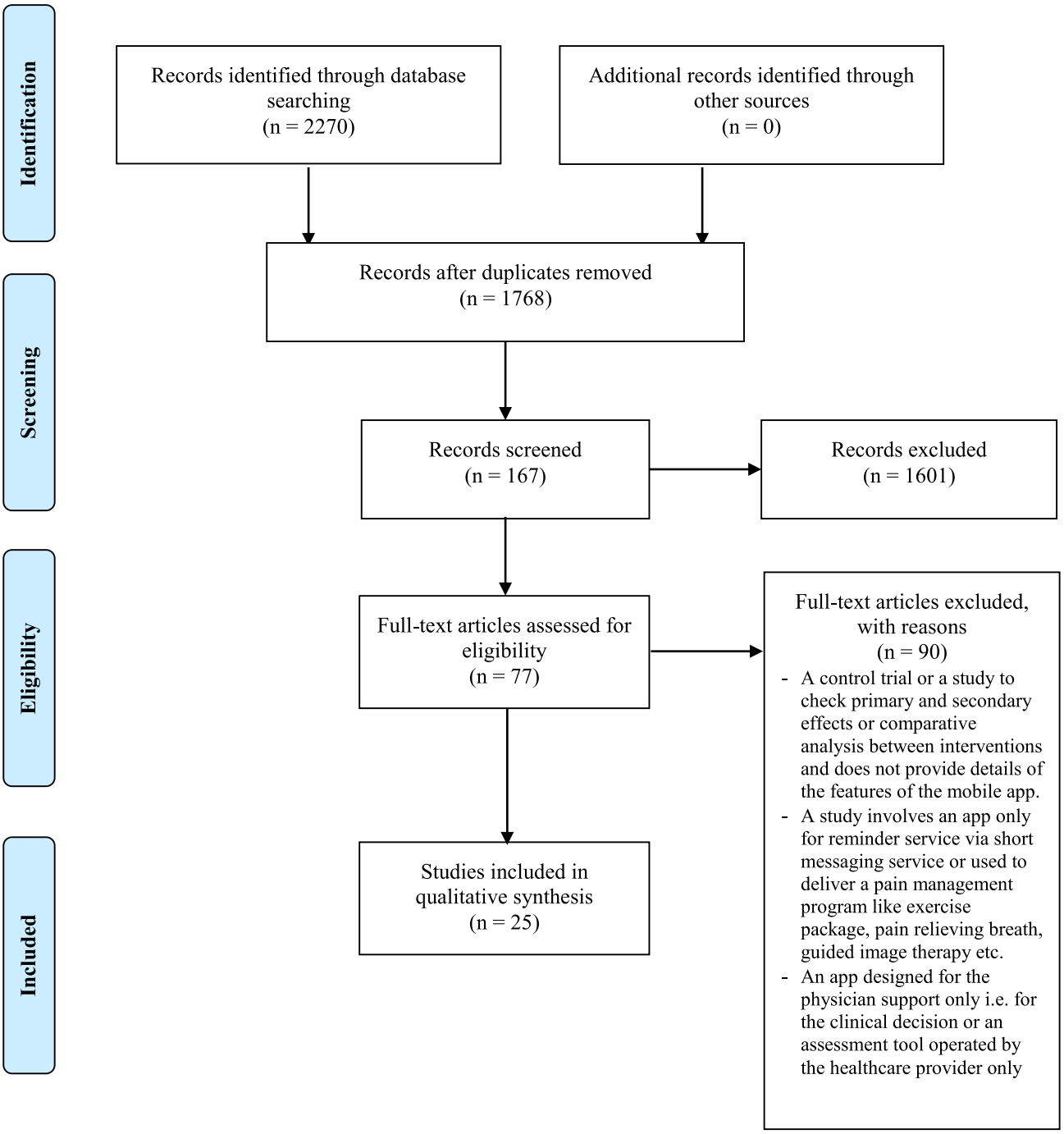

FIGURE 1. Study selection process – PRISMA Flow Diagram From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097 For more information, visit www.prisma-statement.org.

reviewing the full text on pre-defined exclusion and inclusion criteria.

A Study was included if:

1. it provides details of the app in terms of features, development or architecture involving some Mobile Device.

2. the pain management app involves the patient's handling.

3. the pain management app involves evaluation by real users or by experts.

A Study was excluded if:

1. it is a controlled trial or a study to check primary and secondary effects or comparative analysis between interventions and does not provide details of the features of the mobile app.

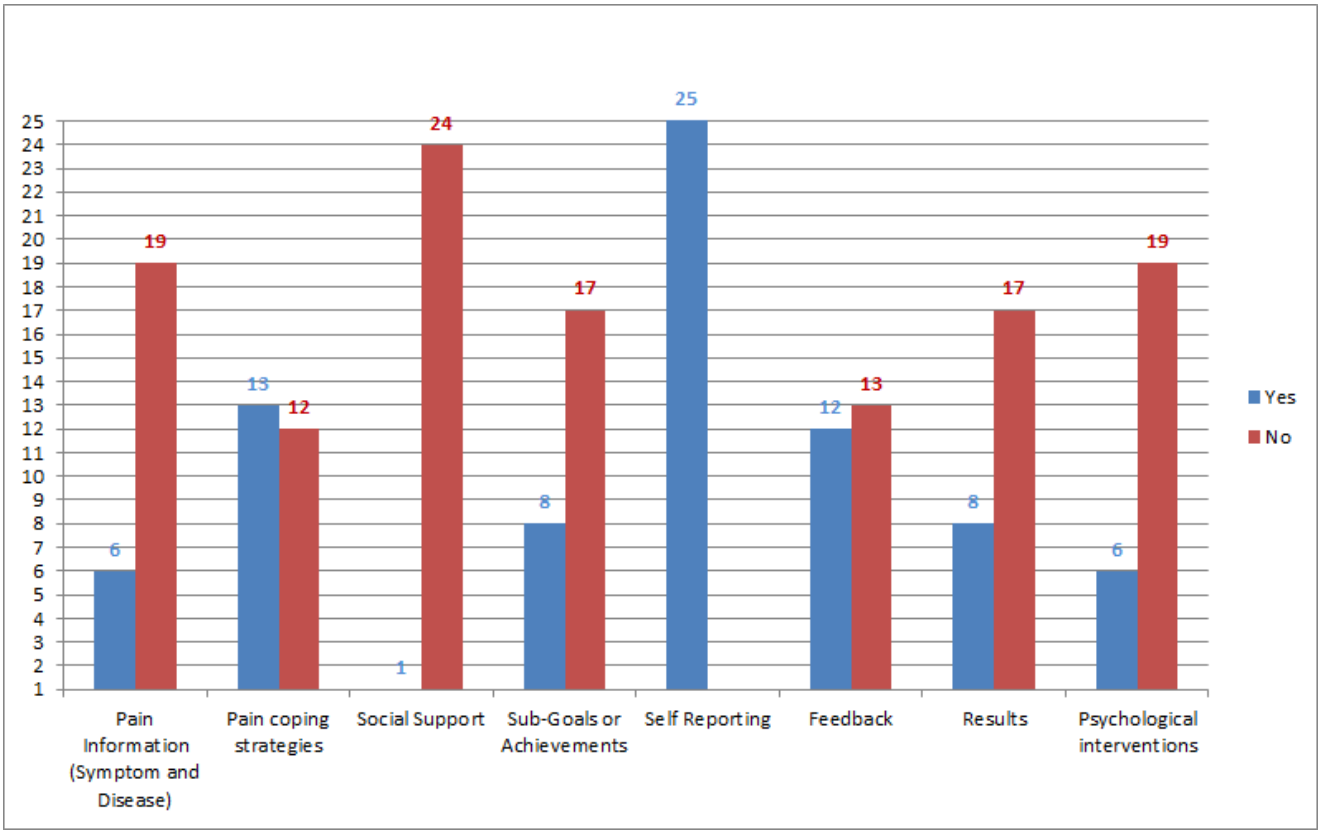

FIGURE 2. Statistical results of features provided by the pain management mobile applications.

2. it involves a mobile app only for reminder service via short messaging service or used to deliver a pain management program like exercise package, pain relieving breath, guided imagery therapy etc.

3. it involves an app designed for the physician support only i.e. for the clinical decision or an assessment tool operated by the healthcare provider only.

D. QUALITY ASSESSMENT

Two researchers conducted an independent investigation to reduce biases. For a mutual agreement among the researchers, dissimilarities had been discussed. Quality was assessed based on four factors [24] 1) relevancy of research design in the study context, 2) clarity of aims and objectives of the study, 3) research findings with identified limitations of the study, and 4) research contribution of the study. An ordinal score system was used for the grading purpose where 0 stands for no, 0.5 stands for fractional and 1 stands for yes, as the assessment response. More than 80% of the selected studies responded positively to the quality assessment. Quality and bias assessment ensures reliability of the selected literature for this systematic review.

E. DATA EXTRACTION

On the basis of the above-mentioned inclusion and exclusion criteria, twenty-five studies were identified as the most relevant for data extraction and analysis. Various features of pain management mobile applications, as explained in the studies, were extracted and maintained in the excel sheets. Each study was then marked against the presence or absence of a particular feature. These data were assessed for the numerical and analytical statistical purpose. Other than these factors, some supporting data for the descriptive statistics were also extracted i.e. title, reference, study type/research focus, problem, objective and conclusion.

III. RESULTS

This systematic review evaluates the mobile interventions for pain self-management. The objective of the study was to identify the necessary components for pain self-management and analyze the current state of the mobile apps documented in the literature. A total of twenty-five papers were reviewed and year based analysis indicates that the number of publications increased from one publication in 2005 to three publications in 2013 and five publications in 2014. This raising publication trend seems descent to two publications in 2015, one publication in 2016 and two publications in 2017.

RQ1: The general features of the pain management mobile apps documented in the scientific journals are: pain information, pain coping strategy, social support, sub-goals and achievements, self-reporting, feedback, and results/patient report. Results, as shown in Fig. 2 indicates that six

apps [25]–[30] provided pain information with respect to symptoms and disease, thirteen apps provided pain coping strategies [25]–[37], one app provided social support component [28], eight apps [26], [28], [30], [32]–[34], [37], [38] had sub-goals or achievements, all apps had self-reporting feature, twelve apps [25]–[29], [32], [33], [35]–[37], [39]–[41] had feedback component and eight apps [28]–[30], [32], [33], [36], [38], [42] provided results to patients.

RQ2: In this review, we found that only six studies [25]–[27], [31], [34], [37] were based on psychological pain management interventions. A prominent technique adopted in five studies was cognitive behavior therapy (CBT). Reference [27] used CBT with the theoretical framework of Acceptance and Commitment Therapy (ACT). Reference [26] is based on the framework of cognitive behavioral fear-avoidance model and CBT, and contained elements from the acceptance and commitment therapy. Reference [34] involved autogenic technique, mindfulness meditation, and guided imagery. Reference [37] is based on a few cognitive and behavioral skills i.e. guided imagery, progressive muscle relaxation, diaphragmatic breathing and mindfulness, and distraction.

The year wise analysis, as shown in Table 1, revealed no prominent trend of features.

IV. DISCUSION

A. AWARENESS, EDUCATION AND KNOWLEDGE

Self-management is a multidimensional phenomenon and is comprised of various important factors like goal-setting, self-monitoring, evaluation and adaptive reaction [43]. In pain self-management, patient adopts self-health care measures to treat the pain. Treatment usually involves proper medication and some activity that needs to be adjusted constantly [44], [45]. This adjustment comes from pain education that a patient acquires through social support or via an informative website [44]. Thus education/knowledge is an important attribute that gives awareness about the disease, pain symptoms, and pain coping strategies. The literature review has revealed that only 24% of the apps provided complete pain education.

In [44] a model of patient education is proposed in the context of self-management. It is comprised of certain steps: defining the problem domain, identifying suitable methods, sufficient training to use the methods, and increase self-efficacy (confidence to achieve sub-goals) by involving social influential factors. This knowledge may lead to a change in behavior and improved health condition.

Education/Knowledge must be an integral part of a health care setting and it must be patient-centered [9]. Interventions that involve pain education for the implementation of standard pain assessment and management is more effective than others. Education of health care provider is also important in this context, to train patients and convey suitable strategies to them and take advantage of decision making in the clinical setup. Education level also varies with a population [46]. It is necessary to give patients and caregivers (in their family) pain education and social support to reach the ultimate goal of pain self-management [7].

Patient education must be oriented to decision making and adopting suitable self-management regime. Learning communication skills to properly convey the experiences should also be part of patient education [44]. If some intervention requires complex behavioral change, information alone is not effective. Proper training is required to learn how the information can be accurately utilized to implement self-management strategies [13], [47].

B. SOCIAL SUPPORT

Information can be attained from a valid information resource or via social support. Providing social support along with the information dissemination is normally related with the mutual support organizations that offer self-help [48]. This survey reveals that only one study incorporated the component of social media support in the design of pain self-management app. A feature of social facilitation supports homebound patients to connect to family, friends and a network of people having the same interests [49], [50], which supports them to overcome the barriers of expression. The inclusion of this component has positive effects to improve the cognitive function of a person [50]. Through this channel, patients can express their pain effectively, which sometimes they cannot express due to social fear, professional stigmas or low confidence [49]. One can observe and learn from the activities of other patients [51]. In this way, they can also learn communication skills from each other and get encouragement [49].

Social support is highly influential in pain management and has indirect proportionality with pain intensity. Patients with increased pain participate less in social activities. High social support can provide a great cure to lessen the pain [52]. Thus, a pain self-management app must provide social connectivity to the supporting network specific to that disease which is under consideration [13].

C. SELF-EFFICACY AND MOTIVATION

In pain self-management, there are two interlinked key factors: motivation and awareness. Pain management interventions that involve behavioral and psychosocial changes show that self-efficacy is the significant factor that gives patient motivation to excel in self-management skills [53]. Self-efficacy is a belief or confidence of an individual to achieve a defined goal. Self-efficacy has a direct influence on motivation and performance [43], [54]. Self-efficacy is vital as it helps to grasp the information accurately and apply it with confidence [55].

Goal setting and feedback are vital sub-factors to enhance self-efficacy, motivation, and performance [45], [54]. Goal setting gives the motivation to render the effort in performing some task and achieve the desired goal. Motivation increased when one realized that he/she is performing and progressing well and that can be informed via proper feedback for

TABLE 1. Features provided by the pain management mobile applications – year wise sorting.

Study	Application / System Name	Pain Information	Pain coping strategies	Social Support	Sub-Goals or Achievements	Self-Reporting	Feedback	Results	Psychological Interventions
Serif, T. and G. Ghinea 2005 [63]	-	-	-	-	-	✓	-	-	-
Stinson, J.N., et al. 2006 [64]	-	-	-	-	-	✓	-	-	-
Kearney, N., et al. 2006 [39]	-	-	-	-	-	✓	✓	-	-
Sorbi, M.J., et al. 2007 [25]	-	✓	✓	-	-	✓	✓	-	✓
Anatchkova, M.D., et al. 2009 [42]	-	-	-	-	-	✓	-	✓	-
McClellan, C.B., et al. 2009 [31]	DPAD	-	✓	-	-	✓	-	-	✓
Luckmann, R. and A. Vidal 2010 [32]	EPTAD	-	✓	-	✓	✓	✓	✓	-
Hachizuka, M., et al. 2010 [65]	-	-	-	-	-	✓	-	-	-
Rosser, B.A., et al. 2011 [33]	-	-	✓	-	✓	✓	✓	✓	-
Jacob, E., et al. 2012 [66]	-	-	-	-	-	✓	-	-	-
Spyridonis, F., et al. 2012 [67]	Paindroid	-	-	-	-	✓	-	-	-
Baggott, C., et al. 2012 [56]	mOST	-	-	-	-	✓	-	-	-
Kristjánsdóttir, Ó.B., et al. 2013 [26]	-	✓	✓	-	✓	✓	✓	-	✓
Stinson, J.N., et al. 2013 [38]	Pain Squad	-	-	-	✓	✓	-	✓	-

TABLE 1. *(Continued.)* **Features provided by the pain management mobile applications – year wise sorting.**

Study	Application / System Name	Pain Information	Pain coping strategies	Social Support	Sub-Goals or Achievements	Self-Reporting	Feedback	Results	Psychological Interventions
Nes, A.A., et al. 2013 [27]	-	✓	✓	-	-	✓	✓	-	✓
Garcia-Palacios, A., et al. 2014 [68]	-	-	-	-	-	✓	-	-	-
Pombo, N., et al. 2014 [40]	-	-	-	-	-	✓	✓	-	-
Stinson, J.N., et al. 2014 [28]	-	✓	✓	✓	✓	✓	✓	✓	-
Jibb, L.A., et al. 2014 [35]	-	-	✓	-	-	✓	✓	-	-
Blodt, S., et al. 2014 [34]	Relaxback, Relaxneck	-	✓	-	✓	✓	-	-	✓
Maguire, R., et al. 2015 [41]	ASyMS-R	-	-	-	-	✓	✓	-	-
Jonassaint, C.R., et al. [36]	-	-	✓	-	-	✓	✓	✓	-
Fortier, M.A., et al. [37]	-	-	✓	-	✓	✓	✓	-	✓
Jamison, R.N., et al. [30]	-	✓	✓	-	✓	✓	-	✓	-
Hochstenbach, L.M.J., et al. [29]	-	✓	✓	-	-	✓	✓	✓	-

achievements [54]. Goal setting and achievement raise confidence and encourage one to progress [51].

An interesting finding of the survey is that all the identified apps consist of self-reporting feature, but only four apps involved a full assessment of pain episodes. For complete pain assessment it is necessary to analyze the recorded data either automatically or remotely by a health care provider [13], generate self-analysis report for the patient, and provide feedback. Nevertheless, information overload could be a barrier to the use of such technology by the healthcare providers [50]. Hence, to overcome this issue, accurate analysis of data from a human expert or automated system that results in generation of a summary of the patient's report is required. Moreover, automated systems should have a threshold of processing, after which an alert will be sent to the healthcare provider for their feedback. Apps that provide automated feedback should be rigorously checked for accuracy by healthcare governing bodies as they can mislead to severe harm [13].

D. SETTING AND ACHIEVING SUB-GOALS

Social support, goal setting, goal achievement, and overall compliance play important roles to change the patient's lifestyle and affects motivation positively; thus supporting the persuasiveness of mobile app usage [51]. Achievement of sub-goals always provides motivation to proceed towards the accomplishment of the main goal of self-management. This important component, setting the sub-goals, was only

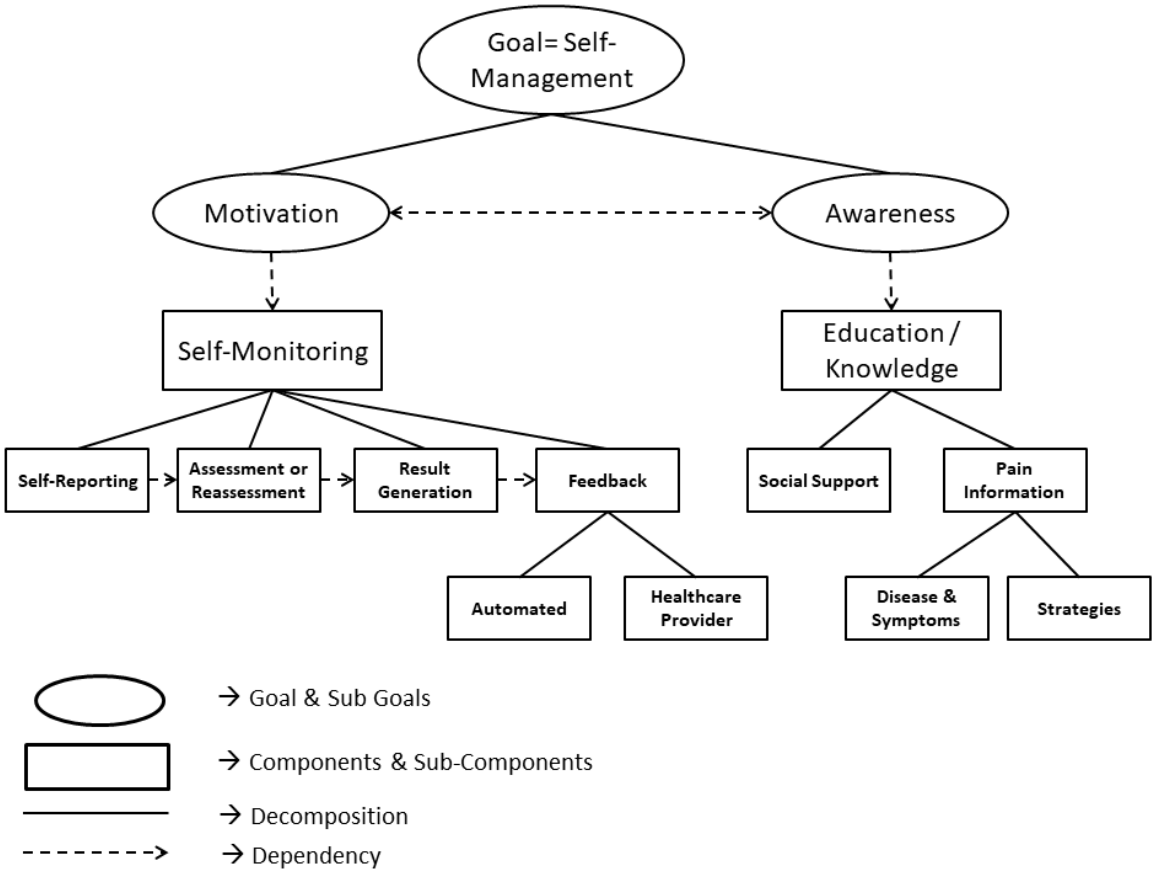

FIGURE 3. Conceptual model of pain self-management mobile applications.

found in 32% of apps. Some apps also involved rewarding strategy after achieving some goals [38], [56]. These apps were specifically targeting adolescents and the rewarding system was appealing to them and resulted in high compliance rates. Besides medication adherence, pain self-management also involves behavioral change [57] and some pain coping strategies among the patients to improve their physical and psychological functioning, thus improving quality of life.

E. PAIN COPING STRATEGIES

Pain coping strategies help the patients to self-manage pain. Review results revealed that 52% of apps provide pain coping strategies. Here involvement of psychological component could prove to be more effective. Literature suggests the importance of incorporating psychological components for the behavioral change in pain self-management. The internationally recognized National Institute for Health and Care Excellence (NICE) and the International Association for the Study of Pain (IASP) encourage the incorporation of Cognitive Behavioral Therapy principles in the online interventions for pain management for effective results [19]. It will help patients to learn the pain coping strategies. Only 24% of the apps were comprised of the psychological component.

V. TOWARDS BUILDING A CONCEPTUAL MODEL OF PAIN SELF-MANAGEMENT MOBILE SOLUTIONS

Currently, there are no guidelines for the functionality of pain management mobile applications. In a review of self-management approaches for people with chronic illnesses [58], main components of self-management with the variations and sub-components were identified. The main components are not distinctive and are classified as information, drug management, symptom management, dealing with psychological consequences, life style, social support, communication and other methodologies like career planning, decision making and goal setting etc. There are some features identified in face-to-face pain self-management programs of randomized controlled trials: self-care skills training, education, self-monitoring, social support and goal setting [18]. Hence, based on the phenomenon of pain self-management as discussed above and the identified features from the previous studies and the current review, a conceptual model is proposed to ascertain the necessary elements to be incorporated in a pain self-management solution, as shown in Fig. 3.

Self-management is the root element of this model. In pain self-management, patients adopt self-health care measures to manage pain. As per the cognitive-behavioral and

multidisciplinary pain management process, patients learn and implement the techniques to manage their pain. Being a challenging phenomenon of learning and practicing pain self-management, lack of patient's motivation could prevent the adoption of necessary changes [45]. Motivation helps patients to grasp the information about the disease, pain symptoms and pain coping strategies for awareness and implement it for self-management of pain symptoms. In this way, awareness and motivation are inter-linked factors and important sub-components of pain self-management [45], [59]–[62].

The main component of motivation is self-monitoring that helps to record and track pain symptoms from where progress could be observed. Self-monitoring is comprised of various interlinked sub-components. The first sub-component under self-monitoring is self-reporting where patients provide details about the symptoms via assessment questionnaire using a mobile application. Next step to self-reporting is pain assessment or reassessment in which the recorded pain data is assessed to provide the results. Result generation based on the assessment of the recorded data is the third step. It provides the users with self-analysis report showing progress over a time frame. Results from clinical perspective will be helpful. The results should consist of pain summary over a period of time with a graphical visualization of pain intensity, location and frequency, thus showing pain trend and improvement to adjust the pain management regime by the healthcare provider. Feedback is also a vital element that is linked to the results. Motivation increased when one realized that he/she is performing and progressing well and that can be realized via proper feedback for achievements. In case of no or less improvement, feedback could help to seek awareness to adjust the treatment regime. This also shows motivation is linked with awareness i.e. another main component of self-management.

For strategies to enhance awareness of pain self-management, acquiring education/knowledge is an important attribute. In the context of healthcare mobile application, education/knowledge can be attained as pain information about the disease, pain symptoms, and pain coping strategies via the authorized information resource/repository in the pain management mobile applications or from social support where people of similar pain pattern or symptoms can provide support to cope with the situation. Thus, education/knowledge must be an integral part of the health care setting. As self-management regime needs to be adjusted periodically, the adjustment strategies also come from education/knowledge. Therefore, it is necessary to give patients pain education/knowledge to increase awareness and reach the ultimate goal of pain self-management.

The proposed conceptual model presented an approach of self-management that could also be implemented as a generic self-management measure for other chronic diseases. A study focusing on the self-management interventions of arthritis, asthma and diabetes in primary care, has shown that regardless of the distinctive nature of these diseases, there are numerous shared characteristics as far as the idea of self-administration is concerned. Some of the common measures like life style changes, awareness of the disease management strategies, social support, communication and management of psychological symptoms could be adopted for other chronic diseases in their specified context [58].

Nevertheless, individuals living with such chronic conditions have to carry out certain disease specific measures in the administration of their particular conditions [48]. This disease specific management could be customized at the self-reporting level, e.g. for the symptom/condition management of arthritis, patients have to self-monitor for pain, fatigue, stiffness, swollen joints, inflammation and restricted physical functioning etc. Whereas, for asthma, symptom management requires monitoring of breathlessness, coughing, wheezing, pain and fatigue and may require a need for emergency treatment. Similarly, in diabetes, symptoms management would involve glycemic control, diet, frequency of urination, hypoglycemia, etc.

Thus, implementation of the self-management intervention requires analyzing the objectives and the complexity of the issues that differ among the chronic diseases [47].

VI. EXPERT-BASED VALIDATION OF THE CONCEPTUAL MODEL

A. PARTICIPANTS AND STUDY PROTOCOL

The healthcare providers from the University of Malaya Medical Centre (UMMC), who are experts in pain management, were invited to participate in the evaluation session. The purpose of this session was to evaluate from the perspective of medical doctors the conceptual model in the aspects of comprehensiveness, accuracy, and dependencies among the elements of the model, and the appropriateness of the proposed model in guiding the development of pain management mobile applications (or systems in general). Nine medical doctors who are practically involved in providing the pain management services took part in the study. Four of the participants were male and five were female, with 5 to 7 years of experience in providing pain management services. All the participants were gathered for the validation session in UMMC's Primary Care Department on 9 January 2018. They were briefed about the background and objective of the study. Consent was given by the participants to proceed with the study. Then, they were provided with the questionnaires to validate the conceptual model.

B. EVALUATION INSTRUMENT

A questionnaire was designed as the evaluation instrument. The questionnaire was first reviewed by a senior medical expert of UMCC and expert in the domain of human-computer interaction (HCI), to assess its understandability. The questionnaire was revised in two rounds based on the feedback of the expert. The final questionnaire was comprised of four parts. Part A was the introduction of the background and purpose of the study. Part B gathered the participants' details. Part C provided a detailed description of the

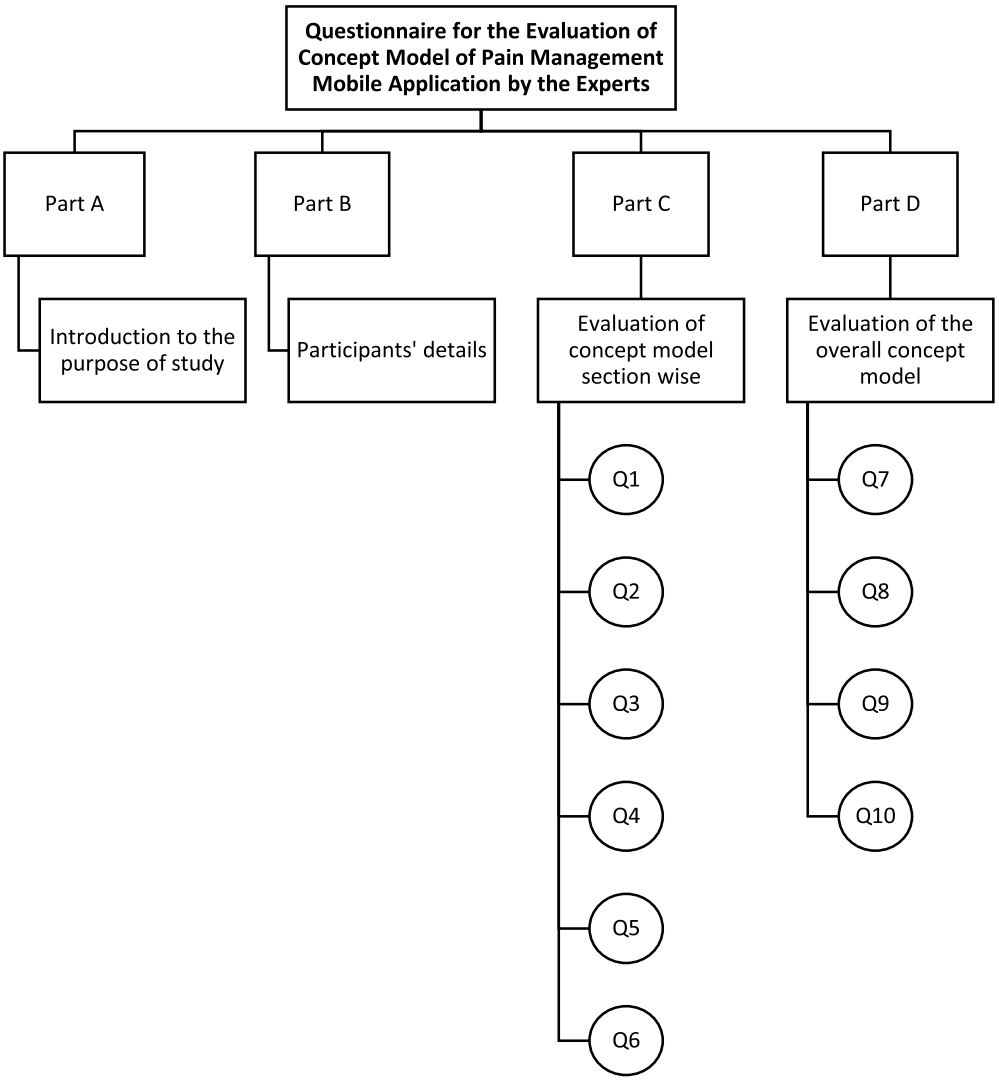

FIGURE 4. Structure of the questionnaire.

main components and sub-components of the model. It has 6 closed-ended questions to assess the comprehensiveness of the model section by section, i.e. whether all the necessary elements have been included in the model or not. It also has 6 questions to measure the correct representation of the dependencies and interlinking between the elements. Each question was also accompanied by an open-ended question to gather the participant's opinion in case of any discrepancy or disagreement with the model. Part D was designed to evaluate the completeness (i.e. have all the necessary elements been included in the model) and appropriateness (i.e. how useful is the model in designing and developing pain management mobile app) of the proposed model and acquire the participants' recommendations for its improvement. Similar to Part C, it contained 4 close-ended questions, each accompanied by an open-ended question. All the close-ended questions in the questionnaire were based on a 5-point Likert scale: Strongly Agree, Agree, Neither Agree nor Disagree, Disagree and Strongly Disagree. Fig. 4 outlines the questionnaire.

C. VALIDATION RESULTS AND DATA ANALYSIS

The frequency of opinions for each question was quantitatively analyzed in terms of the cumulative sum of responses of the 5-points Likert scale as depicted in Table 2. The descriptive answers of the open-ended questions are also listed in the table. The rationale of the participants' opinions, in case of any discrepancy or disagreement to the model, is also recorded.

The frequency of responses indicates that the experts were either agreed (mean score 53%) or strongly agreed (mean score 42%) in terms of the section-wise comprehensiveness and accuracy of dependencies among components and sub-components of the model. Two experts had shown neutral consent on the automated feedback as automated feedback may not be accurate in their opinion. Moreover, two experts

TABLE 2. Response set of the validation session.

Steps of evaluation	Questions	Response Options					
		Strongly Agree (No. of responses)	Agree (No. of responses)	Neither Agree nor Disagree (No. of responses)	Disagree (No. of responses)	Strongly Disagree (No. of responses)	Justification in case of agreement or disagreement
Part C: Evaluation of the concept model – Section wise	Q1: Self-Management	2 (22.22%)	7 (77.77%)	-	-	-	
	Q1: Motivation	2 (22.22%)	7 (77.77%)	-	-	-	
	Q1: Awareness	3 (33.33%)	6 (66.66%)	-	-	-	A Patient needs to know that he/she is in pain. Pain is affecting daily routine activities, that he/she will have an awareness to reduce pain.
	Q2	1 (11.11%)	8 (88.88%)	-	-	-	
	Q3: Self-Monitoring	4 (44.44%)	5 (55.55%)	-	-	-	
	Q3: Self-Reporting	7 (77.77%)	2 (22.22%)	-	-	-	
	Q3: Assessment or Reassessment	5 (55.55%)	2 (22.22%)	-	2 (22.22%)		
	Q3: Result Generation	4 (44.44%)	5 (55.55%)	-	-	-	
	Q3: Feedback (Automated)	4 (44.44%)	3 (33.33%)	2 (22.22%)	-	-	Automated feedback may not be accurate.
	Q3: Feedback (Healthcare Provider)	5 (55.55%)	4 (44.44%)	-	-	-	
	Q4	2 (22.22%)	7 (77.77%)	-	-	-	
	Q5: Education / Knowledge	5 (55.55%)	4 (44.44%)	-	-	-	Knowledge of self-management will improve motivation.
	Q5: Social Support	3 (33.33%))	4 (44.44%)	-	2 (22.22%)	-	
	Q5: Pain Information – Disease & Symptoms	5 (55.55%)	4 (44.44%)	-	-	-	
	Q5: Pain Information – Strategies	5 (55.55%)	4 (44.44%)	-	-	-	
	Q6	2 (22.22%)	7 (77.77%)	-	-	-	
Part D: Evaluation of the overall concept model	Q7: Complete	-	7 (77.77%)	2 (22.22%)	-	-	
	Q8: Appropriate	9 (100%)	-	-	-	-	
	Answers of the open-ended questions						

TABLE 2. *(Continued.)* **Response set of the validation session.**

	Q9	"Monitoring by healthcare on weekly to a monthly basis in regard to the severity of pain" "Red flags to give education" "No sharing of pain to others, also don't need social support" "Alert/notification for uncontrolled pain from data of self-monitoring comorbidities should be included" "History of drug allergies" "Different pain score modalities might be needed" "Data must be recorded and sent to healthcare provider time to time"
	Q10	"Add information regarding the history of disease and pain patient had before" "Also add allergies to certain medications" "They are elderly who are unable to grade their pain severity therefore unable to provide data, not all elderly are familiar in using a smartphone so how to target or solve their group of the population?" "Who will give a response in place of a healthcare provider, either pain specialist or general physician?" "Pain management concept to be individualized according to patient's diagnosis."

disagreed on the assessment and reassessment and social support. A proper explanation for disagreement could not be grasped from them, except that one expert expressed in Question 9 that pain data should not be shared with others as no social support is required. For awareness, one of the experts mentioned that ''Patient needs to know that he/she is in pain. Pain is affecting daily routine activities, that he/she will have an awareness to reduce pain''. In support of education or knowledge, one expert explained: ''Knowledge of self-management will improve motivation''. All experts agreed to the overall appropriateness of the structure of the proposed model, and 80% of the experts agreed to the overall comprehensiveness, only 2 experts gave neutral consent for this evaluation.

In the context of the open-ended questions for the recommendations or additional comments for the overall improvement of the model, no suggestions were recorded. The experts rather gave their opinion on the utility of features of pain management mobile applications. Three experts were concerned of the weekly or monthly monitoring of the patients by the healthcare providers with regard to pain severity and pain data must also be delivered to the healthcare providers from time to time. Three experts were of the view to record the history of the disease, any comorbidities, and allergies to certain medications. Two experts suggested incorporating red flags for severe pain. For educational or awareness, applications must generate an alert notification in case of pain severity. However, two experts were skeptical of the responses to those alerts, as to either a pain specialist or any general physician available at that time will be responsible to respond. As mentioned in the quantitative results earlier, two experts were of the view that pain data should not be shared with others; hence, social support is not required. Moreover, opinion to provide personalized feedback was also recorded via two experts. Four experts were concerned about the provision of various pain score modalities as the elderly might not be familiar with smartphone technology and face problem to input pain data. With the view of assessment or reassessment, two experts added that the elderly are usually unable to grade their pain so it will be difficult for them to rate their pain and provide accurate data.

The experts recognized the importance of pain management and gave positive feedback to the proposed conceptual model. From their feedback, the proposed model has provided several opportunities for pain management, especially to empower the patients to monitor their own pain conditions. There are also challenges faced by the proposed model, among which are reducing the users' cognitive load when using the mobile applications and usability issues with elderly users.

VII. CONCLUSION

Previously, some studies were conducted on the patient-centered pain management mobile applications retrieved from the smartphone application platforms. The purpose of those studies was to evaluate the primary functionality, content, and quality of the pain management mobile applications. This study focuses on the analysis of the pain management mobile applications that are proposed in the scientific literature. Analysis results revealed that pain management mobile applications documented in the scientific journals were not comprehensive in the pain self-management. To address this limitation, a conceptual model is proposed to evaluate the comprehensive of pain management mobile applications. In this context, motivation and awareness are the vital and interlinked key factors to regulate pain self-management. In addition, goal setting and feedback are significant to enhance self-efficacy, thus motivating patients to render effort in performing specified tasks and achieve the main goal of self-management. Moreover, the involvement of interventional pain management techniques can aid in pain self-management.

REFERENCES

[1] C. Perera, "The evolution of e-health—Mobile technology and mHealth," *J. Mobile Technol. Med.*, vol. 1, no. 1, pp. 1–2, 2012. doi: 10.7309/jmtm.1.

[2] G. Eysenbach, "What is e-health?" *J. Med. Internet Res.*, vol. 3, no. 2, p. e20, 2001.

[3] *mHealth for Development: The Opportunity of Mobile Technology for Healthcare in the Developing World*, Vital Wave Consulting, Washington, DC, USA, 2009.

[4] A. C. Norris, R. S. Stockdale, and S. Sharma, "A strategic approach to m-health," *Health Informat. J.*, vol. 15, no. 3, pp. 244–253, Sep. 2009. doi: 10.1177/1460458209337445.

[5] R. N. Jamison and R. R. Edwards, "Integrating pain management in clinical practice," *J. Clin. Psychol. Med. Settings*, vol. 19, no. 1, pp. 49–64, Mar. 2012. doi: 10.1007/s10880-012-9295-2.

[6] Y. J. Chuna and P. E. Patterson, "A suggestion for future research on interface design of an Internet-based telemedicine system for the elderly," *Work*, vol. 41, pp. 353–356, Jan. 2012. doi: 10.3233/WOR-2012-0181-353.

[7] M. Y. Martin, M. Pisu, E. A. Kvale, and S. A. Johns, "Developing effective cancer pain education programs," *Current Pain Headache Rep.*, vol. 16, no. 4, pp. 332–342, Aug. 2012. doi: 10.1007/s11916-012-0269-8.

[8] L. D. Marceau, C. Link, R. N. Jamison, and S. Carolan, "Electronic diaries as a tool to improve pain management: Is there any evidence?" *Pain Med.*, vol. 8, pp. S101–S109, Oct. 2007. doi: 10.1111/j.1526-4637.2007.00374.x.

[9] M. W. Stomberg, B. Platon, A. Widén, I. Wallner, and O. Karlsson, "Health information: What can mobile phone assessments add?" *Perspect. Health Inf. Manage./AHIMA, Amer. Health Inf. Manage. Assoc.*, vol. 9, Oct. 2012.

[10] S. Töyssy and M. Helenius, "About malicious software in smartphones," *J. Comput. Virol.*, vol. 2, no. 2, pp. 109–119, 2006. doi: 10.1007/s11416-006-0022-0.

[11] G. Lawton, "Is it finally time to worry about mobile malware?" *Computer*, vol. 41, no. 5, pp. 12–14, May 2008.

[12] B. A. Rosser and C. Eccleston, "Smartphone applications for pain management," *J. Telemed. Telecare*, vol. 17, no. 6, pp. 308–312, 2011. doi: 10.1258/jtt.2011.101102.

[13] J. L. Bender, R. Y. K. Yue, M. J. To, L. Deacken, and A. R. Jadad, "A lot of action, but not in the right direction: Systematic review and content analysis of smartphone applications for the prevention, detection, and management of cancer," *J. Med. Internet Res.*, vol. 15, no. 12, p. e287, 2013.

[14] A. Buijink, B. J. Visser, and L. Marshall, "Medical apps for smartphones: Lack of evidence undermines quality and safety," *BMJ Evidence-Based Med.*, vol. 18, no. 3, pp. 2–90, 2013.

[15] C. Reynoldson, C. Stones, M. Allsop, P. Gardner, M. I. Bennett, S. J. Closs, R. Jones, and P. Knapp, "Assessing the quality and usability of smartphone apps for pain self-management," *Pain Med.*, vol. 15, no. 6, pp. 898–909, 2014.

[16] L. S. Wallace and L. K. Dhingra, "A systematic review of smartphone applications for chronic pain available for download in the United States," *J. Opioid Manage.*, vol. 10, no. 1, pp. 63–68, 2014.

[17] R. de la Vega and J. Miró, "mHealth: A strategic field without a solid scientific soul. A systematic review of pain-related apps," *PLoS ONE*, vol. 9, no. 7, 2014, Art. no. e101312. doi: 10.1371/journal.pone.0101312.

[18] C. Lalloo, L. A. Jibb, J. Rivera, A. Agarwal, and J. N. Stinson, "'There's a pain app for that': Review of patient-targeted smartphone applications for pain management," *Clin. J. Pain*, vol. 31, no. 6, pp. 557–563, Jun. 2015. doi: 10.1097/AJP.0000000000000171.

[19] P. Portelli and C. Eldred, "A quality review of smartphone applications for the management of pain," *Brit. J. Pain*, vol. 10, no. 3, pp. 135–140, Aug. 2016. doi: 10.1177/2049463716638700.

[20] J. C. Alexander and G. P. Joshi, "Smartphone applications for chronic pain management: A critical appraisal," *J. Pain Res.*, vol. 9, pp. 731–734, Sep. 2016. doi: 10.2147/JPR.S119966.

[21] U. M. Shah and T. K. Chiew, "A systematic literature review of the design approach and usability evaluation of the pain management mobile applications," *Symmetry*, vol. 11, no. 3, p. 400, 2019.

[22] B. Kitchenham, "Procedures for performing systematic reviews," Dept. Comput. Sci., Keele Univ., Keele, U.K., Tech. Rep. TR/SE-0401, 2004, vol. 33, pp. 1–26.

[23] D. Moher, A. Liberati, J. Tetzlaff, D. G. Altman, and G. Prisma, "Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement," *Ann. Internal Med.*, vol. 151, no. 4, pp. 264–269, 2009.

[24] G. Guyatt, D. Rennie, M. O. Meade, and D. J. Cook, *Users' Guides to the Medical Literature: A Manual for Evidence-Based Clinical Practice*. Chicago, IL, USA: AMA Press, 2002.

[25] M. J. Sorbi, S. B. Mak, J. H. Houtveen, A. M. Kleiboer, and L. J. van Doornen, "Mobile Web-based monitoring and coaching: Feasibility in chronic migraine," *J. Med. Internet Res.*, vol. 9, no. 5, p. e38, 2007. doi: 10.2196/jmir.9.5.e38.

[26] O. B. Kristjánsdóttir, E. A. Fors, E. Eide, A. Finset, T. L. Stensrud, S. van Dulmen, S. H. Wigers, and H. Eide, "A smartphone-based intervention with diaries and therapist feedback to reduce catastrophizing and increase functioning in women with chronic widespread pain. part 2: 11-month follow-up results of a randomized trial," *J. Med. Internet Res.*, vol. 15, no. 3, p. e72, 2013.

[27] A. A. Nes, H. Eide, O. B. Kristjánsdóttir, and S. van Dulmen, "Web-based, self-management enhancing interventions with e-diaries and personalized feedback for persons with chronic illness: A tale of three studies," *Patient Edu. Counseling*, vol. 93, no. 3, pp. 451–458, Dec. 2013. doi: 10.1016/j.pec.2013.01.022.

[28] J. N. Stinson, "*iCanCope with pain*: User-centred design of a Web- and mobile-based self-management program for youth with chronic pain based on identified health care needs," *Pain Res. Manage.*, vol. 19, no. 5, pp. 257–265, 2014.

[29] L. M. J. Hochstenbach, A. M. Courtens, S. M. G. Zwakhalen, J. Vermeulen, M. van Kleef, and L. P. de Witte, "Co-creative development of an eHealth nursing intervention: Self-management support for outpatients with cancer pain," *Appl. Nursing Res.*, vol. 36, pp. 1–8, Aug. 2017. doi: 10.1016/j.apnr.2017.03.004.

[30] R. N. Jamison, D. C. Jurcik, R. R. Edwards, C. C. Huang, and E. L. Ross, "A pilot comparison of a smartphone app with or without 2-way messaging among chronic pain patients: Who benefits from a pain app?" *Clin. J. Pain*, vol. 33, no. 8, pp. 676–686, Aug. 2017. doi: 10.1097/AJP.0000000000000455.

[31] C. B. McClellan, J. C. Schatz, E. Puffer, C. E. Sanchez, M. T. Stancil, and C. W. Roberts, "Use of handheld wireless technology for a home-based sickle cell pain management protocol," *J. Pediatric Psychol.*, vol. 34, no. 5, pp. 564–573, Jun. 2009. doi: 10.1093/jpepsy/jsn121.

[32] R. Luckmann and A. Vidal, "Design of a handheld electronic pain, treatment and activity diary," *J. Biomed. Inform.*, vol. 43, no. 5, pp. S32–S36, Oct. 2010. doi: 10.1016/j.jbi.2010.05.005.

[33] B. A. Rosser, P. McCullagh, R. Davies, G. A. Mountain, L. McCracken, and C. Eccleston, "Technology-mediated therapy for chronic pain management: The challenges of adapting behavior change interventions for delivery with pervasive communication technology," *Telemedicine J. e-Health*, vol. 17, no. 3, pp. 211–216, Apr. 2011. doi: 10.1089/tmj.2010.0136.

[34] S. Blödt, D. Pach, S. Roll, and C. M. Witt, "Effectiveness of app-based relaxation for patients with chronic low back pain (Relaxback) and chronic neck pain (Relaxneck): Study protocol for two randomized pragmatic trials," *Trials*, vol. 15, Dec. 2014, Art. no. 490. doi: 10.1186/1745-6215-15-490.

[35] L. A. Jibb, B. J. Stevens, P. C. Nathan, E. Seto, J. A. Cafazzo, and J. N. Stinson, "A smartphone-based pain management app for adolescents with cancer: Establishing system requirements and a pain care algorithm based on literature review, interviews, and consensus," *JMIR Res. Protocols*, vol. 3, no. 1, p. e15, 2014. doi: 10.2196/resprot.3041.

[36] C. R. Jonassaint, N. Shah, J. Jonassaint, and L. De Castro, "Usability and Feasibility of an mhealth intervention for monitoring and managing pain symptoms in sickle cell disease: The sickle cell disease mobile application to record symptoms *via* technology (SMART)," *Hemoglobin*, vol. 39, no. 3, pp. 162–168, 2015. doi: 10.3109/03630269.2015.1025141.

[37] M. A. Fortier, W. W. Chung, A. Martinez, S. Gago-Masague, and L. Sender, "Pain buddy: A novel use of m-health in the management of children's cancer pain," *Comput. Biol. Med.*, vol. 76, pp. 202–214, Sep. 2016. doi: 10.1016/j.compbiomed.2016.07.012.

[38] J. N. Stinson, L. A. Jibb, C. Nguyen, P. C. Nathan, A. M. Maloney, L. Lee Dupuis, J. T. Gerstle, B. Alman, S. Hopyan, C. Strahlendorf, and C. Portwine, "Development and testing of a multidimensional iPhone pain assessment application for adolescents with cancer," *J. Med. Internet Res.*, vol. 15, no. 3, p. e51, 2013. doi: 10.2196/jmir.2350.

[39] N. Kearney, L. Kidd, M. Miller, M. Sage, J. Khorrami, M. McGee, J. Cassidy, K. Niven, and P. Gray, "Utilising handheld computers to monitor and support patients receiving chemotherapy: Results of a UK-based feasibility study," *Supportive Care Cancer*, vol. 14, no. 7, pp. 742–752, Jul. 2006. doi: 10.1007/s00520-005-0002-9.

[40] N. Pombo, P. Araújo, J. Viana, and M. D. da Costa, "Evaluation of a ubiquitous and interoperable computerised system for remote monitoring of ambulatory post-operative pain: A randomised controlled trial," *Technol. Health Care*, vol. 22, no. 1, pp. 63–75, 2014. doi: 10.3233/THC-130774.

[41] R. Maguire, E. Ream, A. Richardson, J. Connaghan, B. Johnston, G. Kotronoulas, V. Pedersen, J. McPhelim, N. Pattison, A. Smith, and L. Webster, "Development of a novel remote patient monitoring system: The advanced symptom management system for radiotherapy to improve the symptom experience of patients with lung cancer receiving radiotherapy," *Cancer Nursing*, vol. 38, no. 2, pp. E37–E47, Mar./Apr. 2015. doi: 10.1097/NCC.0000000000000150.
[42] M. D. Anatchkova, R. N. Saris-Baglama, M. Kosinski, and J. B. Bjorner, "Development and preliminary testing of a computerized adaptive assessment of chronic pain," *J. Pain*, vol. 10, no. 9, pp. 932–943, Sep. 2009. doi: 10.1016/j.jpain.2009.03.007.
[43] A. Bandura, "Social cognitive theory of self-regulation," *Organizational Behav. Hum. Decis. Process.*, vol. 50, no. 2, pp. 248–287, 1991.
[44] E. Taal, J. J. Rasker, and O. Wiegman, "Patient education and self-management in the rheumatic diseases: A self-efficacy approach," *Arthritis Rheumatism*, vol. 9, no. 3, pp. 229–238, 1996.
[45] M. P. Jensen, W. R. Nielson, and R. D. Kerns, "Toward the development of a motivational model of pain self-management," *J. Pain*, vol. 4, no. 9, pp. 477–492, 2003.
[46] M. R. Lovell, T. Luckett, F. M. Boyle, J. Phillips, M. Agar, and P. M. Davidson, "Patient education, coaching, and self-management for cancer pain," *J. Clin. Oncol.*, vol. 32, no. 16, pp. 1712–1720, Jun. 2014. doi: 10.1200/JCO.2013.52.4850.
[47] S. Newman, L. Steed, and K. Mulligan, "Self-management interventions for chronic illness," *Lancet*, vol. 364, no. 9444, pp. 1523–1537, 2004. doi: 10.1016/s0140-6736(04)17277-2.
[48] J. H. Barlow, J. Sturt, and H. Hearnshaw, "Self-management interventions for people with chronic conditions in primary care: Examples from arthritis, asthma and diabetes," *Health Edu. J.*, vol. 61, no. 4, pp. 365–378, 2002.
[49] K. L. Becker, "Cyberhugs: Creating a voice for chronic pain sufferers through technology," *Cyberpsychol., Behav. Social Netw.*, vol. 16, no. 2, pp. 123–126, Feb. 2013. doi: 10.1089/cyber.2012.0361.
[50] M. Levine, J. E. Richardson, E. Granieri, and M. C. Reid, "Novel telemedicine technologies in geriatric chronic non-cancer pain: Primary care providers' perspectives," *Pain Med.*, vol. 15, no. 2, pp. 206–213, 2014.
[51] R. Gasser, D. Brodbeck, M. Degen, J. Luthiger, R. Wyss, and S. Reichlin, "Persuasiveness of a mobile lifestyle coaching application using social facilitation," in *Persuasive Technology*. Berlin, Germany: Springer, 2006, pp. 27–38.
[52] J. Chatwin, J. Closs, and M. Bennett, "Pain in older people with cancer: Attitudes and self-management strategies," *Eur. J. Cancer Care*, vol. 18, no. 2, pp. 124–130, Mar. 2009. doi: 10.1111/j.1365-2354.2007.00885.x.
[53] T. J. Somers, A. A. Wren, and R. A. Shelby, "The context of pain in arthritis: Self-efficacy for managing pain and other symptoms," *Current Pain Headache Rep.*, vol. 16, no. 6, pp. 502–508, Dec. 2012. doi: 10.1007/s11916-012-0298-3.
[54] D. H. Schunk, "Self-efficacy, motivation, and performance," *J. Appl. Sport Psychol.*, vol. 7, no. 2, pp. 112–137, 1995.
[55] J. Cho, D. Park, and H. E. Lee, "Cognitive factors of using health apps: Systematic analysis of relationships among health consciousness, health information orientation, eHealth literacy, and health app use efficacy," *J. Med. Internet Res.*, vol. 16, no. 5, p. e125, 2014.
[56] C. Baggott, F. Gibson, B. Coll, R. Kletter, P. Zeltzer, and C. Miaskowski, "Initial evaluation of an electronic symptom diary for adolescents with cancer," *JMIR Res. Protocols*, vol. 1, no. 2, p. e23, 2012. doi: 10.2196/resprot.2175.
[57] M. N. K. Boulos, S. Wheeler, C. Tavares, and R. Jones, "How smartphones are changing the face of mobile and participatory healthcare: An overview, with example from eCAALYX," *BioMed. Eng. OnLine*, vol. 10, no. 1, p. 24, 2011. doi: 10.1186/1475-925X-10-24.
[58] J. Barlow, C. Wright, J. Sheasby, A. Turner, and J. Hainsworth, "Self-management approaches for people with chronic conditions: A review," *Patient Edu. Counseling*, vol. 48, no. 2, pp. 177–187, 2002.
[59] J. D. Fisher and W. A. Fisher, "Theoretical approaches to individual-level change in HIV risk behavior," in *Handbook of HIV Prevention*. Boston, MA, USA: Springer, 2000, pp. 3–55.
[60] J. D. Fisher and W. A. Fisher, "The information-motivation-behavioral skills model," in *Emerging Theories in Health Promotion Practice and Research: Strategies for Improving Public Health*, vol. 1. San Francisco, CA, USA: Wiley, 2002, pp. 40–70.
[61] W. A. Fisher, J. D. Fisher, and J. Harman, "The information-motivation-behavioral skills model: A general social psychological approach to understanding and promoting health behavior," *Social Psychol. Found. Health Illness*, vol. 82, pp. 82–106, Jan. 2003.
[62] J. Suls and K. A. Wallston, *Social Psychological Foundations of Health and Illness*. Hoboken, NJ, USA: Wiley, 2003.
[63] T. Serif and G. Ghinea, "Recording of time-varying back-pain data: A wireless solution," *IEEE Trans. Inf. Technol. Biomed.*, vol. 9, no. 3, pp. 447–458, Sep. 2005.
[64] J. N. Stinson, G. C. Petroz, G. Tait, B. M. Feldman, D. Streiner, P. J. McGrath, and B. J. Stevens, "e-Ouch: Usability testing of an electronic chronic pain diary for adolescents with arthritis," *Clin. J. Pain*, vol. 22, no. 3, pp. 295–305, 2006.
[65] M. Hachizuka, K. Yoshiuchi, Y. Yamamoto, S. Iwase, K. Nakagawa, K. Kawagoe, and A. Akabayashi, "Development of a personal digital assistant (PDA) system to collect symptom information from home hospice patients," *J. Palliative Med.*, vol. 13, no. 6, pp. 647–651, Jun. 2010. doi: 10.1089/jpm.2009.0350.
[66] E. Jacob, J. Stinson, J. Duran, A. Gupta, M. Gerla, M. A. Lewis, and L. Zeltzer, "Usability testing of a Smartphone for accessing a Web-based e-diary for self-monitoring of pain and symptoms in sickle cell disease," *J. Pediatric Hematol./Oncol.*, vol. 34, no. 5, pp. 326–335, Jul. 2012. doi: 10.1097/MPH.0b013e318257a13c.
[67] F. Spyridonis, T.-M. Grønli, J. Hansen, and G. Ghinea, "Evaluating the usability of a virtual reality-based Android application in managing the pain experience of wheelchair users," in *Proc. IEEE Annu. Int. Conf. Eng. Med. Biol. Soc. (EMBC)*, Aug./Sep. 2012, pp. 2460–2463.
[68] A. Garcia-Palacios, R. Herrero, M. A. Belmonte, D. Castilla, J. Guixeres, G. Molinari, R. M. Baños, and C. Botella, "Ecological momentary assessment for chronic pain in fibromyalgia using a smartphone: A randomized crossover study," *Eur. J. Pain*, vol. 18, no. 6, pp. 862–872, 2014. doi: 10.1002/j.1532-2149.2013.00425.x.

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