A Cornell Consensus Conference on Later-Life Pain & New Technologies: A Non-Technical Report

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Background Information

The world's population continues to age. A baby born in the U.S. in 1900 had a life expectancy of around 50 years, while one born in 2000 has an estimated life expectancy of around 80 years. This trend is taking place in developed countries and many developing countries as well. The total number of older adults on the planet is expected to increase from around 800 million to over 2 billion by 2050.[1] One leader described the gains in life expectancy and the impact this will have on societies as the "defining challenge of our age."[2]

Advancing age is associated with many chronic conditions. The incidence of diseases such as cancer, arthritis, diabetes, heart failure, and dementia increases with age. As the number of chronic conditions increases, an individual's risk of developing difficulties performing activities such as bathing, dressing, and walking; being hospitalized; and dying, also increases. Having multiple chronic conditions leads to substantial health care costs. About 70% of all health care spending in the U.S. goes to care provided to individuals with two or more chronic conditions.[3] Researchers have coined the term "burden of chronic illness" when referring to the profound impact chronic conditions have on aging individuals, their families, and the society at large.

Chronic pain is one of the most common and disabling conditions that adults face as they age.[4] In one survey of adults ages 65 and above living in the U.S., more than 50% reported experiencing bothersome pain in the past month.[5] Similar findings have been reported in studies of older adults living in Australia, Europe, and Asia.[6] The current definition of chronic pain is any type of pain that persists beyond the expected time of healing, which is typically 12 weeks.[7] Chronic pain is more than just an unpleasant sensation; it can negatively affect a person's emotions, they way they think, and what they do.[4,6] Painful musculoskeletal conditions (e.g., osteoarthritis, chronic back pain) are especially common in older persons.[4,6,8] Chronic pain that occurs through damage to the nervous system with diseases like diabetes and shingles, known as neuropathic pain, occurs commonly among older individuals. Other types of chronic pain are also common in older adults, including cancer pain and pain that occurs as a consequence of cancer treatment.[4,6,8]

Chronic pain is a significant public health problem.[4] Individuals with (versus those without) chronic pain are more likely to develop impairments in physical functioning (e.g., ability to walk without the need of an assistive device), perceive their health to be poor, develop depression, experience social isolation and anxiety problems, and experience falls.[4,6,8] Sadly, having chronic pain also increases a person's risk for thinking about (as well as carrying out) suicide.[9-14] Given the costs of treatment and the many impairments associated with this condition, chronic pain poses a significant economic burden at a societal level.[4,6,8] Despite the fact that chronic pain is common and frequently disabling, it is often undertreated, particularly among older adults.[4,6,8] This finding has been documented in many different healthcare settings, including hospitals, nursing homes, emergency rooms, and primary care practices. There are several reasons why this happens, including barriers at the patient- (e.g., many older adults believe that pain treatments are dangerous or that pain is something that should be endured), provider- (e.g., not enough education about how to manage pain), and system- (e.g., many treatments are very costly, while others are not available in many communities) level.[4,6,8,15]

Over the past 15 years, a number of efforts have been undertaken to address the problem of poorly treated pain. These efforts have included: 1) educating healthcare providers (e.g., nurses, physical therapists, and physicians) about optimal ways to assess and manage pain; 2) creating a new subspecialty, i.e., Pain Medicine, in the U.S.; 3) developing and implementing guidelines on how to optimally assess and manage pain in older persons;[16,17] 4) mandating that healthcare systems in the U.S., including hospitals, nursing homes, and doctors' offices ask patients at each visit whether they are experiencing pain and if so, how severe is it; and 5) publishing more research that can help clinicians make more informed decisions about how best to assess and treat pain. Despite these efforts, the healthcare system's ability to effectively manage patients' pain in many countries continues to be poor.[18-21] These results indicate an urgent need for new approaches to improve how pain is assessed and managed. New approaches are particularly needed in the care of older adults given that pain is so common and often undertreated in this group.

Can New Technologies Improve the Way Pain is Assessed & Managed?

Given the rapid increase in the number of aging adults living with multiple chronic conditions including chronic pain, rising healthcare costs, and a shortage of caregivers to help care for older individuals with multiple chronic conditions, many experts have asked whether emerging technologies (in particular mobile technologies) can help to address these important and related challenges.

While there is no agreed upon definition for mobile health (referred to hereafter as mHealth), the World Health Organization defines mHealth as the "practice of medical and public health through the use of mobile devices."[22] A related definition is "the provision of health services and medical and public health practices delivered via mobile devices, mobile phones, patient monitoring devices, personal digital assistants, and other wireless devices."[23] These devices often take the form of applications (referred to hereafter as apps) that can be stored on portable devices such as tablets and smart phones and also include wearable devices. These devices have the ability to:

- Track/Monitor Symptoms and Goals Over Time: Many apps allow individuals to enter health information to include pain score, mood score, and activity level, while others allow the entry of data such as an individual's weight, blood pressure, glucose level, exercise endurance, etc. Some of the information can be tracked automatically by the devices (e.g., amount of time spent in one spot, number of steps taken on a given day) so there is no need for an individual to enter the information. Many of the devices can analyze the information to help a device user determine whether a given condition (e.g., the level of pain a person experiences) is changing over time or whether certain goals (e.g., amount of exercise performed daily) are being met.

- Deliver Health Interventions: Many apps now provide instruction in specific techniques such as mediation, yoga, tai chi, etc. An example might be a brief video that is displayed on the screen of a phone or tablet that illustrates how to perform a certain maneuver such as a tai chi movement. In addition, many health-related apps provide general education about a given condition.

- Provide Reminder Prompts: This might take the form of a text message reminding an

individual to engage in a specific activity such as taking a medication at a certain time, engaging in techniques learned during a recent therapy session, or getting more exercise. A number of studies have evaluated reminder prompts delivered as text messages to individuals' phones as a way to encourage them to take their medications as directed. These studies found that individuals who received the prompts were more likely to take their medications on a regular basis than individuals who did not receive the reminder prompts on their devices.[24]

- Share Information: Many devices allow for the wireless transmission of information. Various types of information that individuals might record on their devices can be sent directly to their physician, other healthcare providers, or loved ones. This might take the form of an individual's daily pain, mood, and physical function scores over a defined period of time, which could be sent to their physician prior to a scheduled office visit. The results could be reviewed at the time of the visit and decisions could be made about whether to change treatment based on the findings.

- Enhance Socialization: Many devices provide ready access to the Internet, where individuals can send or receive email messages and access social networking sites (e.g., Facebook, Twitter, and/or Instagram) and other online communities. Given that many older adults with chronic pain report social isolation, this function could help to increase an individual's ability to socialize with others.

- Serve as a Way of Distracting Individuals From the Experience of Pain: Helping patients to engage in thoughts or activities that distract their attention from pain is a commonly employed technique in many psychological treatments for patients with pain. Research suggests that mHealth devices can provide "immersive experiences" serving as effective distraction from an individual's pain stimuli.[25,26]

- Educate Affected Individuals: Access to the internet allows individuals to educate themselves about a given health condition, including evidence-based approaches to its assessment and management as well as new treatments that may provide value.

- Streamline Activities Required to Manage Chronic Conditions: This ability automates certain chronic condition management activities such as the need for medication

refills. Walgreens, a large U.S.-based pharmacy chain, has created a popular app that allows consumers to scan a barcode on a prescription. This information is sent electronically to their pharmacy prompting renewal of the medication. The app allows individuals to avoid the hassle of (and the time spent) requesting medication refills over the telephone.

- Facilitate Research/Generate New Knowledge: This benefit could occur if large numbers of individuals agree to enter information over time using one or more mHealth tools. The results generated by this group of individuals could be collected and analyzed to better understand the impact of a given chronic pain condition on affected individuals. Research directed at determining whether a type of treatment could be delivered using mHealth tools (e.g., an app that teaches patients how to do a series of back stretching exercises) could provide new information about the value of specific treatments for various chronic pain conditions.

How Many Applications Are Currently Available and Are They Used?

Individuals with Android phones had access to as many as 2.2 million apps in June 2016.[27] The corresponding number of apps for individuals with Apple devices (e.g., iPhone, iPad) was 2 million.[27] The total number of apps judged to be health-related, as opposed to those designed primarily for entertainment, news, social networking, or games, was 259,000.[28] Only a small number of health-related apps, however, have had success. In one report published in 2015, "a mere 36 apps comprised 50% of all downloads of all health-related apps," indicating limited to no use of the vast majority of apps on the market.[29] In contrast to this finding, the adoption of health-oriented devices (e.g., wearable devices such as the FitBit or Apple Watch, "smart" health electronics) continues to grow rapidly.[30] However, this growth is likely taking place with younger to middle-aged adults who may be more tech savvy than older adults. Finally, only limited research has been conducted to determine how often and for how long individuals continue to employ apps over time. Some research suggests that many adults who download the apps do not use them citing concerns such as privacy, hidden fees they were not aware of, and waning interest.[31]

Although many questions remain about older adults' willingness to use, as well as

their actual use of, mHealth devices and health-related apps, these technologies present an exciting opportunity to change how individuals age in the coming century. This change is most likely to happen if the technology is created in a manner that unequivocally meets the needs of older adults. Meeting older adults' needs through technology applications is a concept that has been referred to as "gerontechnology."[32]

What is Known About Older Adults' Use of and Attitudes Regarding These Technologies?

Younger (vs. older) adults are still far more likely to regularly access the internet and download apps on their mobile phones and other devices. This age difference, i.e., greater numbers of younger (vs. older) adults purchase and use the devices, is often referred to as the "digital divide." However, internet and mobile phone use is becoming increasingly commonplace among older adults. Surveys indicate that mobile phone use by individuals ages 60 and above continues to increase rapidly.[33] As of 2012, approximately 2 in 3 older adults reported accessing information via the internet, more than 3 in 4 owned a mobile phone, and more than 1 in 4 reported owning a tablet.[33] Another survey found that older adults were more likely to own a mobile phone as opposed to a desktop or laptop computer.[34] While young adults continue to be the group most likely to use Facebook, older adults are accessing this social network site in increasing numbers. Among older adults who go online, two-thirds access social networking sites such as Facebook, MySpace or LinkedIn.[35] Finally, a recent survey of smartphone users found that 37% of older versus 18% of younger smartphone users were more likely to describe their smartphone use as "connecting" versus "distracting," suggesting that older adults are more likely to rely on their phone as a way to socialize.[36]

Surveys indicate that older adults are interested in using mobile tools to help them manage their chronic illnesses.[37] Various surveys have been conducted to identify the factors that motivate older adults to use mobile phones.[31,38-40] These factors include enjoyment that results from use of the device, a sense of safety, ability to connect with others, freedom, and social influence, i.e., the influence of others that are using the devices. Other factors felt to increase the likelihood that an older adult will use mHealth technologies include: 1) perception that the device provides a clear benefit to the user; 2) confidence in a person's

ability to learn how to use the device in order to obtain a benefit; 3) availability of training (e.g., tutorial programs that teach a user how to operate a device); 4) access to support and assistance if needed when learning how to operate a device; 5) functionality, i.e., are the elements that have to be performed (e.g., viewing information on a screen, hearing a message or a prompt, pressing buttons or other elements of the device) easy to learn and carry out?; and 6) the individual's social network, i.e., an older adult is more likely to use a new technology if other members of her/his social network such as family members and friends are also using it.[37] Barriers to adoption of mHealth devices among older adults include cost, fear of technology, complexity of the device, and desire for privacy.[31]

Studies have been conducted of older adults with chronic pain to gauge their attitudes and beliefs about the new technologies.[41-43] In one study, older adults shared that the following conditions could increase their chances of using mHealth devices to help them manage their pain problems.[41] Many of the factors are the same as those reported above and include: 1) receiving appropriate training in the use of a device before they start using it; 2) tailoring the devices so that they could be used by older adults with various physical limitations (e.g., accommodating persons who have vision or hearing problems); 3) ability to obtain support/assistance if questions arise once they begin using the device; 4) using wearable/portable devices instead of wall or home mounted devices; and 5) being informed that use of the device could help to improve their condition, i.e., is there evidence that persons who use an mHealth device (versus those who don't) are more likely to achieve favorable results? Older adults in this study also identified factors that would cause them not to use the devices. These included concerns about: 1) device malfunction; 2) high cost, 3) poor technologic literacy; 4) older adults' memory deficits, and 5) keeping their health data private.

In another study of older adults with chronic pain, researchers inquired about participants' attitudes to smartphones/apps as a way of helping them to take pain medications on a regular basis.[42] Many participants did not see any value in using smartphones and apps. These participants felt that their current strategies for obtaining prescribed medications and taking them on a regular basis were already working well. This

finding reinforces the notion that potential users of mHealth tools need to perceive a clear benefit to the use of a given device before they will adopt/use it.

A third study of older adults with chronic pain found broad acceptance of the use of these tools as a means of providing healthcare to older adults with chronic pain, particularly if it did not replace in-person care.[43] Acceptance of the technology was strongly linked to the level of social support. Those who lived alone or did not have relatives living nearby were more likely to be open to using the new technology than those who lived with others or had relatives living nearby. The authors of the study also reported that participants' openness to the use of the technology might change if they believed that the technology would reduce visits from health professionals such as social workers and nurses.

These results highlight many challenges and opportunities for increasing the use of mHealth devices and health-related apps by older adults with chronic conditions, including those with chronic pain. The research conducted to date suggests that older adults are interested in using these tools as a way to manage their pain conditions. The results provide strong support for future research to address the concerns listed above, including the development of tools that are easy to use and associated with a clear perception of benefit among older users. Tools are most likely to be adopted if they can be 1) implemented along with initial education/training that instills confidence in an older person's ability to use the device successfully over time, and 2) supplemented with ongoing support when questions arise.

mHealth Technologies for Use by Individuals with Various Pain Conditions

Studies of mHealth tools for use by individuals with pain are summarized below, and include formal reviews of various apps on the market designed for individuals of any age with chronic pain conditions, as well as research examining mHealth devices used by older adults with chronic pain. Because so few studies have evaluated the benefits and risks of these technologies among older adults, studies that examined mHealth tools in individuals younger than 65 years of age are summarized below. Several studies that have examined these devices to help older adults manage conditions other than chronic pain are also summarized to highlight their potential more broadly in older populations.

Reviews of mHealth Applications (Apps) on the Market

Hundreds of apps have been developed for use by individuals with pain problems, e.g., those with back pain, arthritis, fibromyalgia, headache. Some of the apps are free while others have to be purchased from online stores. At least 5 reviews have evaluated mHealth apps for use by individuals with pain.[44-48] The findings from these studies are remarkably similar and include the following:

- Most apps focus primarily on educating individuals about their pain condition(s) and how to optimally manage pain. That is, most apps provide education.

- Many apps allow individuals to enter information (e.g., pain and mood scores) that can be analyzed and displayed on a screen, allowing users to determine whether changes are occurring over time. For example, determining whether the level of pain decreases after starting a new treatment.

- Some apps (fewer than half analyzed in the reviews) provide skills training, i.e., teach individuals how to perform a specific technique/activity such as breathing exercises, tai chi, and meditation, as a means of reducing a person's pain.

- Few apps allow a user to send the recorded information electronically to their physician, another healthcare provider, or a loved one.

- Few apps mention any risks that may be posed as a consequence of using them. With any health intervention, there is always the possibility that a given drug or treatment may benefit or possibly harm an individual.

- Most apps did not say whether key stakeholders (e.g., individuals who have the condition that is supposed to be helped by the app, caregivers who may provide help to the individual at home, physicians and other healthcare providers who have the responsibility of delivering care to affected individuals) played any meaningful role in the design and testing of the apps. The researchers conducting the reviews concluded that the likelihood that this happened (i.e., stakeholder involvement in design and evaluation) was very low.

- Many apps made claims about various benefits that were likely to occur if an individual used them. However, in almost all cases these claims were not supported

by any evidence. Supporting evidence could take the form of reporting results from a study that evaluated individuals with a given condition such as back pain and found that individuals who used the app were more likely to achieve a desirable outcome such as less pain, better function, improved sleep, etc. than those who did not use the app.

These findings point to the need for 1) involvement of key stakeholder groups, i.e., individuals who have the condition of interest, caregivers of affected individuals, and healthcare providers in the design and testing of pain-related apps, 2) research that determines the actual benefits *and risks* associated with use of the tools, and 3) more oversight/regulation regarding how apps are advertised to prospective users.

Studies Evaluating mHealth Tool Use by Older Adults With Chronic Pain

A search of various sources found only three studies that examined mHealth tools for use by older adults with chronic pain. One study examined the feasibility of having older adults with osteoarthritis of the knee record their pain scores using an app on their mobile phones.[49] The investigators asked participants to record their pain levels on a daily basis using a paper survey and the app that had been placed on their mobile phones. The investigators found that both methods (paper and phone) produced almost identical results and that participants had no difficulty entering the information onto their phones. The authors concluded that collecting information regarding an older individual's pain level using mobile phones was feasible and may provide benefits in the delivery of healthcare to aging adults with osteoarthritis.

In the second study, researchers asked older Spanish-speaking adults with chronic pain to watch a video shown on a portable computer in a waiting room prior to seeing their doctor.[50] The video educated patients about the importance of communicating specific information about their pain (e.g., its severity, location, and impact on function) to the physician during the visit. The computer program also encouraged patients to practice what they might say to their doctor about their pain prior to the visit, which was a type of coaching. Participants who received the intervention (watched the video and received the computer-based coaching) did not report any reductions in pain one month after they visited

their doctor, but they were prescribed more strong pain medications. The authors concluded that the intervention may have increased participants' confidence in communicating their pain concerns, which led to physicians prescribing strong pain medication to this group.

Finally, in an ongoing study that is taking place in the U.S., researchers are enrolling older adults with osteoarthritis of the knee who receive an injection in the affected knee.[51] The medication that is injected into the knee joint is intended to enhance the knee's lubrication and shock absorption. After the knee injection, half of the participants in the study are asked to 1) wear an activity monitor that tracks the number of steps taken each day, 2) use a smartphone app that tracks their pain, mood, and quality of sleep ratings, and 3) read educational materials about the benefits of walking. The app has the ability to compare the number of steps taken on any given day and uses this information to send text messages to participants to either maintain or increase their level of physical activity based on their previous amount of walking. The remaining participants are individuals enrolled in a 'control arm.' This group receives the knee injections, literature that describes the benefits of walking, and wearable activity monitor but do not have access to the app. The investigators will examine both groups' pain and physical activity levels, their mood scores and how fast they can walk 20 feet at 1, 2 and 3 months after receiving the knee injection.

As of March 2017, few studies have 1) examined mHealth tools as a way of improving how we assess pain or deliver non-drug treatments to older adults with chronic pain or 2) determined whether the effects of a treatment can be enhanced using these tools, e.g., by reinforcing use of certain pain-reducing behaviors such as practicing meditation. More studies are needed to assess the benefits *and risks* of mHealth tools among older adults with various chronic pain conditions. Another shortcoming is that few apps have been evaluated using the most rigorous tool to determine whether a given intervention provides benefit, i.e., by conducting large-scale randomized controlled trials. Finally, it will be important to learn what types of outcomes (e.g., less pain, the ability to socialize more, the ability to ambulate more without pain) are perceived as important to achieve by older adults with chronic pain when using the devices.

Studies of mHealth Tool Use by Adults (Not Older Adults) With Pain

A search of various sources found that a larger number of studies have evaluated the role of mHealth tools in younger persons (individuals younger than 65 years of age) with chronic pain. A few key studies in this category are described briefly below.

In one study researchers enrolled 25 adults with cancer pain and evaluated the feasibility and acceptability of delivering a psychological therapy designed to help patients cope with pain and other burdensome symptoms.[52] The therapy was delivered to patients in their own homes via computer. The therapist and patient communicated via skype (patients and therapists spoke with one another and saw a live picture of each other on their computer screens in real time). Of the four scheduled therapy sessions, study patients participated in an average of three sessions. Participants rated the program quality as good or excellent.

In a second study, 68 participants with chronic pain were asked to download an app on their phone that then prompted them to enter pain, pain interference, and mood scores over a 4-week period.[53] Half of the participants received text messages on their phones twice every day that contained a positive message designed to provide support and encourage-ment. At the end of the 4-week study, participants who received the supportive text messages reported less pain and lower amounts of pain interference compared to those who did not receive the messages.

In another study, investigators enrolled 600 individuals under the age of 65 with a history of back pain.[54] One-third of the participants received access to a program that could be used on their phones, tablet computers, or desktop computers. The program provided education about optimal ways to manage back pain and back pain flares, and also included an activity-monitoring component that allowed this subgroup of participants to develop their own tailored approaches to managing their back pain. Finally, participants in this subgroup received twice weekly email messages that were positive and affirming about their ability to manage their back pain. Measures of pain were compared in this group to two other groups of participants: One group received 8 email messages over the 8-week study that encouraged them to access information about back pain on the internet, while the other group received usual care, which meant they were asked to continue what they were already doing for their back pain. Participants who received the mHealth intervention did much better (reported

less pain, fewer back pain flares) than participants in the other two groups.

In a fourth study, investigators enrolled 105 patients younger than 65 years of age with chronic pain and trained them how to use an app on their phones that allowed participants to 1) enter information about their pain level (after receiving a prompt to enter this information on a daily basis), 2) establish personal goals, and 3) access education about various pain topics, including optimal ways to manage pain.[55] All 105 study patients were asked to record information daily over a 3-month period. All participants also received a FitBit (a physical activity tracker worn around the wrist) that allowed them to track their daily activity levels. Finally, half of the participants received weekly supportive messages about their progress (delivered via a text message on their phone), and also could communicate (by sending text messages) with a member of the research staff if they had questions during the study. The remaining 50% of participants could not communicate with members of the research team. Participants found the app easy to use and most reported they would be willing to continue to use the app after the study was over. Over the course of the 3-month study, participants entered information about their symptoms approximately 30% of the time (reported data on 30 out of 90 days).

These findings indicate that it is feasible to use the new technologies to deliver interventions to individuals with chronic pain who are less than 65 years of age and that most participants judged the quality of care delivered using these devices as good to excellent.

Studies of mHealth Tool Use by Older Adults With Chronic Conditions Other Than Chronic Pain

We identified four studies that evaluated older adults' use of mHealth tools with chronic conditions other than pain.[56-59] One study evaluated older adults' use of four apps designed to help them manage medications taken on a daily basis.[56] Most participants in this study felt they could carry out the tasks the app asked of them, but did not see this approach as offering any distinct advantage over what they were already doing with respect to medication management. A second study evaluated older adults' use of a website program entitled *iCanFit* designed to promote physical activity among seniors.[57] Participants provided feedback about how easy (or hard) it was to use the program and how satisfied they were

completing the computer tasks. Most participants in this study reported high levels of satisfaction and perceived usefulness with the computer program.

In the third study, researchers enrolled older adults with diabetes and evaluated their ability to use an app designed to help them keep track of their glucose readings. The results entered into the mobile devices were then sent to their physicians.[58] Participants felt that much more information should have been provided regarding additional explanations about how to use the app. In the fourth study older adults with mobile phones who did not exercise regularly were enrolled.[59] Half of the participants received a booklet about the benefits of exercise and 5 text messages each week encouraging them to exercise over the 12-week study. The remaining participants got the exercise booklet only. Participants that received the booklet and reminder text messages (vs. those that got the booklet only) increased their physical activity over the 12-week study period.

These results indicate that research evaluating the role of mHealth and online programs for use by older adults is at an early stage but expanding. Most studies to date have focused on evaluating older adults' experiences using the tools, rating how easy or hard it was to use them. They underscore the importance of having older adults rate the usefulness and perceived value of these devices and of having older adults provide direct feedback as to how the devices can be optimally adapted to best meet their needs.

Summary Review

The health of aging populations in most developed countries has not kept pace with improvements in life expectancy. Many older adults spend their final years coping with and managing the consequences of multiple chronic conditions. One of the most common and disabling conditions that older adults face is chronic pain. U.S.-based health systems are not good at caring for patients with chronic pain, particularly those who are older. Numerous initiatives have been undertaken to address the problem; these efforts have been necessary but ample research indicates that there is substantial room for improvement.

Experts have asked whether mHealth technologies can improve the way chronic pain is managed. Much of the work to date has focused on the development of apps that can be stored on portable devices such as tablets and smartphones. As of 2016, the total number of

apps available to users was around 2 million. Approximately 10% of the apps are designed to help individuals improve their health generally or help them manage specific health conditions. These devices have the potential to help individuals with chronic pain engage in activities/behaviors such as performing specific exercises, taking medications as prescribed by their physician, and using mHealth tools as a way to distract them from pain, which could help older adults cope more effectively with pain and decrease one's risk of experiencing negative health consequences from pain.

Younger adults are still more likely to use smartphones, tablets, and apps as compared with older adults, but these age differences appear to be gradually narrowing. Studies of older adults with various chronic conditions, including those with chronic pain, support the notion that older adults are interested in and willing to try the devices. Factors felt to increase the likelihood of device use in older adults include a perception that the device will provide a clear benefit and availability of training to include tutorial programs that teach a user how to operate the device.

Hundreds of apps have been developed for individuals with various pain problems. These tools provide mostly education while some allow users to record information about specific symptoms (e.g., pain and mood) and determine if these symptoms are changing over time. Most apps claim that individuals will benefit directly if they use the device (e.g., experience less pain and improved function), but there is little evidence to support these claims. There is also little evidence that key groups—potential device users such as patients and their healthcare providers—have contributed to the design and testing of the devices. Little information is available regarding possible risks associated with device use and whether tangible benefits can be achieved by individuals who use them. To date, only a handful of studies have examined whether mHealth tools can improve how we assess and manage pain among older adults. Finally, the hypothesis that use of mHealth tools will inevitably lead to improved care (including better health outcomes) for individuals with chronic pain has yet to be established. Development of technology has occurred at a pace that has outstripped our ability to evaluate its value and appropriate role in the healthcare system.[60]

Gaps

We reviewed existing research studies for this report and identified gaps that further research could address. These knowledge gaps are shown in the Table below. To identify the gaps we used an established method[61] that involves searching the published scientific literature on any given topic for phrases such as "limited information is available regarding…" "more research is needed in the area of …" and "Only one study examined…" Knowledge gaps have also been provided by the authors of this report that include experts in the fields of gerontology and geriatric medicine, pain care, technology, and the behavioral and social sciences.

Table. Knowledge Gaps and Recommended Studies to Address the Gaps.

Gaps	Suggested Studies
What are the short- and long-term benefits/risks of mHealth devices as tools to assess and/or manage pain in older adults?	Determine the short- and long-term benefits and risks of various mHealth devices in studies of older adults with chronic pain
What outcomes do older adults believe are most important to achieve by using mHealth devices?	Identify the types of results older adults with pain most hope to achieve by using mHealth devices
Can key stakeholder groups (e.g., older adults, clinicians) help to design and test more useful/effective mHealth tools?	Determine the benefits (e.g., ease of use, perceived usefulness, regular use of device over time) of obtaining key stakeholder input into the design and evaluation phase of mHealth tools
What factors increase or decrease older adults' willingness to try mHealth tools and willingness to use the devices over time?	Identify factors at the individual (e.g., social, cognitive, physical factors); family (e.g., level of family support and reinforcement) and health-system (e.g., level of physician support) level that promote engagement in and ongoing use of mHealth devices
Can mHealth devices help to promote positive behavior change in older adults with chronic pain?	Determine whether desired behaviors (e.g., taking pain medications on regular basis, exercising, meditating on regular basis) can be achieved by using these devices
What are healthcare providers' attitudes, preferences and receptivity regarding the use of mHealth tools in clinical practice?	Conduct studies to determine healthcare providers' attitudes, preferences and receptivity to use of mHealth tools in the care of older patients with chronic pain
Gaps	**Suggested Studies**

Can the use of mHealth tools increase adherence with existing pain therapies thereby enhancing their effectiveness?	Conduct studies that determine the 'added value' of monitoring or helping to reinforce certain behaviors (e.g., performing back stretching exercises regularly) among older adults *AND* can mHealth devices enhance adherence to existing treatments (e.g., can they increase the likelihood that older adults will take prescribed pain medications on regular basis)
Are healthcare systems ready and willing to incorporate information/data generated by mHealth devices?	Conduct studies that evaluate healthcare system "readiness" to adopt/incorporate information generated by mHealth devices
What are the specific barriers and facilitators to incorporating mHealth devices into patient care?	Conduct studies that identify key barriers & facilitators to incorporating information generated by mHealth devices directly into health systems, e.g., into their electronic health records
Can the use of mHealth tools help to lower healthcare costs?	Determine whether healthcare costs increase, remain the same or decrease when mHealth devices are employed in populations of older patients with pain (e.g., those receiving cancer treatment or undergoing rehabilitation after joint replacement or receiving care at home after a painful injury)
What is the role of paid and informal caregivers in helping to encourage older adults' use of mHealth devices	Identify the role older adults' caregivers might play in helping older adults use mHealth devices
What are the triggers motivating older adults to use an mHealth tool?	Determine the triggers that facilitate engagement with and continued use of mHealth tools by older adults with chronic pain
Can mHealth tools help to increase access to health care, particularly in underserved populations	Conduct studies to determine whether access to healthcare, particularly in underserved populations, can increase through use of mHealth devices
Which subgroups of older adults with pain and which types of pain problems are most likely to benefit most from the use of mHealth devices	Identify specific groups of older adults with various pain disorders (e.g., those with back pain versus those with pain due to diabetes versus those with fibromyalgia) that are most likely to benefit from mHealth device use

Conclusions

This review is the starting point for the consensus workshop to be held at the Weill Cornell Medical Center in New York City on April 7th, 2017. The report highlights what researchers believe are the most important knowledge gaps regarding mHealth technologies and their role in providing pain care to aging adults. **The goal of the conference is to**

create a research agenda for mHealth and later-life pain care that will guide the field by combining the input from multiple stakeholder groups to include the researcher viewpoints (listed above), as well as the viewpoints of older individuals with chronic pain, clinicians who provide care to older adults, behavioral and social scientists working in the area of aging, technology experts and researchers, policy experts, and pain researchers/specialists. The key question at hand is what knowledge is most needed to improve practice. The April 7th workshop will be devoted to merging the views of the researchers with those voiced by the other groups. Our experience hosting similar conferences like this in the past leads us to believe that it is critically important to create a research agenda that extends beyond what researchers believe we need to know.[62-64] At the workshop, we will ask for your thoughts about what researchers feel are the most important knowledge gaps.

- Where are they correct?
- What do they miss?
- What additional gaps and recommendations should be considered?

After we generate a list of research recommendations during the conference, we will ask conference attendees to rank these topics in terms of perceived importance. The resulting research agenda will represent the joint priorities of all stakeholder groups attending the conference to include mostly importantly the views and perspectives of older adults themselves. We believe this exercise can help to guide research in this area toward answering the most pressing questions, and in so doing advance the delivery of (and outcomes associated with) pain care for older adults. In preparation for the conference, we ask that you reflect on the above priorities to determine whether or not they resonate with you. **Based on your own experience, what are important areas where knowledge is limited, i.e., what areas do *you* think need more research?**

Thank you for taking the time to read this report. We look forward to an engaging conversation on this important topic when we see you on April 7th.

References

1. http://www.un.org/en/development/desa/population/publications/pdf/ageing/WPA2015_Report.pdf. Last accessed March 24th, 2017.

2. Global Agenda Council on Ageing. Technological innovations for health and wealth for an ageing global population. Geneva Switzerland, pp 1-21, 2016.

3. https://www.cdc.gov/chronicdisease/about/multiple-chronic.htm. Last accessed March 25, 2017.

4. Institute of Medicine (US) Committee on Advancing Pain Research, Care, and Education. Relieving Pain in America: a Blueprint for Transforming Prevention, Care, Education, and Research. National Academies Press (US), 2011.

5. Patel KV, Guralnik JM, Dansie EJ, Turk DC. Prevalence and impact of pain among older adults in the United States: Findings from the 2011 National Health and Aging Trends Study. Pain 2013;154(12):2649–57.

6. Reid MC, Eccleston C, Pillemer K. Management of chronic pain in older adults. BMJ 2015 Feb 13;350:h532. doi: 10.1136/bmj.h532.

7. http://www.iasp-pain.org/PublicationsNews/Content.aspx?ItemNumber=1673. Last accessed March 24, 2017.

8. Makris UE, Abrams RC, Gurland B, Reid MC. Management of persistent pain in the older patient: a clinical review. JAMA 2014 Aug 27;312(8):825-36. doi: 10.1001/jama.2014.9405.

9. Braden JB, Sullivan MD. Suicidal thoughts and behavior among adults with self-reported pain conditions in the National Comorbidity Survey replication. J Pain 2008;9(12):1106-1115.

10. Edwards RR, Smith MT, Kudel I, Haythornthwaite J. Pain-related catastrophizing as a risk factor for suicidal ideation in chronic pain. Pain 2006;126(1-3):272-279.

11. Ilgen MA, Kleinberg F, Ignacio RV et al. Non-cancer pain conditions and risk of suicide. JAMA Psychiatry 2013;70(7):692-97. doi:10.1001/jamapsychiatry.2013.908

12. Fishbain DA, Bruns D, Disorbio JM, Lewis JE. Risk for five forms of suicidality in acute pain patients and chronic pain patients vs pain-free community controls. Pain Med 2009;10:1095-05.

13. Tang NK, Crane C. Suicidality in chronic pain: a review of the prevalence, risk factors and psychological links. Psychol Med 2006;36:575-86.

14. Hassett Aquino JK, Ilgen MA. The risk of suicide mortality in chronic pain patinets. Curr Pain Headache Rep 2014;18:436. Doi: 10.1007/s11916-014-0436-1.

15. Reid MC. Expanding targets for intervention in later life pain: What role can patient beliefs, expectations, and pleasant activities play? Clin Geriatr Medicine 2016;32(4):797-805.

16. Abdulla A, Adams N, Bone M, Elliott AM, Gaffin J, Jones D, et al. Guidance on the management of pain in older people. Age Ageing 2013;42 (Suppl 1):1-57.

17. American Geriatrics Society Panel on Persistent Pain in Older Persons. Pharmacological management of persistent pain in older persons. J Am Geriatr Soc 2009;57:1331-46.

18. Haller G, Agoritsas T, Luthy C, Piguet V, Griesser AC, Perneger T. Collaborative quality improvement to manage pain in acute care hospitals. Pain Med 2011;12:138–47.

19. Breivik H, Eisenberg E, O'Brien T. The individual and societal burden of chronic pain in Europe: the case for strategic prioritisation and action to improve knowledge and availability of appropriate care. BMC Public Health 2013;13:1229
DOI: 10.1186/1471-2458-13-1229.

20. Neufeld NJ, Elnahal SM, Alvarez RH. Cancer pain: a review of epidemiology, clinical quality and value impact. Future Oncol 2017;13(9):833-41. (doi:10.2217/fon-2016-0423)

21. Doherty S, Knott J, Bennetts S, Jazayeri M, Huckson S. National project seeking to improve pain management in the emergency department setting: Findings from the NHMRC-NICS National Pain Management Initiative. Emerg. Med. Australas 2013; 25:120–6.

22. World Health Organization. mHealth: New horizons for health through mobile technologies. Second global survey on eHealth. Geneva, Switzerland: WHO Press; 2011. [2016-03-02].

23. Whittaker R, Merry S, Dorey E Maddison R. A development and evaluation process for mHealth interventions: examples from New Zealand. J Health Communication 2012;17(Suppl 1):11-21.

24. Thakkar J, Kurup R, Laba TL, et al. Mobile telephone text messaging for medication adherence. A Meta-analysis. JAMA Intern Med 2016;176(3):340-349. doi:10.1001/jamainternmed.2015.7667

25. Wiederhold BK, Gao K, Kong L, Wiederhold MD. Mobile devices as adjunctive pain management tools. Cyberpsychol Behav Soc Netw 2014 2014 Jun 1; 17(6): 385–389. doi: 10.1089/cyber.2014.0202.

26. Guillory JE, JT, Woodruff C, Keilman J. Text messaging reduces analgesic requirements during surgery. Pain Med 2015;16(4):667-72.

27. http://www.iab.com/wp-content/uploads/2016/10/Digital-Advertising-Fast-Facts-Oct-2016.pdf. Last accessed March 25, 2017.

28. http://research2guidance.com/r2g/r2g-mHealth-App-Developer-Economics-2016.pdf. Last accessed March 25, 2017.

29.http://www.imshealth.com/files/web/IMSH%20Institute/Reports/Patient%20Adoption%20of%20mHealth/IIHI_Patient_Adoption_of_mHealth.pdf. Last accessed March 25, 2017.

30. Piwek L, Ellis DA, Andres S, Joinson A. The rise of consumer health wearables: Promises and barriers. Plos Med February 2, 2016 http://dx.doi.org/10.1371/journal.pmed.1001953

31. McGaughey RE, Zeltmann SM, McMurtrey ME. Motivations and obstacles to smartphone use by the elderly. Developing a research framework. Int J Electronic Finance 2013;7(3/4):177-95.

32. Plaza I, Martin L, Martin S, Medrano C. Mobile applications in an aging society: Status and trends. J Systems and Software 2011;84:1977-88.

33. http://www.pewinternet.org/2014/04/03/older-adults-and-technology-use. Last accessed March 25, 2017.

34. http://www.pewinternet.org/2015/10/29/the-demographics-of-device-ownership. Last accessed March 25, 2017.

35. http://www.pewinternet.org/2011/08/26/65-of-online-adults-use-social-networking-sites. Last accessed March 25, 2017.

36. http://www.pewresearch.org/fact-tank/2015/04/29/seniors-smartphones. Last accessed March 25, 2017.

37. Cho J. The impact of post-adoption beliefs on the continued use of health apps. Int J Med Informatics 2016;87:75-83.

38. https://www.cs.ubc.ca/~joanna/papers/GRAND2012_Tang_MobilePhone.pdf. Last accessed March 25, 2017.

39. Lee C. Adoption of smart technology among older adults: Challenges and issues. Gerontological Soc of America Public Policy and Aging Report. December 17, 2013. Doi:10.1093/ppar/prt005.

40. Coleman GW, Gibson L, Hanson VL, Bobrowicz A, McKay A. Engaging the disengaged: How do we design technology for digitally excluded older adults? DIS 10 Proceedings of the 8th ACM Conference on Designing Interactive Systems pp 175-178. Aarhus, Denmark — August 16 - 20, 2010.

41. Parker SJ, Jessel S, Richardson JE, Reid MC. Older adults are mobile too! Identifying the barriers and facilitators to older adults' use of mHealth for pain management. BMC Geriatrics 2013;13:43. Doi:10.1186/1471-2318-13-43.

42. Richardson JE, Lee JI, Nirenberg A, Reid MC. The potential role for smartphones among older adults with chronic noncancer pain: A qualitative study. Pain Med. 2017 Jan 20. pii: pnw284. doi: 10.1093/pm/pnw284.

43. Currie M, Philip LJ, Roberts A. Attitudes towards the use and acceptance of eHealth technologies: A case study of older adults living with chronic pain and implications for rural healthcare. BMC Health Services Research 2015;15:162.

44. Reynoldson C, Stones C, Allsop M, et al. Assessing the quality and usability of smartphone apps for pain self-management. Pain Med 2014;15:898-908.

45. de la Vega R, Miro J. mHealth: A strategic field without a solid scientific soul. A systematic review of pain-related apps. PLOS One 2014;9(7):e101312.

46. Lalloo C, Jibb LA, Rivera J, Agarwal A, Stinson JN. There's a pain app for that: Review of patient-targeted smartphone applications for pain management. Clin J Pain. 2015 Jun;31(6):557-63. doi: 10.1097/AJP.0000000000000171.

47. Wallace LS, Dhingra LK. A systematic review of smartphone applications for chronic pain available for download in the United States. J Opioid Manag. 2014 Jan-Feb;10(1):63-8. doi: 10.5055/jom.2014.0193.

48. Rosser BA, Eccleston C. Smartphone applications for pain management. J Telemed Telecare. 2011;17(6):308-12. doi: 10.1258/jtt.2011.101102.

49. Bellamy N, Wilson C, Hendrikz J, et al. Osteoarthritis Index delivered by mobile phone (m-WOMAC) is valid, reliable, and responsive. J Clin Epidemiol 2011;64:182-90.

50. McDonald DD, Walsh S, Vergara C, Gifford T, Weiner DK The effect of Spanish virtual pain coach for older adults: A pilot study. Pain Med 2012;13:1397-1406.

51. Jones D, Skrepnik N, Toselli RM, Leroy B. Incorporating novile mobile health technologies into management of knee osteoarthritis in patients treated with intra-articular hyaluronic acid: Rationale and protocol of a randomized controlled trial. JMIR Res Protocols 2016 Jul-Sep;5(3):e164.

52. Somers TJ, Abernethy AP, Edmond SN, et al. A pilot study of a mobile health pain coping skills training protocol for patients with persistent cancer pain. J Pain Symptom Manage 2015; 2015 Oct;50(4):553-8. doi: 10.1016/j.jpainsymman.2015.04.013.

53. Guillory J, Chang P, Henderson CR Jr, et al. Piloting a text message-based social support intervention for patients with chronic pain: Establishing feasibility and preliminary efficacy. Clin J Pain 2015 Jun;31(6):548-56. doi: 10.1097/AJP.0000000000000193.

54. Irvine AB, Russell H, Manocchia M, et al. Mobile-web app to self-manage low back pain: Randomized controlled trial. J Med Internet Res 2015 Jan;17(1):e1.

55. Jamison RN, Jurcik DC, Edwards RR, Huang CC, Ross EL. A pilot comparison of a smartphone app with or without 2-way messaging among chronic pain patients: Who benefits from a pain app? Clin J Pain. 2016 Nov 24. [Epub ahead of print]

56. Grindrod KA, Li M, Gates A. Evaluating user perceptions of mobile medication management applications with older adults: A usability study. JMIR Mhealth Uhealth 2014 Jan-Mar 2(1): e11.

57. Hong Y Goldberg D, Dahlke DV, et al. Testing, usability and acceptability of a web application to promote physical activity (iCanFit) among older adults. JMIR Human Factors 2014;1(1):e2. Doi: 10:2196/humanfactors.3787.

58. Isaokovic M, Sedlar U, Volk M, Bester J. Usability pitfalls of diabetes mHealth apps for the elderly. J Diabetes Res 2016; Article ID 1604609, 9 pages http://dx.doi.org/10.1155/2016/1604609.

59. Muller AM, Khoo S, Morris T. Text messaging for exercise promotion in older adults from an upper-middle-income country: Randomized controlled trial. J Med Internet Res 2016 Jan; 18(1):e5. Doi: 10.2196/jmir.5235

60. Nilsen W, Kumar S, Shar A, et al. Advancing the science of mHealth. J Health Communication 2012;17:5-10.

61. Riffin C, Pillemer K, Chen EK, Warmington M, Adelman RD, Reid MC. Identifying key priorities for future palliative care research using an innovative analytic approach. Am J Public Health. 2015 Jan;105(1):e15-e21.

62. Sabir M, Breckman R, Meador R, Wethington E, Reid MC, Pillemer K. The CITRA research-practice consensus-workshop model: exploring a new method of research translation in aging. Gerontologist 2006 Dec;46(6):833-9.

63. Sabir M, Wethington E, Breckman R, Meador R, Reid MC, Pillemer K. A community-based participatory critique of social isolation intervention research for community-dwelling older adults. J Appl Gerontol 2009;28(2):218-34.

64. Pillemer K, Chen EK, Riffin C, Prigerson H, Reid MC. Practice-based research priorities for palliative care: Results from a research-to-practice consensus workshop. Am J Public Health. 2015 Nov;105(11):2237-44. doi: 10.2105/AJPH.2015.302675.