eHealth: Towards improving self-management of acute pain in older adults following a fracture

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Chams Cherid designed and conducted the environmental scan presented in chapter 1 and participated in all aspects of the 2 other studies including the development of the protocols, submission to Research Ethics Board, design and administration of surveys presented in chapters 3 & 4, collected all data, analyzed results, wrote the first draft and revisions of the 2 manuscripts for publication. These projects were funded through an operation grant of the Canadian Institutes for Health Research to Dr. Suzanne Morin. The candidate received a travel grant from Osteoporosis Canada to present a poster to the Age-Well annual meeting in 2018.

Dr. Suzanne N Morin supervised every project, supervised the designs, collection of data and analyses and reviewed the results and provided feedback and direction in manuscript writing.
Michelle Wall participated in the coordination of the projects, safeguard of the data and the revision of the results.

Manuscript 1:

The candidate, Chams Cherid, designed the protocol and participated in the survey development. He recruited and administered the surveys and analysed the data. He wrote the first draft of the manuscript and edited subsequent drafts. He is the primary author. Dr. Morin supervised all aspect of the projects, revised the drafts and is responsible for the study results. Both had access to the data and vouch for the validity of the data.

Ms. Michelle Wall helped oversee the statistical analysis and revised the manuscript. Drs. Amel Baghdadli, Nancy Mayo, Gregory Berry, Edward Harvey, Anthony Albers and Stephane Bergeron participated in the survey design, helped with participant recruitment, participated in the interpretation of the results and provided comments on the manuscript (Chapter 3).

Manuscript 2:

The candidate, Chams Cherid, designed the protocol and participated in the survey development. He sent the survey to participants, tabulated and analysed the data. He wrote the first draft of the manuscript and edited subsequent drafts. He is the primary author. Dr. Morin supervised all aspect of the projects, revised the drafts and is responsible for the study results. Both had access to the data and vouch for the validity of the data.

Dr. Marija Djekic-Ivankovic provided supervision for the qualitative analysis and revised the manuscript. Ms. Michelle Wall, Drs. Nancy Mayo, Gregory Berry, and Céline Gélinas participated in the survey design, in the interpretation of the results and provided comments on the manuscript.

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ABBREVIATIONS

App: Application

BMD: Bone mineral density

ED: Emergency department

eHEALS: electronic health literacy scale

eHealth: Electronic health

MARS: Mobile app rating scale

mERA: mHealth evidence reporting and assessment

mHealth: Mobile health

NRS: Numeric rating scale

NSAID: Non-steroidal anti-inflammatory drug

PAINAD: Pain Assessment in Advanced Dementia Scale

QofL: Quality of life

RCP: Royal College of Physicians

VAS: Visual analogue scale

VDS: Verbal descriptor scale

VRS: Verbal rating scale

WHO: World Health Organization

ABSTRACT

Acute pain management in older adults following a skeletal fracture is very challenging. Pain is often poorly managed both in-hospital and post-hospital discharge and is associated with harmful outcomes such as increased falls, loss of autonomy and low quality of life and can, in certain instances, evolve into chronic pain. Mobile applications (apps) downloadable on devices such as smartphones and tablets can offer targeted interactive interventions to support patients in acute pain self-management following hospital discharge. However, little is known about the availability and quality of mobile apps for acute pain management in older adults, and the current levels of technology adoption and electronic health (eHealth) literacy in a population of older adults seen in orthopedic clinics. Furthermore, it is important to seek the voice of clinicians when developing a mobile app so that the content is evidence-based, credible and of high value.

In this scholarly work, we sought to 1) identify mobile apps currently available for self-management of acute pain and characterize their features (content and functionalities), 2) identify the current level of technology adoption and eHealth literacy among older adults who recently suffered a fracture, to determine if use of mobile digital devices to optimize care interventions would be feasible, acceptable and 3) identify what clinicians believe are the most important content or functionalities to include in a mobile application for self-management of acute pain in older adults following a recent skeletal fracture.

Following an environmental scan, where we were unable to identify high quality mobile apps for the self-management of acute pain, we conducted two surveys. In the first, we invited adults ≥50 years with a recent fracture to complete a self-administered survey composed of 21 closed-ended questions, including the eHealth literacy scale (eHEALS). A total of 401 participants completed the survey (women: 64%; ≥65 years old: 59%). Most respondents (81%) owned at least one mobile device: smartphone (49%), tablet (45%). The majority (65%) of older adults participating in this survey used the Internet in the 6 months prior to the survey (50-64 years: 84%;

65-74 years: 76%; ≥75 years: 61%) and approximately 69% of those who used the Internet had high eHealth literacy (eHEALS ≥26). Among adults ≥75 years who reported owning a smartphone and/or tablet, 60% had recently used the Internet and 64% indicated being interested in using technology to improve their health. Although the eHEALS scores and technology adoption in the ≥75 years group were significantly lower compared to younger age groups, our results do support the development of mobile applications for the management of acute pain in this patient population with recent fractures.

In the second study, we surveyed clinicians across Canada with expertise in osteoporosis, fractures, rehabilitation and pain management using a snowball sampling method. The survey constituted of one question sent through email asking for recommendations for the most important content or functionalities to include in a mobile app for the self-management of acute pain following a recent fracture. Forty-two clinicians responded to our survey (response rate 1st wave 60%; 2nd wave 60%) and 230 references were extracted. Appropriate medical information, pain management modalities, pain self-management strategies were the most cited content recommendations while the primary app functions highlighted were the ability to receive direct feedback from the app (interactiveness), pain self-monitoring and access to healthcare providers.

Fracture pain management is challenging in older adults. The adoption of technology and high eHealth literacy levels are now common among older adults which support the use of mobile apps to improve management of outpatient conditions such as acute pain following a fracture. This work will support the development of a mobile app that will meet evidence-based standards and will support self-management of acute pain following a skeletal fracture in older individuals. This will improve quality of life by reducing pain levels while engaging in activities of daily living and promote healthy lifestyle behaviors to reduce the risk of subsequent injurious falls.

RÉSUMÉ

La gestion de la douleur aiguë chez la personne âgée après une fracture du squelette est très difficile. La douleur est souvent mal gérée tant à l'hôpital qu'à la sortie de l'hôpital et est associée à des conséquences néfastes telles que l'augmentation du nombre de chutes, la perte d'autonomie et une qualité de vie médiocre et peut, dans certains cas, évoluer à une douleur chronique. Les applications mobiles (apps) téléchargeables sur des appareils tels que les smartphones et les tablettes peuvent offrir des interventions interactives ciblées pour aider les patients à prendre en charge eux-mêmes la douleur aiguë après leur sortie d'hôpital. Cependant, on dispose peu d'informations sur la disponibilité et la qualité des apps pour la gestion de la douleur aiguë chez la personne âgée, ainsi que sur les niveaux actuels d'adoption de la technologie et de littératie en matière de santé électronique (cyber-santé) chez les patients qui visite la clinique d'orthopédie. En outre, il est important de rechercher la voix des cliniciens lors du développement d'une app afin que le contenu soit fondé sur des preuves, crédible et de grande valeur.

Dans ce travail savant, nous avons cherché à 1) identifier les apps actuellement disponibles pour l'autogestion de la douleur aiguë et à caractériser leurs caractéristiques (contenu et fonctionnalités), 2) à identifier le niveau actuel d'adoption de la technologie et de connaissances en cyber-santé chez la personne âgée récemment atteintes d'une fracture, afin de déterminer si l'utilisation d'appareils numériques mobiles pour optimiser les interventions de soins serait faisable, acceptable et 3) déterminer, d'après les cliniciens, le contenu et/ou fonctionnalités les plus importants à inclure dans une application mobile de gestion autonome de la douleur aiguë chez la personne âgée suite à une fracture récente du squelette.

Après une analyse de l'environnement, dans laquelle nous n'avons pas pu identifier d'apps de haute qualité pour l'autogestion de la douleur aiguë, nous avons mené deux sondages. Lors du premier, nous avons invité des adultes âgés de 50 ans ou plus présentant une fracture récente à remplir un sondage auto-administré composé de 21 questions fermées, y compris l’échelle de littératie en cyber-santé (eHEALS). Au total, 401 participants ont répondu au sondage (femmes: 64%; ≥ 65 ans: 59%). La plupart des répondants (81%) possédaient au moins un appareil mobile: smartphone (49%), tablette (45%). La majorité (65%) des adultes âgés participant à cette enquête ont utilisé Internet au cours des 6 mois précédant l'enquête (50 à 64 ans: 84%; 65 à 74 ans: 76%; ≥ 75 ans: 61%) et environ 69% de ceux qui utilisaient Internet avaient une haute littératie en cyber-santé (eHEALS ≥26). Parmi les adultes de 75 ans et plus ayant déclaré posséder un smartphone et/ou une tablette, 60% avaient récemment utilisé Internet et 64% étaient intéressés par l'utilisation de la technologie pour améliorer leur santé. Bien que les scores eHEALS et l'adoption de la technologie dans le groupe des 75 ans et plus soient significativement inférieurs aux groupes d'âge plus jeunes, nos résultats appuient le développement d'applications mobiles pour la gestion de la douleur aiguë chez cette population de patients souffrant de fractures récentes.

Dans la deuxième étude, nous avons interrogé, à l'aide d'une méthode d'échantillonnage “snowball”, des cliniciens à travers le Canada possédant une expertise en ostéoporose, fractures, réadaptation et en gestion de la douleur. L'enquête consistait en une question envoyée par courriel électronique demandant des recommandations sur le contenu ou les fonctionnalités les plus importants à inclure dans une app pour l'autogestion de la douleur aiguë suite à fracture récente. Quarante-deux cliniciens ont répondu à notre sondage (taux de réponse 1ère vague 60%; 2ème vague 60%) et 230 références ont été extraites. Les informations médicales appropriées, les modalités de gestion de la douleur, les stratégies de gestion de la douleur étaient les recommandations les plus citées, tandis que les fonctions principales mentionnées furent la possibilité de recevoir un retour direct de l'app (interactivité), l'auto-surveillance de la douleur et l'accès aux prestataires de soins de santé.

La gestion de la douleur suite à une fracture est difficile chez la personne âgée. L'adoption de la technologie et les niveaux élevés de littératie en cyber-santé sont maintenant courants chez la personne âgée et soutiennent l'utilisation d’apps pour améliorer la gestion des conditions ambulatoires telles que la douleur aiguë suite à une fracture. Ce travail soutiendra le développement d'une app qui respectera les normes fondées sur des preuves scientifiques et soutiendra la gestion autonome de la douleur aiguë à la suite d'une fracture du squelette chez la personne âgée. Cela améliorera leur qualité de vie en réduisant les niveaux de douleur tout en participant aux activités de la vie quotidienne et en promouvant des modes de vie sains afin de réduire le risque de chutes préjudiciables.

CHAPTER 1
BACKGROUND

1.1 Osteoporosis

1.1.1 Prevalence and burden of disease

Osteoporosis is a common skeletal disease characterized by low bone mass and an increased risk of fractures (1, 2). Worldwide, there is annually an estimated 9 million osteoporotic fractures (3, 4) which lead to excess morbidity, pain, poor quality of life (QofL) and mortality (5, 6). In Canada, the cost of care associated with osteoporosis-related fractures is currently estimated at $4.6 billion per year and has increased in recent years (7). This rise can largely be explained by an aging population with multiple comorbidities who sustain an increased number of fractures (8, 9), under-identification of patients with osteoporosis at high risk for fractures and under-utilization of available fracture preventive strategies (4, 10). Following fracture repair, many older patients will require care in skilled nursing or rehabilitation facilities because of their inability to return to pre-fracture functional status. Thus, effective interventions that aim to reduce fractures and improve post-fracture care are necessary to yield significant advances in QofL of patients, their family and cost-savings to society (11).

Osteoporosis affects both men and women (12, 13). However, it is more prevalent in women primarily due to accelerated bone loss following menopause (14). Although bone loss increases with age in both sexes, it occurs at a faster rate and at a younger age in women. The prevalence of osteoporosis also varies across ethnicity (15, 16) and is more common in Caucasians (Whites) compared to individuals of other ethnic background (12). Other risk factors include use of medications such as glucocorticoids, chronic health conditions such as rheumatoid arthritis, liver diseases, diabetes and a family history of osteoporosis and fractures (15). The diagnosis of osteoporosis is made by measuring bone mineral density (BMD) using dual-energy x-ray absorptiometry (DXA). BMD correlates with bone strength and is an excellent predictor of future fracture risk (12, 17). As BMD decreases, fracture risk increases exponentially (17). According to the World Health Organization (WHO) criteria, osteoporosis is defined as a reduction in BMD with a T-score of 2.5 standard deviations (SD) or more below that of the mean peak bone mass of young adults (18). Osteoporosis Canada suggests that women and men aged 50 years or over with risk factors should be screened by measuring BMD to determine their risk for future fractures and initiate treatment should they be found to be at high risk (19). To obtain a more accurate measure of patients' fracture risk, further assessments are recommended such as a detailed history of patients' comorbidities, physical examination, spine radiographs (for the presence of vertebral fractures) and use of a fracture risk assessment tool (such as FRAX) to estimate the 10-year estimated fracture probability (20). Identifying osteoporotic patients with high fracture risk early is essential to improve clinical outcomes and reduce the impact of osteoporosis on the healthcare system (4). Once identified, a variety of treatment options are available including anti-osteoporosis medications, optimal calcium and vitamin D intake, exercise and fall-prevention strategies (21).

1.1.2 Skeletal fractures

Bone loss leads to compromised bone strength and contributes to increased risk of fracture (22, 23). This skeletal fragility is often in association with frailty and sarcopenia resulting in poor muscular function, particularly in the elderly (24). Approximately 1 in 3 women and 1 in 5 men will sustain an osteoporotic fracture during their lifetime (12, 25). In clinical practice, the most prevalent fracture sites are the vertebrae (spine), proximal femur (hip), distal forearm (wrist) and humerus, while the pelvis and ribs are less common fracture sites (26). Vertebral fractures constitute the most common osteoporotic fractures and are associated with a high risk for subsequent fractures and mortality (27-29). Hip fractures are generally considered the most serious consequence of osteoporosis (8, 28). Each year, almost 30 000 Canadians experience a hip fracture (30). Worldwide, over 90% of hip fracture patients are aged ≥65 years, about 70% of all hip fractures occur in women (31-33) and most have several comorbidities that increase mortality rates following the fracture (34-36). With rising life expectancy, the International Osteoporosis Foundation expects the incidence of hip fracture to significantly increase both in men and women by the year 2050 up to 6.26 million worldwide compared to 1.66 million in 1990 (37, 38). Distal forearm or wrist fractures account for up to 20% of all fractures treated in the emergency department and are one of the most common injuries encountered in orthopedic practice (39). Most wrist fractures are typically caused by falls and do not usually threaten patients' lives (40). However, especially in older patients, this type of fracture can have an impact on individuals' overall functionality preventing patients from completing key tasks such as preparing meals, household chores, climbing stairs and getting in and out of the car (39, 41).

Loss of autonomy

Following a fracture, subsequent loss of autonomy and mobility result in a poorer QofL (42), such as loss of independence and inability to carry out day-to-day activities (26). These outcomes have an overall negative impact on both physical and mental function (43). In addition, this loss in autonomy increases the risk of falls and fall-related injuries (44). Due to the serious consequences of falls, approximately 40-60% of older adults report a fear of falling (45). These concerns further impact daily living and trigger a self-induced restriction in exercise, physical activity and societal interaction.

Mortality

Most fractures occurring at major osteoporotic sites are associated with an increased relative risk for mortality across all age groups, particularly in men, compared to individuals without fractures (46). Pre-existing poor health status has implications in the excess mortality (47, 48). It is estimated that as many as 10% of patients will die in-hospital following a hip fracture (49, 50) and as many as 30% in the first year following the fracture (50). Mortality risk was also found to significantly increase following vertebral fractures (51). Despite considerable improvement in the healthcare system, mortality risk following fracture remains a concern (52, 53).

Subsequent fractures

After a first fracture, patients are at an increased risk for a subsequent fracture (26, 43, 54). This risk varies according to the location of the previous fracture and the time since the initial fracture, being higher in the first few years (55). It also increases with age and was found to be nearly double in men than women (56). Reasons explaining this increase in risk is not fully understood, but is in part attributable to high risk for falls immediately following a fracture, poorer health status (in men), comorbidities and acute loss of bone mass due to immobility. Despite clinical guidelines recommending treatment to reduce subsequent fracture risk, fewer than 20% of patients who have sustained a fracture receive a diagnosis or anti-osteoporosis therapy which have been shown to be cost-effective in secondary prevention (10). This is a missed opportunity for reducing the burden of the disease.

Pain associated with osteoporosis and fractures

Following a fracture, acute pain is the primary symptom patients experience. Acute pain intensity is generally determined by the site and severity of the injury. Fracture healing usually takes between four to sixteen weeks (54) although pain may persist longer. If not treated early and appropriately, acute pain can progress to chronic pain (defined as pain that is present for more than 12 weeks) (57). Chronic pain can have major individual and social impacts, potentially worsening over time and causing disability, distress and low self-esteem (56). Chronic pain can be associated with sensation of sadness, depression, sleep disturbances, by both the patients and their family members and social circle (58, 59). The transition from acute pain to chronic pain is also associated with enormous burden on the healthcare system (60).

Patients with severe osteoporosis often complain about on-going pain despite the absence of recent fractures. While older adults maintain a stable quantity of neurons and sensory nerve fibers throughout their lifetime, their bone mass undergoes a progressive decrease. The consequential increase in neuronal innervation to bone mass ratio in skeletal structures could be an explanation as to why older adults often feel greater neuropathic pain when there is microarchitectural deterioration of their skeleton compared to younger individuals (61). Therefore, understanding the nature of pain in patients with osteoporosis is essential in the evaluation and management (including self-management) of pain.

1.2 Pain management in older adults

1.2.1 Pain in older adults

In general, pain (of any kind) is the most common reason why individuals visit the emergency department (ED) (62-64). Assessing and treating pain in older adults can be challenging because of age-related physiological changes, comorbidities and polypharmacy (65-67). It is important to properly evaluate and address concerns of older patients with pain. The literature suggests that pain is under-reported, under-documented and under-treated in older adults (68-70). Pain is under-reported as it is often identified by the patient as a symptom associated with underlying illness or disease (known or yet to be diagnosed); this can create fear and anxiety about potential treatments or impending mortality (68, 69). In some patients, under-reporting of pain can be consequential to the incorrect belief associated with the expectation that pain is part of normal ageing (68-70). In addition, older patients are often unknowledgeable about pain assessment systems such as pain scales. Many patients have physical impairments such as hearing or visual loss and cognitive impairments including memory loss, dementia and confusion which can create a communication barrier between patients and healthcare providers and prevent communicating pain experience (71). Poor documentation of pain can be a barrier to pain management (72-74). Since older patients often take multiple medications, there is an increased risk of adverse events with analgesics use and of drug-drug interactions may create concerns among healthcare providers as well as patients' family members (62-64, 75).

Inconsistent approaches to pain assessment, pain documentation and pain management protocols and lack of communication between healthcare professionals can lead to suboptimal pain management in the hospital setting (74).

1.2.2 Acute pain assessment

Effective pain management in older patients requires a multidisciplinary approach based on a comprehensive assessment (68, 76). This enables healthcare providers to deliver quality and individualized care. Due to the lack of a reliable biological marker to measure pain, patient's self-reporting of pain is an essential step to pain assessment (77).

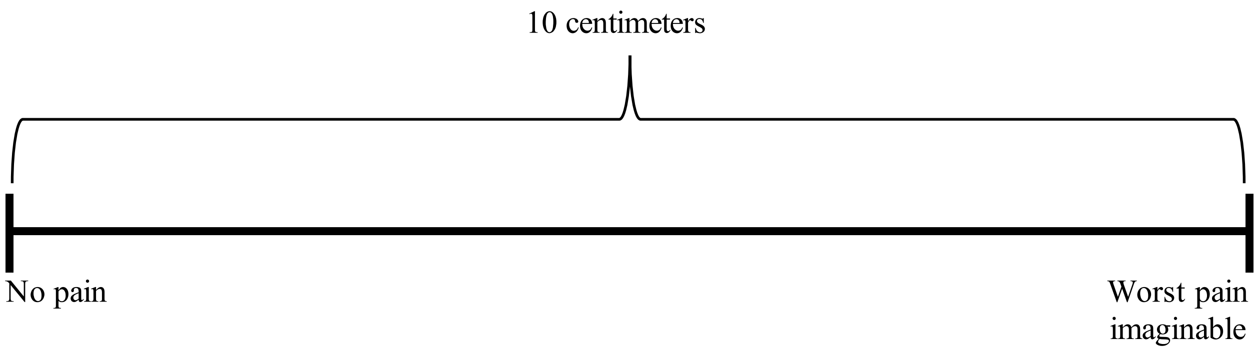
Pain assessment tools

To document acute pain intensity in older adults, there are validated assessment tools commonly used in clinical practice such as: Visual Analogue Scale (VAS), Verbal Descriptor/Rating Scale (VDS or VRS), Numeric Rating Scale (NRS) and the Pain Assessment in Advanced Dementia Scale (PAINAD) (figure 1.1) (65, 77).

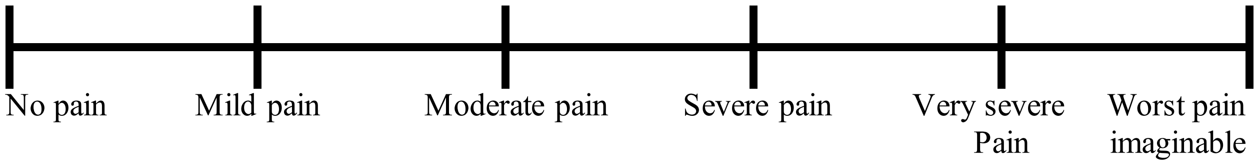
The VAS is often considered as the gold standard for pain assessment (65). It consists of an unmarked 10 centimeters (cm) line where the patient places a mark on the line, best corresponding to their level of pain (the far left corresponds to “no pain” while the far right is marked with the words “worst pain imaginable”). The VAS does not provide an instant score (it must be measured). The clinician measures, using a ruler, the distance in cm between the origin of the scale and the patient’s mark, which will correspond to the pain score. Some patients may require further explanation, particularly when there are issues with understanding how to use the scale (65).

The VDS is a quick and simple tool with standard verbal wording to describe pain intensity (e.g. none, mild, moderate, severe, very severe and horrible). It measures pain level by asking patients to select a word on the scale that best describes their pain. However, language can be a barrier to effective administration (77). The VDS has been validated and is recommended for use in older adults and has been reported to be the easiest to complete and the most preferred by that population (67, 77).

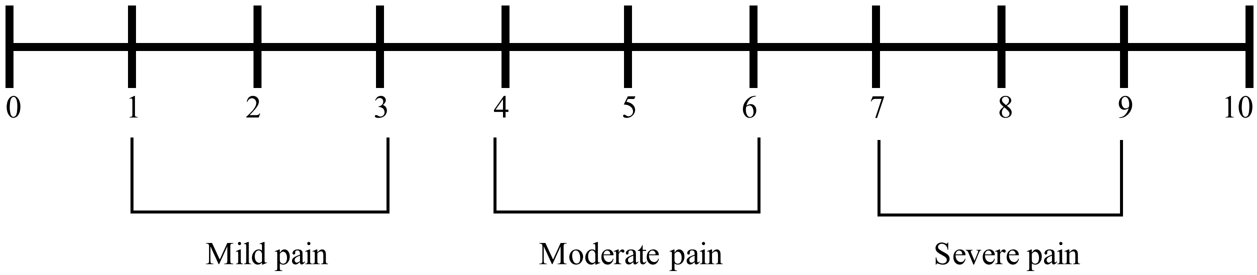
The NRS is a unidimensional 11-item measure of pain intensity widely used in both children and adults in clinical practice (65, 66, 77, 78). It has been validated for use in older adults (79). Respondents select a whole integer (0 to 10) that best reflects their current pain level where 0 represents “no pain”, 1 to 3 “mild pain”, 4 to 6 “moderate pain”, 7 to 9 “severe pain” and 10 “worst pain imaginable”. The NRS does not require any visual cues to be administered and follows a simple scoring system. Nonetheless, patients must be able to discriminate differences in pain intensity which may be difficult for some older adults to complete (77).



Visual analogue scale



Verbal descriptor scale



Numeric rating scale

Figure 1.1 Validated pain assessment scales in older adults

Finally, the PAINAD (table 1.1) is a tool widely used to measure the intensity of pain in older adults with cognitive dysfunction such as dementia (77, 80). The healthcare professional assesses five items while observing the patient’s breathing pattern (labored, noisy, hyperventilation), negative vocalizations (moaning, whining, crying), facial expressions (grimacing, frightened), body language (defensive positions such as guarding or pushing) and consolability. Each item is scored on a 0-2 scale. Although pain assessment tools are useful in measuring pain, they should be used as part of a comprehensive pain assessment to reduce the probability of a patient experiencing unrecognized pain (77, 80). A concise medical history (e.g. chronic conditions, allergies, medications, etc.), drug reactions, physical examination, biopsychosocial assessment, functional impact and social factors should be included in such comprehensive pain assessment as they can influence pain manifestation and treatment (77). These steps are critical in appropriately assessing pain in older adults and will enable healthcare providers to properly document pain assessments in patients' charts.

Table 1.1 Pain Assessment in Advanced Dementia Scale.

Items	0	1	2	Score[1]
Breathing independent of vocalization	Normal	Occasional labored breathing. Short period of hyperventilation.	Noisy labored breathing. Long period of hyperventilation. Cheyne-Stokes respirations.	
Negative vocalization	None	Occasional moan or groan. Low level speech with a negative or disapproving quality.	Repeated troubled calling out. Loud moaning or groaning. Crying.	
Facial expression	Smiling or inexpressive	Sad. Frightened. Frown.	Facial grimacing	
Body language	Relaxed	Tense. Distressed pacing. Fidgeting.	Rigid. Fists clenched. Knees pulled up. Pulling or pushing away. Striking out.	
Consolability	No need to console	Distracted or reassured by voice or touch.	Unable to console, distract or reassure.	

Total:

[1] The total score ranges from 0-10 points. A possible interpretation of the scores is: 1-3=mild pain; 4-6=moderate pain; 7-10=severe pain.

1.2.3 Pain management in the emergency department

The emergency department (ED) is the first hospital contact for assessment and treatment of patients with acute injuries who require evaluation (81). Nevertheless, long waiting times due to overcrowding (82), practitioners' simultaneously caring for many patients, time constraints and the complexity of their structure make EDs difficult and fast-paced environments (83). Pain is the most common reason people seek care in the emergency room setting (84). Healthcare professionals in the ED have a crucial role in assessing and providing treatment for acute pain (70). As mentioned previously, the under-documentation and under-assessment of pain in older adults compared to their younger counterparts is a significant barrier to achieving effective pain management in acute care. Studies have demonstrated disparities such that older adults are less likely to receive medication, therefore, yielding a lower reduction of pain level compared to younger adults (70, 85, 86). A national survey in the United States reported that patients 75 years and older with pain-related ED visits were 19.6% less likely to receive an analgesic and 14.6% less likely to receive an opioid than patients aged 35–54 years with the same intensity of pain (70). An analysis of more than 30 000 patients in Quebec, Montreal with pain who consulted in the ED observed that patients 65 years or older with moderate to severe pain had to wait 1.1 hours longer than younger patients before receiving analgesic medication (87). The analysis used archived data from a real-time computerized medical prescription and nursing records system and identified both physicians and nurses as contributors for the delay in analgesic prescription and administration. This delay was explained in part by older patients having a more complex medical history than their younger counterparts, requiring longer time for physicians' assessment. Patients' families can have an important role to play in managing pain in an informed and productive way (88). They are often involved in the assistance with activities of daily living and provide ongoing support while in hospital and following discharge (89, 90). Overall, communication between family members, patients and healthcare providers is key to the decision-making for an effective treatment (90).

1.2.4 General approach and alternative pain management modalities

Currently, the management of acute pain greatly depends on pharmacological agents because of their ease of use and rapid onset of action (91, 92). Nevertheless, much evidence in the literature suggests that the use of non-pharmacological interventions is also beneficial in reducing pain (92). A systematic review and meta-analysis of 56 studies concluded that non-pharmacological interventions have the potential to improve acute pain management, patient satisfaction, patient outcomes and QofL while reducing overall ED utilization and length of stay when compared to control groups (92). Alternative non-pharmacological modalities for the management of acute pain include heat (hot blanket, heating pad), ice (ice pack, bag of ice), positioning (e.g. using pillows and soft cushions), breathing or relaxation techniques, distractions to alter the perception of pain (e.g. music therapy, aromatherapy, hypnosis, guided imagery) and adequate nutrition (hunger can exacerbate patient's perception of pain).

Ice is routinely used as a treatment immediately following an acute injury to decrease inflammation, swelling and pain (93). Although inflammation is a natural response of the body healing, if left uncontrolled, it may cause a severe sensation of pain. On the other hand, heat treatment is more often used to treat chronic conditions by stimulating blood flow to the affected joint or muscle, allowing the tissues to relax. Orthopedic devices such as casts and splints can be used to support and protect injured bones (94, 95). Using proper positioning and resting the limb on a soft surface can control and decrease the patient's pain, ultimately accelerating the healing process (96). Simple relaxation and breathing techniques can also be used to decrease pain by complementing the effect of prescribed analgesics (97). Relaxation therapy is often used to manage pain especially when integrated in the rehabilitation setting (98). Similarly, distraction techniques can also be used; they revolve on directing the patient’s attention away from pain by focusing their attention on a different stimulus. Such distraction strategies include listening to music, watching a video, praying, singing or talking with others (97). This intervention is preferably used for mild to moderate pain and for brief periods of time. Finally, although a balanced diet won’t necessarily directly decrease pain, it will help in speeding up the healing process leading to lesser intensities of pain (99, 100). A review of the literature on non-pharmacological interventions for pain management in the emergency setting suggested a growing evidence supporting the uptake of these techniques to reduce the reliance on pharmacological interventions as the first-line approach to alleviating pain (101). A systematic review and meta-analysis of 7 randomized trials contrasting multicomponent non-pharmacological interventions to usual care in preventing incident delirium found that alternative modalities (early rehabilitation and mobilisation, nutritional supplementation, cognitive stimulation programs, etc.) were effective in reducing incident delirium and reducing accidental falls in-hospital (102). Moving in this direction may translate into better patient outcomes with less adverse reactions and cost reductions.

1.2.5 Pharmacological pain management modalities

While pain management usually involves both pharmacological and non-pharmacological modalities, pharmacological treatment is often used as the leading option to control acute moderate to severe pain. The WHO three-step analgesic ladder approach to pharmacological management of acute pain (103, 104) comprises of: a) non-opioids (e.g. acetaminophen / acetylsalicylic acid / non-steroidal anti-inflammatory drugs), b) weak opioids (e.g. codeine / tramadol) and c) strong opioids (e.g. hydromorphone / morphine / oxycodone).

1.2.5.1 Analgesics: Non-opioids

Non-opioid analgesics consist of acetaminophen and non-steroidal anti-inflammatory drugs (NSAIDs). Acetaminophen is often used as the initial pharmacotherapy for the treatment of mild-moderate acute pain (76, 105). If pain relief is not achieved with standard dosage, recommendations suggest increasing the dose up to 4 grams per 24 hours before considering using stronger alternative medications (76). NSAIDs are a class of drugs used to effectively manage mild and localized pain (76). Their anti-inflammatory activity is attributed to their selective inhibition of the cyclooxygenase enzyme. Unlike NSAIDs, short-term use of acetaminophen is not commonly associated with significant gastrointestinal bleeding, adverse renal effects or cardiovascular toxicity, making it a safer option for older people (105).

1.2.5.2 Analgesics: Opioids

Oral opioids are rapidly absorbed in the gut and have a high rate of first pass in the liver due to their typical lipophilicity giving them a high bioavailability (106, 107). They are recommended for patients suffering from moderate to severe pain (105, 108). It is now recommended to combine opioids with acetaminophen or NSAIDs as part of the analgesic regimen along with non-pharmacological therapy (68) (figure 1.2). For acute pain relief, short-acting and intermediate-acting opioids (e.g. morphine sulfate, hydromorphone, oxycodone, codeine) are generally the best options (76). According to the American College of Emergency Physicians guidelines, extended release or long-acting opioids should not be used to treat acute pain (109).

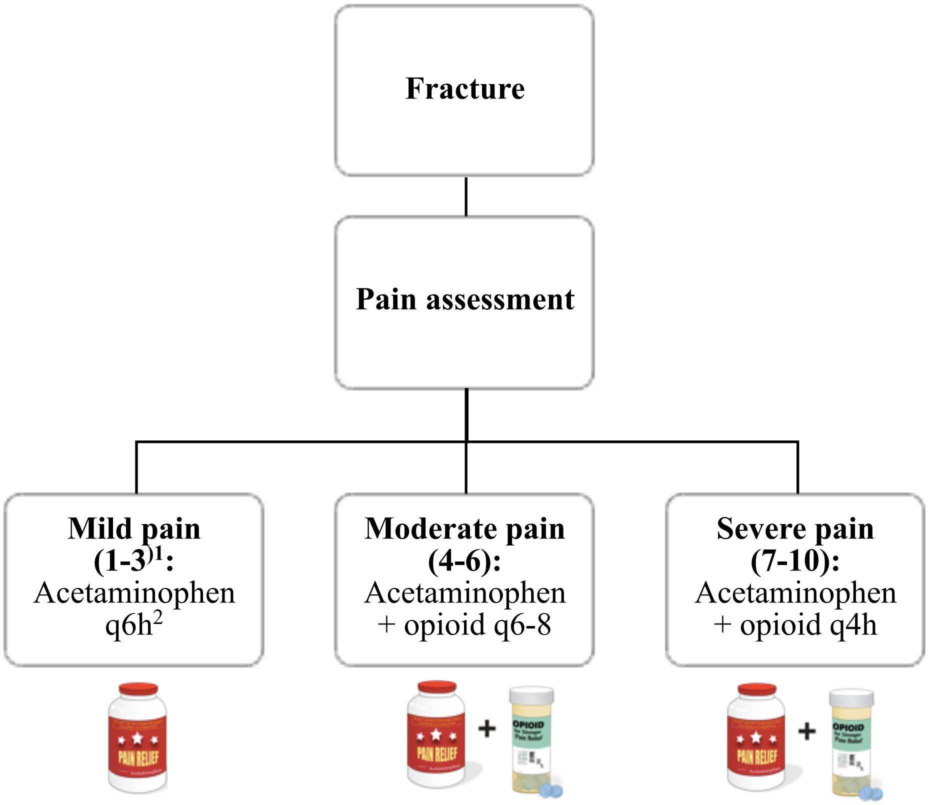


Figure 1.2 Pharmacological choices according to severity of acute pain. Adapted from Gleason et. al.[76]

[1] Pain scores are depicted from the numeric rating scale (0-10)
[2] The letter “q” is used in prescriptions to denote time interval for repetition

When prescribing opioids, the aim is to administer the lowest effective dose (minimum dose to achieve analgesic effect). When managing severe conditions of acute pain in older adults such as fractures, opioid therapy is often favored because of the higher probability of pain-related functional impairment or diminished QofL in that population (68). To assure attainment of therapeutic goals while maintaining safe and responsible medication dosage, patients on opioid analgesics are assessed multiple times during their ongoing treatment. If pain intensity levels remain high, patients should be reassessed appropriately and a higher dose can be administered.

Patients must also be aware and educated to not exceed their maximal safe doses of NSAIDs and acetaminophen when part of a fixed-dose opioid combination regimen.

Opioids affect the central nervous system causing increasing levels of sedation and dizziness. These side effects compromise coordination, increase visual impairment and loss of balance leading to increased risk of falling, particularly in older adults (110-112). Multiple studies report evidence associating opioid use with increased fracture risk (64, 113, 114) secondary to increases in falls. More than 30% of older adults fall each year and in many cases, falls are recurrent (115, 116). Significant associations of fall-related injuries with opioid use, female sex, older age, and use of other mood modifying medications have been demonstrated (112, 117, 118). Considering the comorbidities commonly present in older patients and their use of other medications, selecting an appropriate opioid analgesic for older adults can be a challenge.

An opioid crisis or epidemic has been described in North America. Healthcare professionals, in particular those working in EDs, have expressed serious concerns and consequently have modified their analgesic prescribing behaviors (119, 120). This serious public health crisis is characterized by the misuse and overuse of opioids often resulting in addiction and deaths associated to opioid overdose (121). Prescription opioids by healthcare professionals are, in part, at the root of this current epidemic (122). Recent literature suggests that the quantity of opioid medication prescribed for acute pain management regularly exceeds what is consumed by patients (123, 124). This excess in opioid distribution increases opioids available for misuse or diversion. The Canadian Institute for Health and Information has reported over 9000 opioid-related deaths between January 2016 and June 2018 including 2066 cases during the last six months of that time period (125). Also, approximately 30% of accidental apparent opioid-related deaths in Canada were attributed to adults aged 50 years and over. It is imperative to find an effective multidisciplinary and evidence-based approach to opioid accessibility for medical use and to educate individuals on opioids' benefits, harms and appropriate usage. To date, there has been limited strategies focusing on older adults (126).

1.3 eHealth

Electronic-health (eHealth) is defined as "*an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies. In a broader sense, the term characterizes not only a technical development, but also a state-of-mind, a way of thinking, an attitude, and a commitment for networked, global thinking, to improve health care locally, regionally, and worldwide by using information and communication technology* (127)." Similarly, mobile-health (mHealth) is a rapidly emerging field (128, 129) and holds the potential to offer new opportunities to provide tailored, interactive interventions with real-time monitoring of health status to improve self-management of pain in older adults. Together, eHealth and mHealth include the use of technologies with Internet access such as smartphones and handheld computers (tablets) and focus on connecting patients and their healthcare providers with the goal of enhanced patient-centered care (130). Mobile applications (apps) are innovative and interactive software tools which run on smartphones, tablets and wearable devices (e.g. smartwatches) allowing users to enter data, store it and give access to various functions to meet the needs of those who use them (131).

1.3.1 Uptake of technology in older adults

In recent years, there has been an increased adoption of smartphones and use of health apps by both healthcare professionals and the general public (132). A national survey conducted in 2016 by the Pew Research Center's Internet & American Life Project suggested that older adults have become more connected to the world of digital information than ever before (133). It reported that 67% of adults aged ≥65 years affirmed using Internet compared to 12% in 2000. Also, 42% reported owning a smartphone, equivalent to an increase of 31% since the year 2011. Among people surveyed, 59% of those aged 65-69 years, 49% of adults aged 70-74 years, 31% of adults aged 75-79 years and 17% of adults aged 80 years and older reported owning a smartphone. Although 32% of older adults (≥65 years) reported owning a tablet, the popularity of such devices began in 2010 with the advent of the iPad and is increasing. Internet use among this age group also seems to have increased substantially. Sixty-seven percent reported using Internet while only 12% went online in 2000.

In Canada, the 2016 General Social Survey (Canadians at Work and Home) also reported a rise in Internet use since 2013 from 65% to 81% among adults aged 65 to 74 years and from 35% to 50% among adults aged ≥75 years (134). Altogether, 68% of adults 65 years and older used the Internet at least a few times a month. Smartphone adoption was noted to be at 69% in adults aged 55 to 64 years and 18% among adults 75 years and older. The market for digital mobile devices is growing rapidly and these increasing numbers present new opportunities to leverage technology to facilitate ongoing care, such as pain self-management following a fracture, in the older adult population.

1.3.2 Benefits of eHealth in pain management

Mobile devices and apps are increasingly being used to promote wellness, provide remote care and improve management of symptoms in-hospital and at home (135-137). Some improvement in in-hospital postoperative acute pain management has been demonstrated with the use of app-based interventions (130, 138, 139). However, many of these tools have yet to be tested in the home setting and still lack sophisticated functionalities. A systematic review reported that mobile apps on smartphones or tablets for the management of pain (mostly chronic cancer or non-cancer pain) seemed to be beneficial to patients and were well-liked by patients and healthcare professionals (140). Although patients can benefit from mobile apps for pain management, there is a need for healthcare professional input in the development of such tools and in their content. Knowing which aspects of apps can improve usability and help patients in their pain management also deserves more investigation.

Apps can also be used to engage patients between hospital visits and empower them to take more responsibility in their pain management (141). Content on traditional coping technique strategies, social support and continuous engagement in treatment can be used to promote optimal outcomes. Functionalities such as data input, data storage, interactive educational interventions and step-wise pain management approach can aid in improving QofL and scale down undesirable symptoms. Use of eHealth can also decrease the number of hospital visits (142), costs of treatment (143) and improve the overall patient experience (144). Self-management apps may provide patients with the knowledge and ability to best manage their condition (141).

1.3.3 Barriers to eHealth adoption for acute pain management in older individual

Currently, the app marketplace is not meeting the needs of patients nor of clinicians (145, 146). Reviews published on mobile apps for pain management identified recurring hurdles such as the lack of evidence-based content or involvement of clinicians or patients during the development process (147-149). Many apps were not evaluated in terms of effectiveness on pain-related outcomes nor did they provide evidence-based information for a better pain care self-management for patients. Without the leverage of clinicians in the development of such apps, the content of these mobile apps is unlikely to be useful (141). Another barrier highlighted included the deficiency of functionalities patients find to be important such as social support, participation and goal-setting related to improving pain and functioning. The lack of a standardized protocol for pain assessment and the insufficiency of apps with the functionality to self-monitor pain and functioning were also underlined as barriers (147). A national survey in the United States reported that around half of respondents stopped using health apps due to loss of interest, high data entry burden and hidden costs (150).

Despite a vast literature on eHealth literacy in older adults, there is a knowledge gap in eHealth literacy and technology adoption in non-healthy older adults. Indeed, health literacy must also be considered and evaluated as it is plays a role in the ability to adequately use mHealth technologies such as apps to improve one's health (151, 152). Whether older adults possess the skills to appropriately distinguish trusted sources of health information is uncertain (153, 154). Also, it is unclear if older adults will, and to what extent, adopt mHealth to help improve their care at home (155).

1.3.4 Mobile app development and regulations

There are more than 300 000 mobile apps targeting health and well-being available in app stores (156). These apps are part of a rapidly growing industry with immense potential in delivering accessible, cost-effective healthcare and improve wellness and public health. For successful adoption of a mHealth app, both clinicians and patients must have confidence in its effectiveness and safety measures (156). Health apps have the potential to improve healthcare and reduce costs. Despite this, the development process of mobile apps lacks regulatory guidelines and approach.

Bates et. al identified four important health policy issues that should be considered in a regulatory framework for mobile apps and proposed considerations with regards to each one of them (156). First, establishing the apps' safety is suggested to be of high priority. This includes eliminating false claims, misdiagnoses, providing solutions if dangerous clinical situations arise and protecting private information. App developers could be required to submit their app for verification by a third party or federal health agencies (e.g. Health Canada, FDA, etc.). This would provide a more rigorous and standardized evaluation of apps that are made accessible to patients; ultimately improving apps' health value. Second, the creation of an evidence catalog to allow patients and clinicians to compare and assess which apps are worthy of downloading and support in making a positive difference in their clinical condition. At this moment, app descriptions, reviews and star rating guides are available on app stores; they are often biased and do not usually hold any reputable medical value. Future contributions to monitor apps' strength in terms of content validity would comprise of launching sustainable public open-source directories or sites for app comparisons. App stores could also provide a required display of a label (similar to nutrition facts label) for mHealth apps demonstrating their performance and effectiveness. The third policy issue is interoperability, allowing the app to connect with electronic medical records (EMRs) allowing secure transfer and exchange of data between mHealth apps and EMRs. This would enhance the patient-physician relationship and reduce unnecessary travel, especially for older adults. This requires improving the programming of apps, their interface and interactiveness. Lastly, there is an absence of an incentivizing value to encourage the market to develop mHealth apps to improve care and value for all groups of patients. This includes individuals with low health literacy and high-cost care such as older adults. Substantial gaps exist in terms of what is available in the app stores and what patients and physicians actually need in clinical settings. The above framework would provide a more rigorous development and standardized evaluations of apps, ultimately improving their health value.

1.4 Mobile applications available for acute pain management: An environmental scan

The development and availability of pain self-management apps for users to download and use on their smartphones and tablets is continuing to grow (157). A wide variety of apps are utilized for pain assessment, relief and management. To identify mobile apps available for acute pain management, we conducted an environmental scan between October and December 2018. Our objective was to describe the primary usage of available pain apps (e.g. general musculoskeletal pain, headaches, arthritis, etc.), the type of pain targeted (acute or chronic), mechanisms for protection of privacy and whether the app was interactive or not (diary). The search was conducted on the official app stores of three major smartphone operating systems: iOS (iTunes App Store), Android (Google Play Store), and Windows (Windows Store).

1.4.1 Inclusion and exclusion criteria

Apps which claimed to help users (adults) in pain management and pain tracking were included. We looked to identify apps that were available in English, and where the word "pain" was featured within the keywords, app name or text description. Stores were searched separately using predetermined search terms ("pain", "management", "pain management", "acute pain", "acute pain management"). In addition, the search was expanded using the same search terms in "Pubmed" to identify apps in the literature which may not yet be commercially available. Finally, the app "Read by QxMD" was used to access medical literature and search articles using an additional key word "mobile app" to further expand the search catalog. Apps were included whether they were aimed at patient consumers or at healthcare professionals alone. Apps unrelated to pain or unrelated to pain management/tracking were excluded, as were those which could potentially be applied to pain but were not presented as such. Seventy-nine apps met these criteria.

1.4.2 Data coding and extraction

Information on the identified apps was collected from the store description. Type of pain (acute or chronic), primary use (e.g. pain diary, report for physician), condition-specificity (migraine, cancer), interactiveness and audiovisual components were included in the collection as well as basic commercial information (e.g. cost, privacy). Interactiveness or indicators of engagement included interactions and communication tools capable of empowering users to be active in their health and healthcare (e.g. notifications from app, customization, interacting with healthcare provider, social networking). Privacy comprised of protecting relatively private information with secured app access and secured data sharing. Data were sourced exclusively from the app description. Apps were accessed from the Canadian app stores only. We did not download the apps.

1.4.3 Results

Application purpose and content

Apps available for pain management targeted a range of pain types and pain-associated health conditions. According to app descriptions, 66% (N=52) focused solely on chronic pain while 29% (N=23) addressed both acute and chronic pain (general pain). Four apps (5%) covered general pain-related health conditions and none were advertised for acute pain only (Table 1.2). The majority were available on the iTunes stores (62%) or the Google Play store (61%). The remaining apps (13%) were to be used for research purposes (identified through QxMD) or available through the Windows store (10%). Most apps available for download (44/69; 64%) were free of charge. The most expensive app cost CAN$11.99 and was available on the iTunes store.

Table 1.2 Type of pain targeted by the identified mobile applications for pain management

Type of pain	**Mobile apps** (N=79)
Chronic pain only	52
Acute & chronic pain	23
Other (General health)	4
Acute pain only	0

Some apps required subscriptions (up to USD$300) while others needed the purchase of specific devices (e.g. Quell device, PainKARE device). Such devices were available for up to USD$299.

Forty-two apps were primarily pain management diaries. The majority (N=67; 85%) reported content which included some type of information about pain and its management (condition information, migraines, headaches, cancer, etc.). Twenty four percent (N=19) reported providing information on the disease or condition experienced by users while twenty percent (N=16) provided users with the necessary information to treat their condition. Eighteen percent (N=14) delivered disease specific information on how to manage pain in the instances of, for example, rheumatoid arthritis or sickle cell anemia. Eight apps (10%) were aimed at exclusively managing migraines and headaches while two apps offered information related to pain for each of general health (N=2; 3%), cancer (N=2; 3%) and exercise training (N=2; 3%) (table 1.3).

Most apps (N=61; 77%) allowed recording and storing of information related to pain management as a diary. In addition, 28% (N=22) of apps disclosed that recorded information could be potentially used for research purposes. Six apps (8%) had a peer group or a virtual community reachable to discuss pain management between users. Some apps functioned only as pain scales used to report pain intensities to healthcare providers (N=20; 25%) or as a pain intensity self-assessment (N=2; 3%). Finally, some apps focused on alternative pain management techniques such as meditation (N=5; 6%), hypnosis (N=3; 4%) and music therapy (N=1; 1%). One other app primarily involved light/color therapy (N=1; 1%) to relieve pain (table 1.3). From the app descriptions, only seven apps assured users' protection of information and privacy. Thirty-nine apps were described as interactive.

Table 1.3 Content and primary function of identified mobile applications for pain management

Self-management component	Application content	Application focus	Number of apps (N=79)[1]
Educational skills training	Information provision	Condition/disease information	19
		Treatment information	16
		Disease specific	14
		Migraines/headaches only	8
		General health	2
		Cancer	2
		Exercise training	2
Self-monitoring	Diary tracking	Condition tracking over time	61
		For research purposes	22
		Peer group/community	6
		For HCP use only	4
	Appointment/report	Medication only	1
	Pain scale only	Information sharing with HCP[2]	20
		Pain intensity assessment	2
Relaxation training	Audio relaxation	Meditation	5
		Hypnosis	3
		Music	1
	Light/color therapy	Light/color therapy provision	1

[1] Some apps documented multiple components that could not be reduced to one primary focus
[2] Healthcare provider

1.4.4 Gaps identified

Despite a range of painful conditions (fibromyalgia, headache, migraine, cancer, rheumatoid arthritis, etc.) targeted by the mobile apps, the results of the present environmental scan revealed an absence of high quality interactive apps focused on acute pain self-management. A systematic review conducted by Machado et al. identified smartphone apps for the self-management of low back pain; however, whether the apps targeted acute or chronic low back pain was not specified in their report (158). A review by Rosser et al. identified 111 available smartphone apps marketed for the generic condition of pain. The distinction between apps available for acute pain and those available for chronic pain was also not made in their manuscript. None of the apps identified targeted fracture-related acute pain or acute musculoskeletal injury (159). Lalloo et al. identified 279 patient-targeted apps for pain management and reviewed their content and self-management functionality. They found most apps to be simplistic and not tested for effectiveness on pain-related health outcomes. The type of pain (acute or chronic) targeted by the apps was also not stated in this review, as this was not the primary objective of the study (147). The lack of evidence-based standards acute pain self-management apps on the market is a gap that must be addressed.

Our environmental scan identified that the apps' functionalities were somewhat simplistic and restricted. Most apps were developed to manually enter information relating to pain or a specific pain-related health condition. Some apps illustrated content through the use of smartphone multimedia such as images, audio or video. Apps' content frequently involved providing information on pain, self-reporting pain level intensities and medication use (diary). Although most apps included self-management components such as pain education, self-monitoring and relaxation techniques, these components could not be used in combination approach following user input or data collection. Each element was often isolated and the user's pain management progress was frequently open to the user's interpretation or until a healthcare provider was provided with the entries. None of the apps were comprehensive in terms of pain self-management and lacked in evidence-based content, goal setting, and social support functions (147, 148, 159, 160).

Although we did not collect data on user and healthcare provider input, many studies highlighted the absence of a rigorous assessment on validity and effectiveness on patient-relevant outcomes because of the lack of user and clinician engagement during app development. Reynoldson et al. reported that 86% of pain apps did not involve health care professionals in their design or evaluation of content (160). Lalloo et al. noted that 92% (256/279) of apps included in their review did not describe the engagement of a clinician during the development of content or functionality (147). The paucity of high-quality apps and concerns with regards to trustworthiness and effectiveness of commercially available apps for helping individuals manage their pain carries considerable risk of individuals being misinformed. Devan et al. screened 939 apps to evaluate the contents of smartphone apps which provided information on pain self-management strategies for people with persistent pain. This review focused rather on the in-app communication features identifying only a few apps capable of delivering social support, goal setting, pain education and enabling communication between users and clinicians (161).

To summarize, we have highlighted gaps in the field of mHealth focusing on pain self-management. Namely, none of the apps we have identified in app stores that claimed to provide support for pain management targeted acute pain management in adults. In addition, we documented that most apps served as pain trackers or diaries and did not have a primary function to help or guide users in the self-management (goal setting, behavior change) of their pain. Functionalities incorporated were one-dimensional and lacked intelligent combination. Lastly, there was a lack of involvement of healthcare professionals in the development and evaluation of pain management apps. None of the apps examined were suited to effectively support self-management of acute pain in a population of older adults with a recent musculoskeletal injury such as a fracture.

1.4.5 Conclusion

eHealth interventions have the potential to make health care services more available to patients, allowing patients to access services and help from their own home. Available commercial apps demonstrate a lack in content depth and novel operating functionalities. Although use of mobile devices (smartphones, tablets) create a challenge in terms of guidelines regulations, effectiveness and data safekeeping, a balance between evidence-based clinical content and mHealth adoption must be met. Based on the results of this environmental scan, we feel that research is urgently needed to develop a comprehensive, evidence-based and clinically-informed mobile app to support self-management of pain in older adults.

CHAPTER 2
RATIONALE & OBJECTIVES

Fractures are common in older adults and are an important cause of pain, loss of autonomy and mortality. Older adults who present to the ED with acute pain following a fracture often receive suboptimal pain management (43, 162-166). Opioids, prescribed to patients to treat moderate to severe pain, can result in adverse events such as sedation, dizziness and loss of balance which lead to increased risk of falling and delirium (64, 112). Failure to educate and empower patients with knowledge on pain self-management may result in the inability to use pain medication effectively once at home. Some have developed "opioid fear" following the opioid crisis characterized by multiple reports of overdose deaths (167, 168). eHealth resources have the potential to be effective in the management of medical conditions (140). Use of mHealth technologies is rising rapidly among older adults and offers new opportunities to provide tailored, interactive interventions with real-time monitoring of health status. Smartphone and tablet adoption in Canada is projected to continue to increase (134) and this represents new opportunities to leverage technology to support self-management of selected health conditions, such as acute pain. Nevertheless, the profile of individuals most likely to benefit from such interventions remains unclear and the optimal content and functionalities of mobile apps specifically aimed to the self-management of acute pain needs to be better understood.

Specifically, our objectives are to: 1) describe the level of uptake of technology, of interest in technology to improve health and of eHealth literacy level in older adults who have sustained a recent fracture and 2) identify what healthcare professionals believe to be the most important content and functionalities to be included in a mHealth app for the self-management of acute pain in older adults following a recent fracture.

Our hypotheses were that 1) a majority of older adults with recent fractures own mobile devices and have the eHealth literacy level required to efficiently use mobile apps and that 2) clinicians will recommend including practical content on medication use, pain self-assessment tools and functionalities involving pain tracking and ease of use.

Results obtained from these projects will inform the future development of a mobile app for acute pain self-management following a skeletal fracture.

(To ensure that end-users also provide guidance in the development of a mobile app, a patient survey is currently being developed in partnership with a patient organization, but this work is not part of this thesis.)

CHAPTER 3

Manuscript I

Technology adoption and eHealth literacy in older adults who have recently suffered a fracture: A cross-sectional survey

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3.1 ABSTRACT

Background: The field of mHealth is rapidly emerging and could be harnessed to improve self-management of acute pain in patients with fractures. **Objective:** The study's aim is to identify the current level of technology adoption and eHealth literacy among older adults who recently suffered a skeletal fracture, to determine if the use of a mobile app to optimize acute pain management would be feasible and acceptable. **Methods:** Adults ≥50 years with recent fractures were invited to complete a self-administered survey composed of 21 closed-ended questions, including an 8-item perceived eHealth literacy scale (eHEALS) scored on a 5-point Likert scale, with scores ≥26 indicating higher literacy. **Results:** A total of 401 participants completed the survey (women: 64%; ≥65 years: 59%; university education: 32%). Most participants (67% & 65%, respectively) reported no difficulty in reading printed health material and felt confident in filling out medical forms by themselves. Younger age and higher level of education were contributing factors ($p< 0.05$). The majority (81%) owned at least one mobile device: smartphone 49%, tablet 45%. Median eHEALS scores were similar among men (29, IQR 24-32) and women (29, IQR 25-33), and between younger age group categories (50-64 years: 30, IQR 26-33, and 65-74 years: 29, IQR 25-32), but lower in the oldest age group (≥75 years: 24, IQR 21-29, $p<0.05$). Compared to the youngest age group (referent), the ≥75 years age group had higher adjusted odds of a low eHEALS: <26 (Odds ratio 4.2; 95% confidence interval 2.0-8.9) while adjusting for sex and education level. **Conclusion:** Results demonstrate that there is a significant adoption of mobile technology among older adults and support the creation of an interactive mobile application for the management of acute pain in this population.

3.2 INTRODUCTION

Although growing evidence suggests that the continuum of care can be optimized using mobile and monitoring technologies in older adults (133, 169), the profile of individuals most likely to benefit from such interventions remains unknown. Despite a vast literature about eHealth literacy in older adults, there is a gap in knowledge in eHealth literacy and technology adoption in older adults with health conditions. Studies indicate that health literacy must also be considered and evaluated as it plays an important role in the user's ability to adequately use eHealth to improve their health (152, 170). Whether older adults possess the adequate eHealth literacy to appropriately distinguish trusted sources of health information is uncertain (153, 154).

To this end, we conducted a survey with the objectives of identifying the current level of technology adoption among adults 50 years and older who recently suffered a fracture and to identify the current levels of health and eHealth literacy in this population. This information is crucial to determine if the use of eHealth interventions to optimize acute pain self-management would be feasible, acceptable and effective in daily practice.

3.3 METHODS

3.3.1 Study Population & Survey Sample

Participants were selected from a convenience sample of patients with recent fractures in the orthopedic clinics of three tertiary care academic institutions from the 15th of September 2017 to the 2nd of March 2018. Men and women 50 years and older with a recent fracture were identified by the clinic clerk and invited by research personnel to complete a paper-based survey. Those with visual impairment, cognitive impairment or inability to answer to the questionnaire in English or French were excluded. To reduce selection bias, we selected 3 busy orthopedic clinics (one trauma center, one academic community hospital and one large university-affiliated center) and ensured we had few exclusion criteria. Administrative clinic personnel were instructed to flag every potential participant to the research team. The survey was developed to be self-administered, however, research personnel was available to assist participants if required. Research personnel reviewed the survey responses for completeness prior to participants leaving the clinic area. Surveys were filled anonymously. Research ethics board approval was obtained at all three sites and participation in the survey was considered as providing informed consent.

3.3.2 Survey design

The self-administered questionnaire, comprised of 21 close-ended questions, was developed using a combination of pre-existing published questionnaires and questions created by the research team (Appendix). Face validity was reviewed by the research team which included clinicians and researchers with expertise in orthopedics, geriatrics, eHealth literacy and survey methodology. The questionnaire was pilot-tested for clarity and took approximately 7 minutes to complete (as tested by 10 volunteers of similar demographics as the target population). The survey questions were designed to address three major themes: 1- health literacy, 2-technology adoption and interest in use of Internet to search, evaluate and use health information and 3- eHealth literacy. Questions pertaining to age group category (50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80-84 and 85 years or older), sex, level of education (High school, college, bachelor’s degree, graduate degree, etc.) and mother tongue (French, English or other) were included.

3.3.2.1 Health literacy

The Single Item Literacy Screener (SILS) was used to assess literacy in reading health materials. The SILS is one question that was developed to identify patients with limited reading ability who require help reading health-related materials (Question 1: How often do you need to have someone help you when you read instructions, pamphlets, or other written material from your doctor or pharmacy?, Appendix) (171, 172). Possible answers are 1-always, 2-often, 3-sometimes, 4-occasionally and 5-never. Scores ≤ 3 indicate some difficulty with reading printed health related material (173). The second screening question prompted participants to grade their confidence levels in filling out medical forms (Question 2: How confident are you filling out medical forms by yourself?, Appendix) (172). A score of ≤ 3 (3-somewhat, 2-a little bit and 1-or not at all) is recommended as the cut point to identify patients with limited or marginal health literacy skills (174). Both items have been validated in different populations (173, 174), including older adults (175). Additionally, questions from the Health Information National Trends Survey (HINTS) were used to assess the ability to perform health information searches (Questions 3 and 4, Appendix) (176). The HINTS data collection program was developed to monitor and understand how adults interact with each other by using different communication trends and channels to obtain health information for themselves and/or others despite a rapidly changing health information environment (177). Health information search ability was assessed with the screening question: "Have you ever looked for information about health or medical topics from any source?" with binary outcomes "yes" or "no". Participants who indicated looking for health or medical information were asked to identify the source they typically use. Possible answers to the item assessing the source of information were grouped as follows: 1-Internet, 2-written materials (books, brochures, etc.), 3-health care providers, 4-interpersonal sources (family, friend, etc.), 5-telephone information number and 6-I have never looked for information.

3.3.2.2 Technology adoption

Questions were created to assess which type of electronic devices participants owned, how frequently they used the Internet (if at all), and their willingness to use technology to inform health decisions (Questions 5-9). Questions were set so not to combine both mobile device ownership and use of Internet since some participants may not have access to Internet at home or at all. Participants were asked whether they owned a 1-basic cell phone, 2-smartphone, 3-handheld device for reading, 4-tablet, 5-desktop/laptop or 6-none of the devices mentioned. To assess participants' interest in using technology to help improve their health, 5 possible responses were available: 1-not at all interested, 2-not very interested, 3-neutral, 4-somewhat interested and 5-very interested. Participants were also asked if they had gone online or accessed the Internet or their email during the past 6 months. Participants who answered "no" were asked to not complete the section on eHealth literacy.

3.3.2.3 eHealth literacy

We used the eHealth literacy scale (eHEALS) to assess eHealth literacy. The eHEALS was developed based on the Lily model where researchers identified six core skills or literacies: 1-traditional literacy, 2-health literacy, 3-information literacy, 4-scientific literacy, 5-media literacy, and 6-computer literacy (178). It is an 8-item measure of eHealth literacy that evaluates individuals' combined knowledge, comfort, and perceived skills at finding, evaluating, and applying electronic health information to health problems (179). It has been tested and validated in older adults (180). Each item of the eHEALS is scored on a 5-point Likert scale, and the score ranges from 8 to 40, with a score ≥ 26 indicating high eHealth literacy relating to navigational knowledge and skills in using Internet specifically for the use of eHealth interventions (181).

eHEALS was measured only in those who reported accessing the Internet during the 6 months prior to completing the survey.

3.3.3 Statistical analyses

Each year, 30,000 adults over the age of 50 years sustain a fracture in Quebec, as reported by the Institut national de santé publique du Quebec (182). Based on this population, we estimated our sample size to N=380 participants to ensure a margin of error of ± 5% at a 95% confidence interval for the descriptive statistics (using the following formulas: 1. Sample Size Calculation: Sample Size = (Distribution of 50%) / ((Margin of Error% / Confidence Level Score) Squared) and 2. Finite Population Correction: True Sample = (Sample Size X Population) / (Sample Size + Population – 1) (183, 184).

Data were analyzed for the entire study population using descriptive statistics; continuous variables were expressed as means with standard deviations (SD), or medians with interquartile range (IQR) and categorical variables as frequencies and percentages. Spearman's correlation coefficients were calculated to measure the strength of the relationship between measured literacy levels from Questions 1 and 2 (Low versus High SILS; Limited versus Not Limited Health Literacy). Differences between sub-groups (sex [women vs men], age-groups [50-64 years, 65-74 years and 75 years or older], level of education [University level or lower] and mother tongue [English, French or Other]) were examined for health literacy, mobile device ownership and eHealth literacy using parametric or non-parametric tests, as appropriate. Post-hoc tests were conducted to evaluate pairwise differences in eHealth literacy between the three age-group categories. Logistic regression models were created to examine the association between age-group categories and low eHEALS score (<26). Covariates included sex and education level (as described above). A p value of <0.05 was considered significant. Statistical analysis was conducted using the statistical software package IBM (Armonk, NY, USA) SPSS Statistics 22.0.

3.4 RESULTS

3.4.1 Participants' characteristics

Six hundred and twenty participants were eligible to complete the survey. Because of clinic-associated patient flow issues (i.e. patients dismissed by the surgeons prior to being approached, patients sent to the radiography department and failing to return to clinic, patients' appointment moved to a different time without the research team being made aware, etc.), 210 potential eligible participants were not approach to complete the survey. After initial contact, only nine declined to participate (figure 3.1). A total of 401 men and women agreed to participate in the study and completed the survey (98% response rate). Over half of respondents were ≥65 years (50-64 years: n=164, 65-74 years: n=117 and ≥75 years: n=120), the majority were women (n=258, 64%) and a third reported University-level education (n=130, 32%) while 37% (n=147) completed only high school level education. When queried about their mother tongue, 36% (n=143) reported their mother tongue to be English, 30% (n=122) French and 34% (n=136) "other" (table 3.1).

3.4.2 Participants' health literacy

Two thirds of participants (n=267, 67%) reported having no difficulty with reading printed health material such as prescriptions and pamphlets (Question 1). Participants' overall median score for question 1 was 4 (IQR 3-5) (50-64 years: [median 4, IQR 3-5]; 65-74 years: [median 4, IQR 4-5]; ≥75 years: [median 3, IQR 3-5]). The median score of respondents who attended University was 5 (IQR 4-5) while respondents who did not attend University's median score was of 4 (IQR 3-5) ($p< 0.05$). Respondents whose mother tongue was French or English had a median score of 5 (IQR 3-5); this was higher than those whose mother tongue was neither French nor English (median 4 [IQR 2.3-5]) ($p <0.05$). Most participants (n=262, 65%) felt confident in filling out medical forms by themselves (Question 2). Overall, participants median scores were 4 (IQR 3-5) (50-64 years: [median 5, IQR 4-5]; 65-74 years: [median 4, IQR 3.5-5]; ≥75 years: [mean 3, IQR 1-4]). Forty-four percent of participants with a low level of education had a score ≤ 3 compared to those with higher level of education (16%) (p<05). We demonstrated a moderate, positive correlation between the answers to Questions 1 and 2 ($r_s = .550$, $p < .05$) and 80% of responses were concordant in either high or low literacy categories. The most recent resource used to look for information on health or medical topics was the Internet in 43% (n=172), while 28% (n=111) reached a doctor or their health care provider first and 10% (n=39) discussed their health issues first with a family member.

3.4.3 Mobile device adoption and Internet use

Most respondents (81%) owned at least one mobile device: a basic cellphone (30%); a smartphone (49%) or a tablet (45%). Of those who owned a laptop/desktop, smartphone and/or tablet (n=300), 66% (n=197) owned at least two devices. Smartphone and/or tablet ownership by age group categories was similar between the 50-64 years (n=118, 72%) and 65-74 years groups (n=92, 79%) while 37% (n=45) of adults 75 years and older reported owning a smartphone and/or tablet (figure 3.2). Two hundred and fifty-five (64%) participants claimed to be somewhat or very interested in using technology to help improve their health (76%, 50-64 years; 65%, 65-74 years and 45%, ≥ 75 years and older; 62% in men and 64% in women). This percentage was higher in those who attended university compared to those who did not (80% versus 56%; $p < 0.05$). The majority of those who were somewhat or very interested in using the Internet also scored highly on Questions 1 (72%; median score 5 IQR 4-5) and 2 (76%; median score 5 IQR 4-5).

Of the participants aged 75 years and older who owned a smartphones/tablet (n=45, women 69%, university degree 29%), 60% reported accessing the Internet during the past six months. Sixty four percent expressed interest in using technology to improve their health (51%, 75-79 years; 29%, 80-84 years and 20%, ≥85 years).

Over all, 65% (n=261) of participants reported going online in the previous 6 months, of which 78% (n=203) used the Internet to look for health or medical information for themselves or others (figure 3.3). Twenty-two percent used social media such as Facebook, Twitter and LinkedIn (53%, 50- 64 years; 33%, 65-74 years and 14%, ≥75 years).

3.4.4 eHEALS results

In the 261 participants who reported accessing the Internet during the past 6 months, we documented median eHEALS to be 29 (IQR 24-32) and similar between men (29, IQR 24-32) and women (29, IQR 25-33). Respondents in the younger age group categories of 50-64 years and 65-74 years had similar eHEALS (30, IQR 26-33 and 29, IQR 25-32, respectively); the eHEALS was lower in the oldest (≥75 years) age group (24, IQR 21-29, $p<0.05$) (figure 3.4). Younger age group categories had higher percentages of respondents with eHEALS ≥ 26 (50-64 years, 76%; 65-74 years, 71%) than the older age group (≥75 years, 44%) (figure 3.5). There were no significant differences in the eHEALS by mother tongue, though the percentage of those whose mother tongue was not English or French who had consulted in the internet in the last 6 months was low. There was a statistically significant difference in median eHEALS between participants who did not attend University (median 28, IQR 24-32) and those who did (median 30, IQR 26-33)); $p<0.05$. Compared with respondents in the youngest age category, those who were 75 years and older had higher adjusted odds of low eHEALS < 26 (Odds ratio 4.2; 95% confidence interval 2.0-8.9) while adjusting for sex and education level (table 3.2).

3.5 DISCUSSION

Our results support that there is a substantial adoption of mobile technology among the population of adults 50 years and older. The majority (65%) of older adults participating in this survey used the Internet in the 6 months prior to the survey, and approximately 69% of those who used the Internet had an eHEALS of ≥26, indicating high eHealth literacy. In addition, 64% of participants claimed to own a mobile device (smartphone and/or tablet). Level of education, age and ownership of mobile devices were significant factors which influenced health and eHealth literacy in this population.

A similar study, published in 2018, including 200 community-dwelling adults aged 55 years and older, who were being treated for a chronic disease (diabetes, hypertension, dyslipidemia, or cardiovascular disease) found that 53% of its participants used the Internet and 49% had high eHealth literacy (high eHealth literacy at ≥29) (185). The study reported that 72% of participants owned at least one e-device (e.g. laptop computers, smartphones, tablets) while 47.5% owned two or more. Participants who owned multiple e-devices were more likely to use the Internet (82.1%) than those with one (25.5%) or no e-devices (1.8%). In terms of e-device ownership, our study noted similar findings with 81% of respondent owning at least one mobile device and 49% with two or more devices.

Across all age group categories in our population, Internet was the tool most participants used to search for health or medical information. About two thirds of participants went online suggesting that the majority of older adults integrated Internet technology in their day-to-day lives. These results are comparable to national surveys conducted in 2016 which respectively reported that 68% of Canadian adults and 67% of American adults aged 65 years and older were Internet users (133, 134). Participants also expressed an interest in using technology to improve their health which emphasizes their willingness to use technology to seek out medical or health-related information.

Contrary to popular perception and perpetuated stereotypes that older adults are less likely to use mHealth or eHealth for health information compared to younger adults (186), the majority of our survey participants who identified as Internet users reported going online to obtain medical information and this included participants older than 75 years. Older adults are the fastest growing group in terms of technology adoption and Internet users (133, 134). Indeed, we documented that one in four elderly (≥75 years) respondents who expressed an interest in using technology to improve their health also owned a mobile device.

Most respondents reported not having difficulty reading health-related material filling out medical forms by themselves though younger participants had higher median scores than older ones. In addition to age, low health literacy has been associated with chronic conditions, ethnicity or lower levels of education (187). In our study, respondents with the highest health literacy for both questions had a university level of education. This highlights the importance of education in shaping the health literacy of older adults and has been reported previously systematic reviews (188, 189). In our study, individuals' health literacy could have influenced, to some extent, their eHEALS and their competencies in using web-based resources (Internet). A recent systematic review has determined that health literacy is a key factor which could influence online health information search (190). The authors concluded that future eHealth services or interventions would be more accessible if better adapted to adults with low-literacy. This would include providing comprehensive visual information, animations and a simple interface design.

Many respondents reported owning mobile devices such as smartphones (49%) and tablets (45%). Participants between 50-74 years had a relatively high mobile device adoption. Although ownership was lower in the older age group (37% in respondents ≥75 years), mobile technology ownership was nearly double that reported in previous national surveys (Canadians ≥75 years 18%; Americans 75-79 years 31%; Americans ≥80 years 17%) (figure 3.2) (133, 134). As this segment of population continues to increase its technology adoption, these proportions will most likely increase in all age groups categories of older adults in the future. The next generations of older adults will have already been exposed to this new technology and will certainly be more comfortable using smartphones and tablets. In this study, nearly half (49%) of participants owned at least two devices. This indicates that older adults are gradually embracing technology throughout the last couple of decades. This could also have a positive effect in their health and eHealth literacy through using multiple but different means of communication and search tools.

Respondents in the younger age groups (50-64 and 65-74 years) had high median eHEALS while the older age group (≥75 years) had a slightly lower median eHEALS, but much higher than what one might expect. A recent study which explored the extent to which age, sociodemographic, social determinants, and e-device use influence eHealth literacy among baby boomers and older adults supports these findings (191). The study reports a statistically significant difference in eHEALS according to social media use (Web 2.0), with respondents who claim using Web 2.0 having greater eHealth literacy than those who did not. Interestingly, only 22% of our participants reported using social media such as Facebook, Twitter and LinkedIn. Age and education level were found as good predictors for high eHealth literacy which supports our findings. The use of more e-devices was also found to be a statistically significant predictor for high eHealth literacy. Finally, sex, marital status, race, ethnicity, income, and health status were not significantly associated with eHealth literacy. Although we did not document an association between mother tongue (proxy for ethnic background) and eHealth literacy, the result of this analysis was not robust since we had few who did not claim French or English as their mother tongue in that subgroup. A cross-sectional survey which included 5420 adults aged 65–79 years of the Kaiser Permanente Medical Care Program in Northern California found that black, Latino, Filipino, and older seniors (75–79 years old) were less likely than white and Chinese and younger seniors (65–69 year old) to own mobile devices and also less likely to have the skills and experience to take advantage of mobile-based tools (192). Although concepts associated with ethnicity such as culture and tradition can have an impact on eHealth literacy, there is no clear consensus in the literature regarding ethnicity and eHealth literacy in older adults. Overall, we have demonstrated in this study with a large sample size that in general older adults have high levels of eHealth literacy, even in the older age groups and they are interested in harnessing technology to improve their health.

Limitations

This study has some limitations. The study population was recruited in 3 busy orthopedic clinics of a large urban center which limits generalizability to smaller centers and rural populations. Furthermore, despite our best efforts, we were not able to approach all eligible participants allowing for possible selection bias. Indeed, those who left the clinic very rapidly or did not return to the clinic following radiography may have responded differently. However, since our results are supported by those of similar surveys it is unlikely that these limitations would have altered the results significantly.

To maximize the chances that participants would accept to participate and complete the survey, we restricted the number of questions on the survey and offered assistance to those who required it. This led to a very high response rate (98%). Nevertheless, data on sociodemographic characteristics such as ethnicity, socioeconomic status and marital status were not collected. Immigrant status, particularly being a more recent immigrant may also influence health literacy and acceptability and uptake of a mobile health app. Ethnicity has been shown to be a significant predictor of Internet use and access, as mentioned previously. For example, non-Hispanic white participants were more likely to use the Internet as their first source for health information compared to non-Hispanic black participants and of other ethnic backgrounds in a study evaluating internet use, conducted between 2008 and 2012 in the U.S (193). Also, the price point of the most popular digital devices has increased which may prevent individuals from owning such devices depending on their socioeconomic status, which in turn would influence health and eHealth literacy. Moreover, we did not ask participants whether they searched specific information regarding their fracture or pain management, nor whether they would appreciate finding e-support on how to manage their pain, as the main goal of the survey was to determine technology ownership and eHealth literacy. Finally, the eHEALS tool exclusively measures an individual's self-perception, personal knowledge and competencies related to eHealth literacy but does not allow for a demonstration of the individuals' eHealth literacy skills. This instrument was also developed when most social media platforms were in their early stages of development or had not launched at all. However, this is the only instrument which has been used and validated to this day, including in older adults (180, 181, 191). To compensate this, we used other items (for example Question 9) which assessed the use of social media for health information. It should also be noted that the concept of eHealth literacy is still a new emerging field and will require a constant review.

Conclusion

The results from this study demonstrate significant ownership of mobile devices by older adults and eHealth literacy that would support the use of mobile applications for the self-management of medical condition such acute pain following a fracture. In addition to owning mobile devices, a large proportion of adults in all age-group categories expressed an interest in using technology to improve their health. Adults with higher level of education and aged between 50 and 74 years were more likely to respond positively to questions in regard to technology use and proficiency. However, 40% of adults 75 years and over owned a mobile device, 61% claimed to have used the Internet in the previous 6 months and, of those, 44% had a high eHealth literacy. Although the adoption of mobile-health applications (apps) is rising rapidly among older adults, poor design and usability and inaccurate medical information limit their use. Interactive interventions through mobile technologies, such as smartphones and tablets, could improve clinical outcomes in this population.

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3.7 TABLES & FIGURES

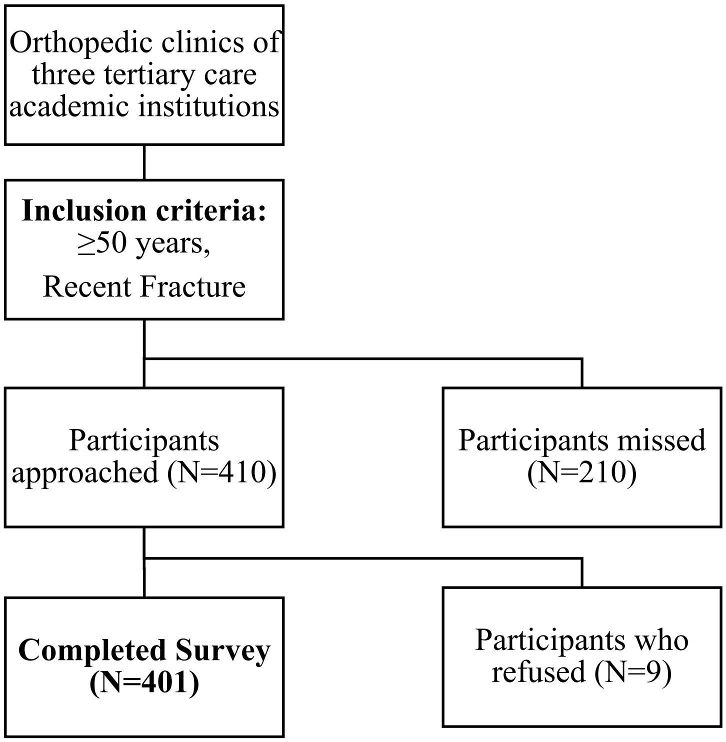


Figure 3.1 Recruitment flow chart of surveyed participants aged 50 years or over on technology adoption and eHealth literacy

Table 3.1 Participants' characteristics

	N=401	N*=261
Age, n (%)		
50-64 years	164 (41)	131 (50)
65-74 years	117 (29)	89 (34)
75+ years	120 (30)	41 (16)
Sex, n (%)		
Women	258 (64)	169 (65)
Level of Education, n (%)		
No high school (HS) diploma	76 (19)	21 (8)
HS diploma/CEGEP/Professional degree	195 (49)	127 (49)
University degree	130 (32)	113 (43)
Mobile device owners, n (%)		
Smartphone and/or tablet	255 (64)	219 (84)
Expressed interest in using technology to improve health, n (%)	255 (64)	209 (80)
Accessed Internet during past 6 months, n (%)	261 (65)	261 (100)
eHEALS score, Median (IQR)**	-	29 (24-32)

*Only participants who accessed Internet during the past 6 months completed the eHEALS
**IQR: Interquartile range

Table 3.2. Odds ratios (OR) with 95% Confidence Intervals (95% CI) for low eHEALS (<26) by age groups

	Unadjusted OR (95% CI)	Adjusted OR (95% CI)
Age Group		
50-64 years	Referent	Referent
65-74 years	1.3 (0.7-2.3)	1.3 (0.7-2.5)
≥75 years	4.0 (1.9-8.2)	4.2 (2.0-8.9)
Sex		
Female		Referent
Male		1.4 (0.8-2.5)
University education		
Yes		Referent
No		1.9 (1.1-3.4)

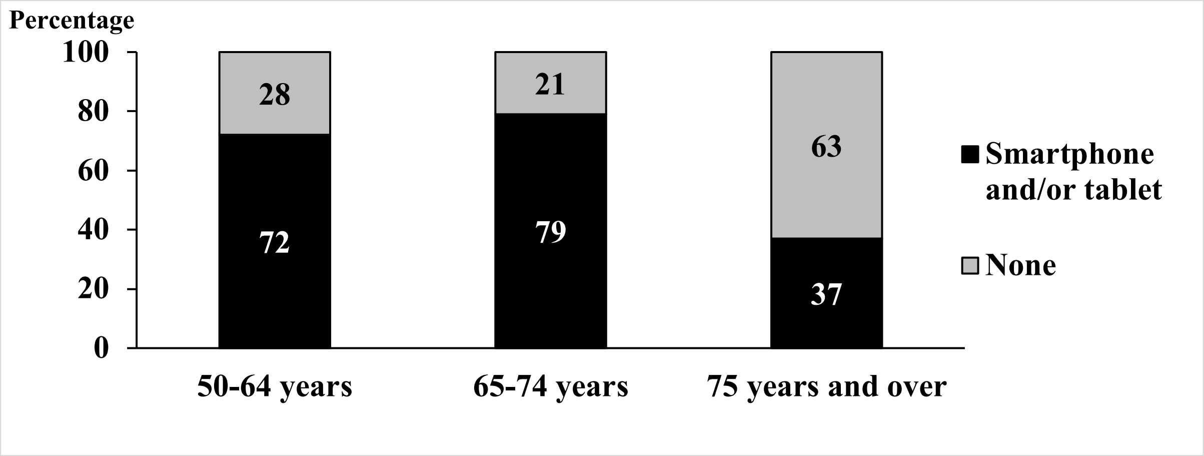


Figure 3.2 Smartphone and tablet ownership by age group categories (N=401).

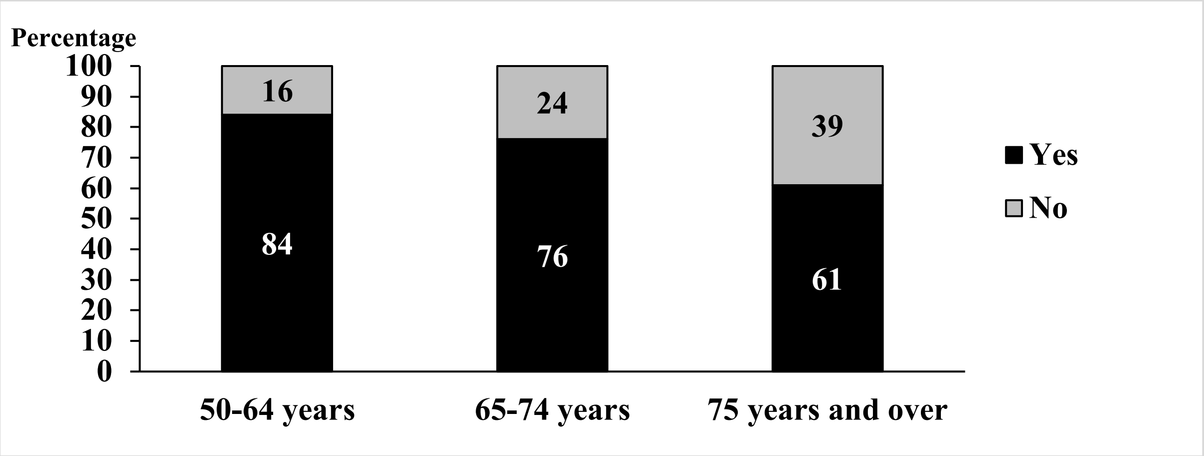


Figure 3.3 Use of Internet to look for health or medical information for oneself or others by age group categories for participants who accessed Internet during the past 6 months (N=261).

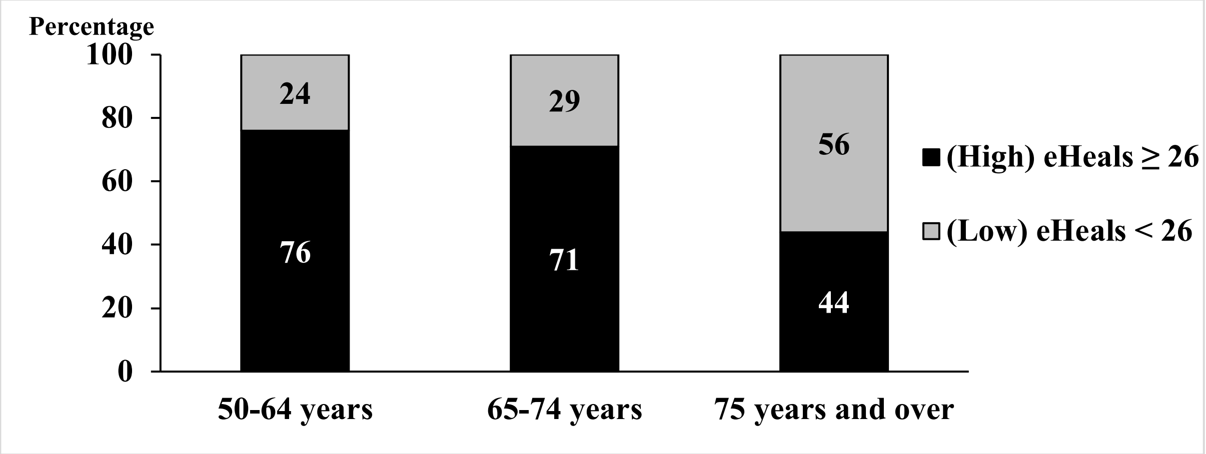
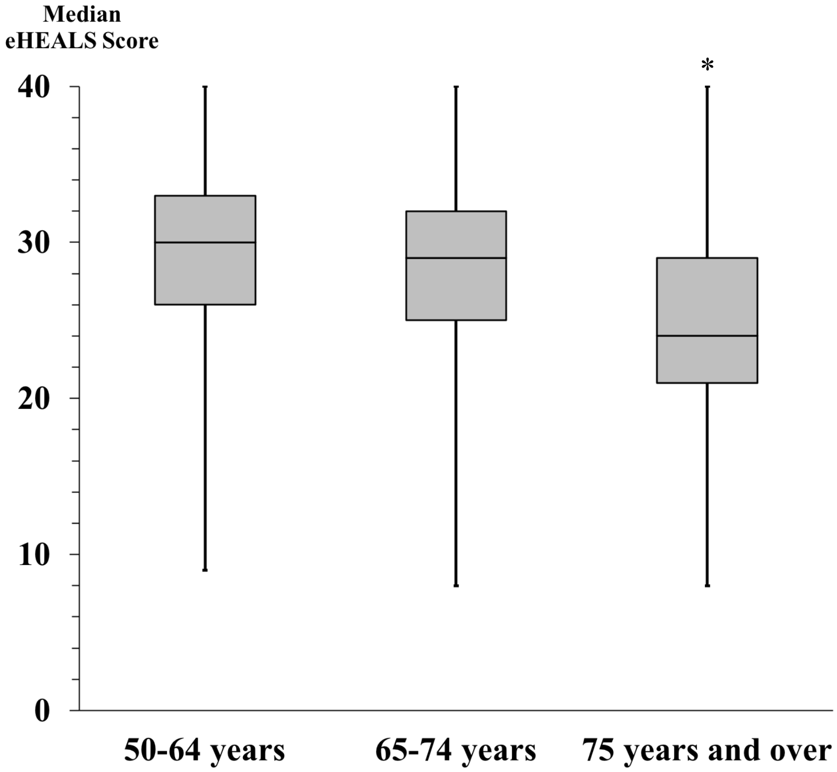


Figure 3.4 Participants' eHEALS by age group categories for participants who accessed Internet during the past 6 months (N=261).



*P<0.05 for 75 years and over vs. other age group categories.

Figure 3.5 Median eHEALS score (Interquartile range; minimum, maximum) by age group categories for participants who accessed Internet during the past 6 months (N=261).

3.8 APPENDIX : Survey questionnaire

Centre universitaire de santé McGill
McGill University Health Centre

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FMU-9997

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Research Survey Title:	Health Information Survey: Where do you look up information about your health?
Protocol number:	MP-37-2018-3763
Researcher responsible for the research survey:	Dr. Suzanne Morin
Co-Investigator(s)/sites:	Dr. Anthony Albers/St-Mary's Hospital Dr. Stephane Bergeron/Jewish General Hospital

Dear Sir/Madam,

You are invited to take part in a research survey about how older adults get information about their health, how often they use technology, such as the Internet, and whether they use technology to find answers to their health-related questions. Your answers will help us find out how to best use technology to help older adults get information about their health.

This survey should take you no longer than 7 minutes to complete. There are no known risks associated with completing this survey. By agreeing to participate in this research survey, you are not waiving any of your legal rights.

This survey is completely anonymous. We do not ask your name. There are no questions that would allow you to be identified by your answers. Your answers will be kept strictly confidential. The results of the survey may be published or shared during scientific meetings; however it will not be possible to identify you.

Your participation in this survey is voluntary. You can refuse to participate or stop completing the survey, at any time, without explanation. However, because the survey is anonymous, it will not be possible for you to ask that your answers be withdrawn once the survey is handed in. Your medical care will not be affected if you decide not to complete the survey.

We truly appreciate your time and participation in this survey. Completing this survey indicates that you are 60 years of age or older, you are being followed in orthopaedics, and declares your consent to participate in this project.

The McGill University Health Centre Research Ethics Board reviewed this survey and is responsible for monitoring it at all participating institutions in the health and social services network in Quebec.

Contact Information:

If you have questions, you may communicate with the researcher responsible for the survey or with someone on the research team at the following number: 514-934-1934 ext. 45742.

For any question concerning your rights as a research participant taking part in this survey or if you have comments, or wish to file a complaint, you may communicate with:

> The Patient Ombudsman of the McGill University Health Centre at the following phone number: 514 934-1934, ext. 44285.

Health Information Survey: Where do you look up information about your health?

Please answer all the questions to the best of your ability. Please mark the appropriate box next to your answer choice with an "x" (X).

1. How often do you need to have someone help you when you read instructions, pamphlets, or other written material from your doctor or pharmacy?
    - ☐ Always
    - ☐ Often
    - ☐ Sometimes
    - ☐ Occasionally
    - ☐ Never

2. How confident are you filling out medical forms by yourself?
    - ☐ Not at all
    - ☐ A little bit
    - ☐ Somewhat
    - ☐ Quite a bit
    - ☐ Extremely

3. Have you ever looked for information about health or medical topics from any source?
    - ☐ Yes
    - ☐ No

4. The most recent time you looked for information about health or medical topics, where did you go first? <u>Please check only one response</u>.
    - ☐ Books
    - ☐ Brochures, pamphlets
    - ☐ Public Health Organization
    - ☐ Family
    - ☐ Friend/Co-worker
    - ☐ Doctor or healthcare provider
    - ☐ Internet
    - ☐ Library
    - ☐ Magazines
    - ☐ Newspapers
    - ☐ Telephone information number
    - ☐ I have never looked for information about health or medical topics

5. Please indicate if you own any of the following electronic devices (check all responses which apply):
    - ☐ A basic cell phone
    - ☐ A smartphone such as iPhone, Android, Blackberry, or Windows phone
    - ☐ A handheld device made for electronic book reading, such as a Nook or Kindle e-reader
    - ☐ A tablet computer like an iPad, Samsung Galaxy Tab, Microsoft Surface Pro, or Amazon Fire
    - ☐ A desktop or laptop computer
    - ☐ I do not have any of the above

6. Please indicate how interested you are in using technology to help improve your health.

1	2	3	4	5
Not at all Interested	Not very Interested	Neutral Interested	Somewhat	Very Interested

7. During the past 6 months, have you gone online to access the Internet or email?
    - ☐ Yes; *continue with question number 8*
    - ☐ No; *please skip to question 11 on the last page*

8. During the past 6 months, have you used the Internet to look for health or medical information for yourself or others?
    - ☐ Yes
    - ☐ No

9. During the past 6 months, have you used the Internet for any of the following reasons to locate or share health information?
    - ☐ Participated in a web-based support group
    - ☐ Used a social networking site, like Facebook, Twitter, LinkedIn
    - ☐ Wrote in a web-based diary or blog
    - ☐ I have not used the Internet for any of the above reasons

10. We would like to ask you for your opinion and about your experience using the Internet for health information. For each statement, please circle the number which best reflects your opinion and experience right now.

a) “I know ***what*** health resources are available on the Internet.”

1	2	3	4	5
Strongly Disagree	Disagree	Undecided	Somewhat Agree	Strongly Agree

b) “I know ***how*** to find helpful health resources on the Internet.”

1	2	3	4	5
Strongly Disagree	Disagree	Undecided	Somewhat Agree	Strongly Agree

c) “I know ***where*** to find helpful health resources on the Internet.”

1	2	3	4	5
Strongly Disagree	Disagree	Undecided	Somewhat Agree	Strongly Agree

d) “I know ***how to use*** the Internet to answer my questions about health.”

1	2	3	4	5
Strongly Disagree	Disagree	Undecided	Somewhat Agree	Strongly Agree

e) “I know how to use ***the health information*** I find on the Internet to help me.”

1	2	3	4	5
Strongly Disagree	Disagree	Undecided	Somewhat Agree	Strongly Agree

f) “I have the skills I need to ***evaluate*** the health resources I find on the Internet”

1	2	3	4	5
Strongly Disagree	Disagree	Undecided	Somewhat Agree	Strongly Agree

g) “I can tell ***high quality*** health resources from ***low quality*** health resources on the Internet.”

1	2	3	4	5
Strongly Disagree	Disagree	Undecided	Somewhat Agree	Strongly Agree

h) “I feel ***confident*** in using the information from the Internet to make health decisions.”

1	2	3	4	5
Strongly Disagree	Disagree	Undecided	Somewhat Agree	Strongly Agree

11. Please indicate your age range:
    - ☐ 50-54 years old
    - ☐ 55-59 years old
    - ☐ 60-64 years old
    - ☐ 65-69 years old
    - ☐ 70-74 years old
    - ☐ 75-79 years old
    - ☐ 80-84 years old
    - ☐ 85 and older

12. Please indicate your sex:
    - ☐ Man
    - ☐ Woman
    - ☐ Prefer not to say

13. Please indicate the highest level of education you completed:
    - ☐ High school – Non-graduate
    - ☐ High school – Graduate
    - ☐ College (CEGEP)
    - ☐ Professional program/Trade
    - ☐ Bachelor’s Degree
    - ☐ Graduate Degree

14. Please indicate your mother tongue:
    - ☐ French
    - ☐ English
    - ☐ Other

Thank you for your participation! Your answers are very important.

CHAPTER 4

Manuscript II

Mobile-health applications for post-fracture acute pain management: Clinicians' recommendations on content and functionality

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4.1 ABSTRACT

Background: Fracture pain management is challenging in older adults. However, there is a lack of tools to empower patients in self-managing their acute pain. Mobile applications (apps) can be harnessed to improve management of outpatient conditions such as acute pain following a fracture. Clinician and end-user input is essential for the optimal development of such tools. **Objective:** To identify clinicians' recommendations on the most important content/ functionalities to include in a mobile app for self-management of acute pain in older adults with a recent fracture following hospital discharge. **Methods:** Potential respondents to an email survey were identified via a snowball sampling of known Canadian clinicians with expertise in older adults' pain management and invited to answer a single open-ended question on the important content and functionalities of a mobile app. Qualitative content analysis was conducted by associating references to app content and functionality themes. **Results:** Thirty-four respondents (response rate 1st wave 60%; 2nd wave 60%) answered the survey: physicians: 19 (56%), nurses: 7 (21%), rehabilitation therapists: 5 (15%) and pharmacists: 3 (9%) generating 159 references on content and 72 on functionalities. Content references addressed three themes. The most frequently mentioned was pain management (n=135) with the key sub-themes of medications (n=67) including analgesic options, safe use and combination regimens; alternative non-pharmacological modalities (n=35) and pain assessment tools (n=12). Two other themes: exercise/physical activity strategies (n=15) and information on fracture prevention (n=9) were also highlighted. Regarding functionalities, respondents felt that interactiveness (n=27) of the mobile app, its ability to record and share information (n=17), provide important contact information (n=15) and its overall user-friendliness (n=11) were important. **Conclusion:** Appropriate medication use, safety and alternative modalities for pain management were the most cited content recommendations whereas interactiveness and a diary component were

the top functionalities noted by respondents. Clinician experts' insight will inform the development of a mobile app for acute pain management alongside results from an ongoing patient survey.

4.2 INTRODUCTION

Pain management is challenging in older adults. Mobile apps can be harnessed to improve management of outpatient conditions such as acute pain following a fracture. Mobile apps claim to hold a variety of functions and content enabling patients to seek relevant information to manage their conditions. However, most apps lack the crucial components required for individuals to optimally understand, self-monitor and self-manage their disease, for example acute pain following a fracture. Furthermore, most apps do not have goal-setting functionalities, nor involvement of clinicians or end-users during the development and trial phases (patients). The viewpoint of both clinicians and end-users is warranted for the development of this mHealth tool. This study focused on the clinician aspect and on what they believe their patients would require to efficiently self-manage acute pain.

4.3 METHODS

4.3.1 Study design and study population

Using survey methodology, we invited a selected sample of clinician-experts to answer a single open-ended question on the required content and functionalities of a mobile app on self-management of acute pain in adults.

To select the study population, we used a snowball/chain referral sampling method (194).

Snowball sampling is based on a referral approach where a number of selected individuals with similar characteristics recruit other individuals with the same characteristics from their community or their networks (195). This sampling method allows for greater participation of the study population and permits to reach out more participants with lesser effort and cost (196). Although snowball sampling does not guarantee random selectiveness and representativeness which prevents any pre-established assumptions when conducting research, we felt this technique would allow for better compliance compared to other sampling techniques. This study used a snowball survey as we required reaching a specific population of experts from various clinical disciplines (nursing, medicine, rehabilitation, pharmacy) in bone health and pain management that would be hard to recruit through large survey methodology. Habitually, it is not required that respondents of the first seed (wave) name those they are referring to the survey but rather it is recommended they encourage them to come forward. This technique is often labeled as cold calling (197). However, for efficiency we asked the initial seed of respondents to name (and provide contact information) potential participants, and then contacted the referred participants on behalf of the first seed respondents. Since we used email instead of telephone calls, we felt this was an appropriate approach.

The first wave involved reaching out to a set study population (first seed) which in turn provided the names of other potential participants (second seed) for the second wave. For this study, the limit was set to two waves, as we felt we would reach saturation in the answers to our survey. The list of members of the first seed was composed of expert clinicians across Canada with expertise in bone health and pain management in adults, with whom we had previous collaborations. This included endocrinologists, orthopedists, physiotherapists, geriatricians, pharmacists, nurses, and emergency physicians. Osteoporosis Canada (national organization working to educate, empower and support individuals and communities in management of osteoporosis) staff responsible for educational programs were contacted as well as clinicians who are members of its scientific advisory council. Participants were invited to answer a single open-ended question on the important content topics and functionalities of a mobile app to be used for the self-management of acute pain following a fracture. Each expert was also asked to identify up to three national experts/clinicians outside their own institution to grow the snowball. These national experts were then contacted and invited to answer the same question. Consent to participate was assumed if the selected expert or healthcare provider answered the question(s) in the email. If a participant did not submit an answer after one week, a maximum of two reminder emails, 5 working days apart were sent. Participants who did not answer any of the emails were excluded from the study.

4.3.2 Content of message

Every participant received a personal email which included a formal introduction, the purpose of the project, one open-ended question and a request for referral of up to three experts in the field to expand the network:

Dear Colleague,

I am writing on behalf of our multidisciplinary team who wishes to develop a mobile application (app) to empower adults 60 years and older to effectively manage their acute pain in the period immediately following discharge from the hospital after a skeletal fracture. Although many apps are available for chronic pain management, none exist to guide acute pain management post-fracture; this gap in acute pain management has been highlighted by patient groups. The pain self-management mobile app we propose to develop will meet regulatory standards, ensuring *privacy and security for end users, and all content will be evidence-based. We are seeking your expert opinion on the following question:*

What do you believe to be the most important content to include or functionality to have on a mobile health app to empower adults over the age of 60 to manage acute pain at home, after discharge from the emergency department, following management of a skeletal fracture? Please list up to five responses:.

In addition, we would be grateful if you could identify other Canadian colleagues with relevant expertise, preferably from a different institution than yours, to expand our network of experts. Please provide up to 3 names and include work emails if possible:

If you are interested, we would welcome you to join our advisory working group to participate in the development of the app.

Your participation to this questionnaire is strictly voluntary. Returning an e-mail with your responses indicates that you consent to have your answers included in our study. For the analysis all responses will be anonymized, so it will not be possible for you to be identified based on your answers

The McGill University Health Centre Research Ethics Board reviewed this survey and is responsible for monitoring it at all participating institutions in the health and social services network in Quebec.

4.3.3 Statistical analysis

Respondents' personal information was not collected. Participants' answers were annotated and anonymized in an excel sheet. The Nvivo software was used to extract data on recurrent answers and potential themes. Qualitative content analysis was conducted by associating references to app content and functionality themes. Content and functionalities were presented in graphs and tables. Emerging themes were compared to recommendations from published clinical guidelines.

4.4 RESULTS

4.4.1 Clinicians' characteristic

A total of 57 clinicians were emailed across Canada. Forty-two clinicians were contacted for the first wave while 15 were reached out during the second wave. Thirty-four respondents (response rate 1st wave 60%; 2nd wave 60%) answered the survey. Of the 34 compiled answers, 24 were in English and 10 in French (figure 4.1). More than half of the respondents (56%) were physicians, 21% were nurses, 15% rehabilitation therapists and 9% were pharmacists. Physicians included clinicians such as emergency physicians, family physicians, orthopedists, geriatricians, endocrinologists, rheumatologists and anesthesiologists while rehabilitation therapists were occupational therapists and physiotherapists. Although pharmacists accounted for 9% of respondents, they provided the most references per clinician (x=9.67) followed by emergency physicians (x=8.25) and nurses (x=8.00). Fifty one percent of references were cited by physicians, 24% by nurses, 13% by pharmacists and 12% by rehabilitation therapists (table 4.1). A total of 159 citations were obtained (first wave: 118; second wave: 41). From the 159 citations, 230 references were extracted (content: 158; functionalities: 72). Saturation of the data (no new ideas) was obtained after 84 citations (122 references; 19 respondents).

4.4.2 Mobile app: Content recommendations

References on content addressed three broad themes: pain self-management, exercise/physical activity strategies and information on fracture management. The theme with most citations was pain self-management (N=135) and this was subdivided into three key sub-themes of a) medication (N=67), b) alternative non-pharmacological modalities (N=34) and c) pain self-monitoring tools (N=12) (table 4.2).

The medication sub-theme included more specific references such as description of available analgesic options, safe use/methods of administration of analgesics (e.g. adverse effects/complications, contraindications, addiction) and combination regimen (as well as dosing and tapering of medications). Less common sub-themes comprised of pharmacology (N=4) and the use of supplements such as vitamin D and calcium for osteoporosis management (N=1).

Alternative modalities (N=34) focused on non-pharmacological options. The most frequently mentioned was rest, ice, compression and elevation (N=11); a common recommendation given by physicians as a first treatment to reduce pain and inflammation. Relaxation techniques such as mindfulness, meditation, and breathing (N=7) and pain relief positioning strategies such as lying down or immobilizing the fractured limb (N=6) were reported as important non-pharmacological solutions to include as content. Six other references underlined the necessity for education on plasters, casts, crutches, braces, canes and walkers (i.e. usage time, weight bearing, mobilization). The third most reported sub-theme under pain management was pain self-assessment methods (N=12). Clinicians referenced the use of pain scales (N=5) in general for assessing pain while others specifically mentioned the use of the visual analogue scale (N=4) or Likert scale (N=3). Lastly, other sub-themes on pain management included expectations and timelines of pain duration (N=9), fracture-specific information (N=3) and finally lifestyle and health modifications (N=3) such as nutrition, sleeping in a better mattress, etc.

The second most cited theme was exercise/physical activity strategies (N=15) which highlighted recommendations on activities of daily living and advice on the timing of exercising or engaging in a physical activity. General recommendations were cited most often (N=10) while fracture-specific recommendations regarding physical activity or exercise (N=3) and rehabilitation (physiotherapy, occupational therapy) programs for healing and fall prevention (N=2) accounted for a third of the references on exercise/physical activity. The third most reported theme was information on fracture prevention (N=9). These references addressed the importance of the information quality and authenticity on fall and fracture prevention.

4.4.3 Mobile app: Functionalities recommendations

References on functionalities addressed five primary themes (table 4.3). Respondents felt that interactiveness (N=27) of the mobile app was the most important functionality to include. Specifically, clinicians emphasized the need for a notification feature (N=24) to identify potential red flags (need to seek medical care) (N=16) or to remind users of taking their medication on time (N=8). Some references highlighted the importance of goal setting, encouragement and rewards (N=2) for every milestone reached. An essential theme respondents cited was the ability to track pain (pain diary) which would allow users the ability to record and share information (N=17). The principal sub-theme under diary was the idea of monitoring (N=14). This included recording information such as pain intensity levels (N=4), drug therapy options chosen (N=3), side effects encountered (N=2), the effectiveness of the chosen therapy (N=2), alternative modalities used (N=1), persistent pain sites (N=1) and overall progress in pain management (N=1). The other sub-theme under diary stressed the idea of sharing information (N=3) with either healthcare providers or other users suffering from pain. In doing so, this could create a peer group or community which could play the role of a support group. Additionally, some references involved linking the user's profile to databases accessible to healthcare providers for a faster and easier communication between the two parties. The next primary theme involved providing users important contact information in case of need (N=15). Such contacts include clinicians or accessible physicians (N=6), resources to call for information (N=5), a troubleshoot number including a list of frequently asked questions (N=2), family (N=1) and peer or support groups (N=1). The fourth most referenced theme was user-friendliness (N=11). Respondents recommended that the mobile app should be easy to use (N=5), should be compatible with most smartphones and mobile devices (N=1), font must be large enough (N=1), navigating through the app must be simple (N=1), available in many languages (N=1) and also accessible through a website (N=1). Lastly, the fifth theme was media (N=2) which comprised of both audio (N=1) and video (N=1). This functionality would allow for listening to information and having access to built-in videos or cartoons with an avatar rather than text to explain and deliver relevant information on pain management.

4.5 DISCUSSION

The results of this study indicate that in terms of content, medication use (efficacy and safety) and alternative modalities for pain management were the most cited content recommendations whereas interactiveness and a diary component were the top functionalities noted by respondents. Participation of healthcare professionals in the development of fracture-pain self-management mobile apps can ensure the quality of health information and the support provided by such apps. The frequent lack of clinical-expert involvement is in part responsible for the inaccuracy and poor quality of health-related apps (131, 198). This absence of clinical-experts' involvement in the development and design of apps has been underlined in studies which focused on the self-management of asthma (199), diabetes (200, 201) and was also consistent with other specialties such as eye care (202) and colorectal disease (203). A systematic review conducted in 2015 which included 52 studies assessing a total of 6520 apps reported that most mHealth apps lacked expert involvement and did not adhere to evidence-based medical information (204). Ultimately, this can lead to the use of unreliable information which can threaten patients' safety.

To improve the quality of mobile apps, through an informed development process, the use of standardised checklists such as the Mobile App Rating Scale (MARS), the Royal College of Physicians' (RCP) Health Informatics Unit checklist and the mHealth evidence reporting and assessment (mERA) checklist have been mentioned.

MARS

Initially developed for testing, classifying, and rating the quality of mobile apps for health and well-being promotion (205), the MARS is a simple, objective, and reliable tool and has been used to classify and assess the quality of apps which claim to target chronic pain management (206). It consists of 23 items grouped into five themes or categories: engagement, functionality, aesthetics, information quality and subjective quality. Each item is scored by the evaluator from 1 (inadequate) to 5 (excellent), and a final mean score is given for each section. The average of the mean values of the first four themes (i.e. engagement, functionality, aesthetics and information quality) gives a final measurement of the app quality. Of the 19 items in the MARS first four categories, the following 12 were cited by clinicians in our study: entertainment, interest, customization, interactivity, target group, ease of use, layout, goals, quantity of information, quality of information, visual information and credibility. Some themes were not mentioned by our clinician experts such as the app's performance and in-app navigation (move through the app). MARS is, for the most part, an objective tool which does not focus on a specific type of mobile health app. Our respondents highlighted themes specific for a mobile app aiming to improve acute pain self-management following a recent fracture. Having been given a limit of only 5 possible answers, respondents invested their choices more so on content recommendations rather than the functionalities recommendations since they are likely to be more familiar with that aspect. Clinicians did not identify cost of the app as a problem area to take into consideration when developing a mobile health app. This concern is likelier to be raised in the patient survey as these burdens affect more end-users. Interestingly, both the MARS and our respondents did not identify, in terms of the quality of the app, how to best evaluate security and privacy of user information. Future mHealth app development must include measures to secure user information to prevent private information theft and potential malicious functions.

RCP Health Informatics Unit

The RCP Health Informatics Unit checklist is an 18-item checklist to help clinicians assess the structure, functions and impact of medical apps (207). It was developed by the RCP Health Informatics Unit with input from app developers and results of the work of Donabedian (208) on factors that determine the quality of medical care. In contrast to the MARS, the RCP checklist includes criteria in the forms of sentences to which possible answers of "yes", "no", "don't know" and "unclear" can be circled. The checklist is divided into 3 sections: a) who developed the app and what' inside it, b) how well does the app work and c) is there any evidence that the app improves the clinical problem.

The first section includes the themes of appropriate target population, applicable outcomes, media (e.g. audio, images, video), app design, medical instructions and privacy. Our survey results have extracted similar themes to those mentioned. However, the theme of privacy was again the evident difference between both item lists. On the other hand, the RCP Health Informatics Unit checklist does not ask to provide detailed information on medication use, how to use them, pain assessment methods or tailored information on the disease itself. In that regards, the checklist lacks specificity.

The second section addresses themes relative to the app's performance level such as response promptness, ease of use, response appropriateness and troubleshooting. Although such themes are not specific to a certain target population, respondents cited similar themes relative to app performance. On the other hand, response promptness was not mentioned by our surveyed clinicians. Such issue can be sometimes intuitive for people who use the app, but not for those recommending it. Also, with today's growing technology, performance can be sometimes a topic that is ignored as it is often assumed that the latest technologies are implemented. The RCP Health Informatics Unit checklist fails to include the possibility of feedback with the user's healthcare provider and/or allowing for users to share their in-app data input.

The last section involves studies and clinical trials conducted to test or examine the app's impact on patient knowledge, potential harms, benefits, cost-effectiveness and usefulness. Our results did not address this issue per se. Respondents emphasized patient knowledge through the relevant information the app would provide as well information to prevent subsequent fracture and persistent pain. Also, potential harms was addressed in terms of medication use. Adverse effects, complications, contraindications and addiction were the main sub-themes noted by clinicians. In the future, it would be imperative to test mobile health apps to assess their effectiveness.

mERA

Lastly, the mERA checklist was developed by the WHO mHealth Technical Evidence Review Group and aims to provide guidance for a complete and transparent reporting on studies that evaluate the feasibility and effectiveness of mHealth interventions. It involves assessing what is in the mHealth intervention (content), the purpose for which it was implemented (target groups) and the technical features around its implementation (209). It consists of 16 items focused on standardizing the reporting on mHealth interventions by providing a checklist of criteria specific to reporting on digital innovations. However, the mERA was not developed to support the design, implementation and evaluation of quality of research studies reporting on the feasibility and effectiveness of mHealth interventions. Rather, it improves the transparency in reporting and promotes the critical assessment of mHealth research evidence for future research findings. Although our study did not explicitly focus on systematic and useful reporting of mHealth interventions and their associated research studies, some items in the checklist certainly revealed recurrent gaps in the conduct of research for the development of mHealth interventions.

For example, “interoperability”, also mentioned previously from Bates et al. (156), enables the connection between the mHealth platform (app for example) and health information systems (electronic medical records). This would allow mHealth interventions to be integrated into the larger healthcare system and facilitate communications between users and healthcare providers. This aspect would also support improving “data security” by implementing reasonable data sharing protocols to protect users’ identities and health information. Although respondents to our survey noted the potential for data sharing options by connecting the app to healthcare providers, they did not reference recommendations relating to data security and information privacy. This could be explained by the difference in concerns with regards to “intervention content”, “usability testing” and “user feedback”. Again, “cost assessment” is a common item among the checklists which was not cited by our respondents. Though, our survey’s objective was not to put an emphasis on how much the app costs or how it is made (software or hardware), but rather to have input on content and functionality recommendations from expert-clinicians.

Limitations

Some limitations influenced the recommendations and conclusions drawn from the current study. First, the sample was small and selected from a Canadian expert-clinician population. This allowed, as intended, an exploration of the insight of a key experts which has been often suboptimal in the development process of health apps according to the literature. Although we made all efforts to include clinicians from all over Canada, many respondents invited us to reach out to colleagues from the same geographic location (province) and within their institutions. This affected our sample size since many clinicians from the first seed (whom we had already contacted) were mentioned in the list of the second wave. We also asked to provide only five recommendations; this was done to encourage selected experts to participate and keep the burden of answering low. This may explain why respondents failed to reference “privacy of information” and “cost of the app” as important aspects to take into consideration. However, saturation was attained fairly rapidly after 84 citations as no more new themes emerged. Despite these limitations, this study’s findings are important because they map out the problems between the commercial and scientific sides of mHealth. Further research must include patients or end-users to formulate a complete conclusion. Our work did not include patients’ or end-users’ recommendations (currently being developed). This is an important step towards developing an effective high-quality app as it would give insight on the likelihood of the adoption of the mHealth intervention among its end-users, allow end-users to participate in the development process of the app and provide feedback on content, user interface, usability and connectivity to drive the success of the app.

Conclusion

The results of this study have provided us with clinicians’ recommendations on important content and functionalities to include in an app for self-management of acute pain following a recent fracture. Appropriate medication use, safety and alternative modalities for pain management were the most cited content recommendations whereas interactiveness and a diary component were the main functionalities noted by respondents. Clinician experts’ insight will inform the development of a mobile app for acute pain management alongside results from an ongoing patient survey.

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4.7 TABLES & FIGURES

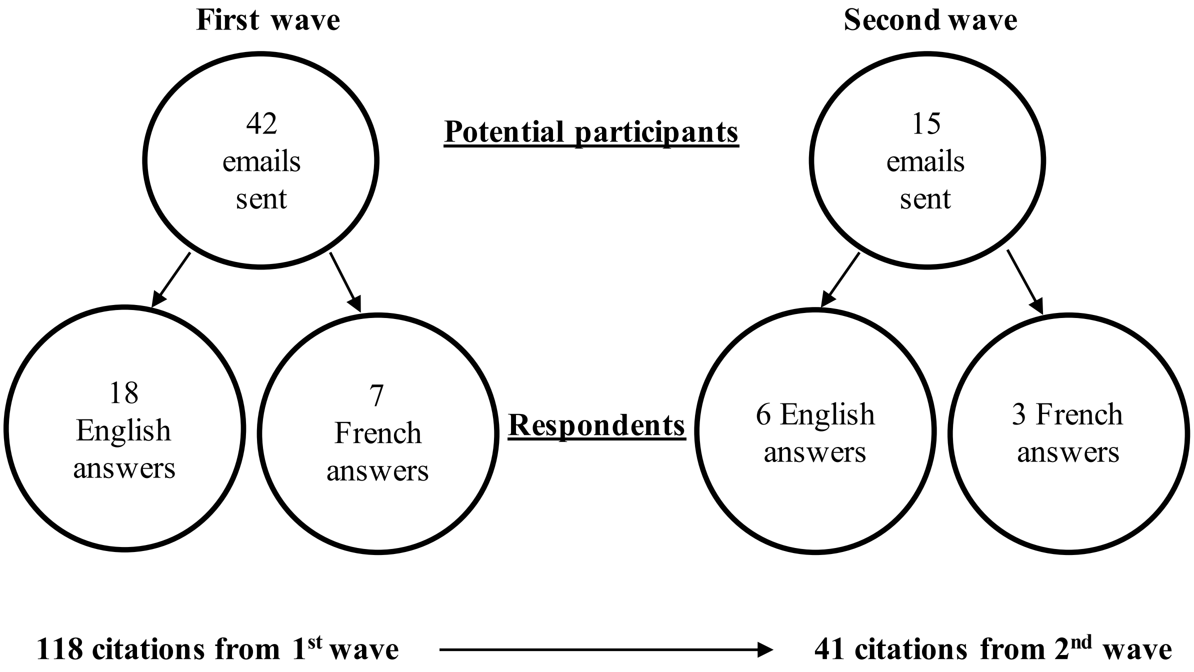

Figure 4.1 Snowball sampling diagram of contacted and participating clinicians for recommendations input on content and functionalities of pain management apps for users with fractures.

Table 4.1 Profession and geographic location of respondents

Provinces	**Physicians** (N=19)	**Nurses** (N=7)	**OT/PT/Kin*** (N=5)	**Pharmacists** (N=3)	**Total** (N=34)
Quebec	7	7	3	1	18
Ontario	8	0	0	0	8
British Colombia	1	0	1	0	2
Alberta	1	0	1	1	3
Nova Scotia	1	0	0	0	1
Manitoba	1	0	0	1	2

*OT = Occupational therapists, PT = Physiotherapists and Kin = Kinesiologists

Table 4.2 The most important themes regarding mobile health application content based on responses by clinicians

CONTENT REFERENCES	**N=158**
Pain self-management	**134**
Medications	**67**
Analgesic options/how to use	25
Safety	22
Adverse effects/complications	17
Contraindications	4
Addiction	1
Dosing combination regimen	15
Pharmacology	4
Supplements (Vitamin D/Calcium)	1
Alternative modalities	**34**
Rest, ice, compression, elevation	11
Relaxation techniques	7
Positioning	6
Assistive devices/cast	6
Non-pharmacological	4
Pain self-assessment methods	**12**
Pain scales	5
Visual analogue scale	4
Likert scale	3
Expectations & timelines of pain duration	**9**
Information on pain management	**6**
Fracture-specific pain management	**3**
Lifestyle & health modifications	**3**
Exercise - Physical activity	**15**
Recommendations	10
Fracture-specific	3
Rehabilitation (physiotherapy, occupational therapy)	2
Information on prevention of falls and fractures	**9**

Table 4.3 The most important themes regarding mobile health application functionalities based on responses by clinicians

FUNCTIONALITIES REFERENCES	N=72
Interactiveness	**27**
Notifications	24
Red flags	16
Alarm for Rx uptake	8
Goal setting (encouragement & rewards)	2
Pain localization	1
Diary	**17**
Tracking	14
Pain intensity	4
Drug therapies	3
Side effects	2
Therapy effectiveness	2
Alternative modalities	1
Pain site	1
Progress	1
Sharing options, linking app to healthcare provider	3
Contact information	**15**
Clinician	6
Resources	5
Troubleshoot for the app	2
Family	1
Peer groups	1
User-friendly	**11**
Ease of use	5
Device compatibility	1
Font	1
Interface	1
Language options	1
Low health literacy	1
Web-based	1
Media	**2**
Audio	1
Video	1

CHAPTER 5: DISCUSSION

5.1 General discussion

Serious injuries such as fractures are common in older adults and an important cause of pain, loss of autonomy and morbidity. Risk for fractures and musculoskeletal injuries increases with age as a result of the onset of osteoporosis (210). Older adults who visit the ED with acute pain following a fracture often receive suboptimal pain management. Failure to effectively manage acute pain in older adults has been associated with poor long-term outcomes such as development of chronic pain, recurrent falls, low quality of life and excess mortality (5, 6). Opioids are often prescribed upon discharge to patients to treat moderate to severe pain, but can also cause adverse effects such as sedation, dizziness leading to increased risk of falling (64). Many have developed "opioid fear" following the opioid crisis characterized by reports of unintentional overdoses and deaths (167, 168). Patients become hesitant to take their prescribed medications resulting in suboptimal acute pain management. To change the trajectory of suboptimal pain medication use, the healthcare system should find innovative solutions to educate and empower patients with knowledge on pain self-management. The rise in mHealth technology adoption can be harnessed to support older adults in acute pain self-management at home. With the advent of digital electronic devices such as smartphones and tablets, this provides novel opportunities to leverage technology to facilitate self-management of acute pain in the older adult population.

In this thesis, I submitted three scholarly projects (2 manuscripts) that followed a logical sequence. First, we assessed the availability of mHealth apps for acute pain self-management. Our environmental scan and literature review identified a paucity of high-quality mHealth apps targeting acute pain self-management (147, 148, 159, 160). In fact, we did not find any app which specifically targeted acute pain management in adults. In addition, we documented that most apps served as pain trackers or pain diaries and did not have as a primary function to help or guide the user in managing their pain. Furthermore, none of the apps were suited to effectively support acute pain in our target population (people with fractures) providing goal setting or interaction with social media or healthcare professionals. We also documented that clinicians and patients are not stakeholders of the development process, leading to lack of applicability, credibility and usefulness. There is a gap in knowledge and in care in this area.

Next, we examined technology adoption and eHealth literacy in adults 50 years and over with recent fractures, recruited from orthopedic clinics of a large urban center. The majority of adults expressed an interest in using technology for improving their health and many were using e-devices such as smartphones and tablets, when compared to results from previous surveys (133, 134, 185). Furthermore, their ability to use these technologies efficiently was demonstrated by the high proportion of individuals with a high functioning level of eHealth literacy (eHeals ≥26). Since our results support the creation or development of an interactive mobile application for the management of acute pain in this population, we sought to obtain input from clinicians. Determining the key assessment criteria which make a mHealth app of high quality, successful and broadly adopted is complex. The results of our last project provide insight, from the perspective of expert-clinicians across Canada, on important content and functionalities a mHealth app must include to improve acute pain self-management in older adults with recent fracture. The ideal app should meet essential quality criteria such as evidence-based content, ease of use, user engagement, customizability, affordability and safety-privacy standards (156, 205). Most of these content and functionality themes were referenced by the clinicians we surveyed.

Wicks et. al have proposed five potential approaches to improve the quality of medical apps (211). The first approach, “boosting the app literacy”, involves providing users with information and documentation on the apps’ data privacy policies, business model, whether it was tested or not (on which population and which context), reliability and validity. Although providing relevant documentation would be of a voluntary nature, it would enable users to have greater trust in the app developers and their app. Highlighting important content and functionalities prior to installing the app could serve as a stepping stone in improving patient's health literacy. The emphasis would be on empowering users and educating them on how to make better decisions relative to choosing an app. However, this is likely a tall order as time and energy would be required on the part of the user for such investigative process. Challenges to assess and understand the complex issues of privacy and security associated would also have to be considered. Without any oversight or enforcement from a third party, this would be a difficult burden on patients who use the app.

The second approach is to assemble an "app safety consortium" composed of stakeholders including developers, regulators, patient advocates and safety researchers. The consortium would investigate user-reported adverse events resulted from the usage of the app. Such approach would be similar to the patient-reported outcomes framework (PROSPER) proposed by Banerjee et al. and used for clinical trials of drugs and medical devices (212). Establishing a consortium would also aim towards developing further risk management policies to address issues more seriously and encourage the scrutiny of poor app designs to prevent harmful events. However, there is no current consortium set up as such and maintaining this group would certainly require funding.

Third is "enforced transparency" where app developers would be forced to submit documentation to an accessible open database available to be reviewed by external third parties or by an association of researchers and clinicians through an automated software. This would allow for the evaluation of the protocols, publications, trials and other relevant aspects of the app in a transparent approach without having to do so manually. In doing so, this would tailor the accessibility of app developers to their users population and clear them to target their population of interest. This would also allow third parties to constantly develop novel softwares to assess the functioning of the apps, ultimately an imperative resource for app developers, app stores, healthcare providers and the public. Though this continuous quality assessment enforced by app stores can enable external validation by third parties, it can certainly have an impact on the developers' competitiveness since this approach would require additional work from their part.

Another approach is to give full responsibility of the active medical review process to those running the app stores. This reviewing process includes all the app aspects from security to quality of mHealth apps. In other words, the approach requires the removal of all mHealth apps. Next, a selected group of clinicians, security experts and quality assurance software engineers would implement a vigorous testing program to assess all apps prior to releasing them to the public. This enforced and robust approach will enable app store management teams to ensure the quality and safety of apps. However, this concept will most likely be very time consuming and very hard to perform due to the complex nature of apps, the various verification steps required and the lack of financial incentive to execute such approach.

Finally, the last approach would be to comply with government regulation of smartphone/tablet apps. Again, this also involves an active medical review of every app before releasing it to the public. Regulators could include the Food and Drugs Administration, Medicines and Healthcare products Regulatory Agency, etc. Having already existing regulatory bodies in place, this approach could increase the public's confidence and prevent app store owners from hiring a team of technologically minded clinicians to review the apps. Despite enhancing throughput of testing programs to review each app, this would be a very slow process and somewhat a barrier to innovation. In the end, all of these approaches will add complications and additional cost to the simple act of downloading an app. Nevertheless, it is of their best interest (patients and healthcare providers) to drive this change to the system in place to avoid serious harm on users and building a safer new healthcare system era.

Lacks in regulation of the app store markets where many apps are being developed without quality, effectiveness assessment and the absence of published literature which tested and supports the use mHealth apps available to the general public, demand concrete steps forward to verify, review apps and limit the spread of the inadequate framework currently in place. Maheu et al. are currently developing an online Interactive Mobile App Review Toolkit (IMART) system to provide verifiable systematized app reviews introduced in an evidence-based "digital health standards thesaurus" (213). This framework would enable individuals to review, develop and make well-thought investment decisions on digital health products such as apps for example. Also, it would assist in investigating which aspects of the app achieve specific outcomes for different target populations. The IMART consists of three components: the Reviewer's Workbook, the Digital Health Review Library and the Review Drafting Wizard. The Reviewer's Workbook is an online instrument which provides interactive measures for scoring and commenting on apps. Reviewers are first asked to identify themselves and the target app. Next, they are invited to fill out a blank online workbook with the informative review which will be stored in the Digital Health Review Library accessible only to that reviewer. A score is then selected from the workbook's rating scale and the commentary is then added to the library. Also, reviewers can add an audio or video file into the final versions of their reviews. Finally, the Review Drafting Wizard is used to generate a compact readable review report which can later be edited by the reviewer. Once the final version is submitted to the Digital Health Review Library, a moderator can decide to make the review available to all those who are searching the library. All in all, the public would have a detailed rating of the app in question as well as a supplemental review report. This is an interesting and promising stepping stone in building a Digital Health Encyclopedia accessible to the public and available to anyone who provides verifiable personal identification.

5.2 Future work and perspectives

In these studies, we established the potential role of mHealth apps in healthcare and the importance of acquiring the perspective of expert clinicians on important content and functionalities an app should include to support acute pain self-management in older adults with fracture. The next step in this project is to engage and survey patients on what they feel should be included in a mobile health app and which assessment criteria are most important for them. Altogether, this will inform the development of a mHealth app that should meet patients' and clinicians' needs. In doing so, this will lead to considerations of implementing digital mobile devices as tools for better care.

Perhaps in the near future, clinicians will be prescribing specific apps to their patients for specific medical problems allowing for remote monitoring, documentation in medical health records and active feedback. The P5 approach is proposed to address aspects of mobile technologies that could be exploited in upcoming advanced mHealth interventions for personalized care (214). This approach relies on five aspects: predictive, personalized, preventive, participatory and psycho-cognitive. Using a predictive model, future mHealth tools can provide specific information through data collection (e.g. heart rate, glycemic level, pain levels, mood, etc.) without the need for frequent physical encounters with healthcare providers. In doing so, this allows autonomous data-analysis for a more precise assessment of the patient's future health state, well-being and potential changes to the patient's health management. Moreover, future mHealth tools must be tailored according to previously collected data on separate user profiles (e.g. age, sex, eHealth literacy, preferences). This personalization factor would use the existing content and functions of the app and adapt its functioning appropriately to each user. Data collection and analysis can be exploited to monitor patients and involve them in preventive programs. Long-term monitoring can allow goal setting, positive behavior changes and enhanced motivation toward management plan and adherence to treatment. This participatory aspect recognizes users as active decision makers who should preserve communications with their healthcare providers (have a personal file that is continually updated) and interact with peers and other patients to improve their health management abilities and benefit from their interactions by sharing their experiences or give useful suggestions (technology embedded in the mHealth tool interface). Lastly, the user-centered design (UCD) approach involves actively incorporating feedback of users to understand their needs and requirements (215). The UCD was developed based on patients psychological characteristics, cognitive capabilities and lived experience of illness. These psycho-cognitive components are important aspects to consider since they involve patient's emotions, their coping skills and decision-making. Future developers must be capable of integrating specific research findings to design and develop advanced mHealth tools which support identification of users (needs, context of app use), personalized decision support and effectiveness at different stages of health management.

5.3 Conclusion

In light of this work, we conclude that there is currently a gap in the availability of high quality tools for effective self-management of acute pain following a fracture which could be bridged by technology, if designed appropriately. Our studies provide evidence that older adults with fractures have the eHealth literacy required to adequately use mobile devices such as smartphones and tablets and most are interested in using technology to improve their health and healthcare providers are interested and able to provide insightful recommendations. Following the patient engagement activities in progress, we aim to develop an innovative evidence-based mHealth tool to support the self-management of acute pain in older adults with recent fractures to improve health outcomes and patient-clinician partnership towards better care.

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