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Older Adults and Mobile Phones for Health: A Review

Jonathan Joe[a,*] and **George Demiris**[a,b]

[a]Biomedical and Health Informatics, University of Washington, Box 357240, 1959 NE Pacific Street, HSB I-264, Seattle, WA 98195-7240, USA

[b]School of Nursing, University of Washington, Box 357266, 1959 NE Pacific Street, Seattle, WA 98195-7240, USA

1. Introduction

New technologies and innovations have promised to make tasks faster, safer, and more efficient and effective. Technological innovations have already been used to bridge health disparities and meet unmet needs of populations[1]. While many previous systems were constructed with clinical professionals and healthcare administration in mind, there has recently been an increasing interest in applying these new technologies to consumer health, empowering patients to take control and play an active role in managing their health. Consumer health technology interventions have been used, for example, to help individuals monitor their own health[2], to provide information and social support[3,4] and for remote home monitoring[5].

One example of a technology that can potentially support a consumer health focus includes mobile phones. Within the United States, an increasing number of people are subscribing to mobile telephony services, rising from 44.2% penetration in 2001[6] to 83% penetration in 2011[7] in American adults. The growth of mobile phones has led to a scenario where mobile phones are considered ubiquitous among the population. In fact, even older adults, who as a subpopulation may be viewed generally as technological laggards, have also been obtaining mobile phones at increased rates. As of 2012, 69% of older adults aged 65 or older owned a cell phone[8]. Consequently, older adults are more likely to own a mobile phone than a desktop (48%) or laptop computer (32%)[8]. This suggests that if system designers were to select a technology platform that would reach the majority of older adults, mobile phones would be ideal due to their high penetrance rate.

Over the next 20 years, the number of adults aged 65 years or older in the United States is projected to grow briskly, rising from 40 million in 2010 to 72 million in 2030[9]. As an individual ages, there is an increased likelihood of having a multiple health problems or comorbidities[10], which leads to an increasing need for health and/or disease management interventions. While medications may be part of the intervention, they cannot help with other activities, such as lifestyle changes and health monitoring. For example, previous interventions include smart homes for health monitoring[11,12], videophones for telehealth applications[13], and sensors for fall detection and mobility[14,15]. These demographic trends, combined with the growth of mobile phone telephony among the older adult

*Corresponding author: Jonathan Joe, jjoe@washington.edu, 206-569-8403;.

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population, suggest that using the mobile phone as a platform for interventions in health may be a viable way forward.

Given the rapid growth of mobile phones, and its potential as a platform for improving the health of older adults, along with the projected growth of population, it is important to examine current evidence of use of mobile phones by older adults for health purposes (including communication, education, and health monitoring), and understand gaps and challenges in order to inform the design of future systems given the ubiquity of mobile phones. The purpose of this literature review was to examine the current state of mobile phone use for health related interventions targeting older adults.

2. Methods

2.1 Literature Search

The literature search was informed by the following research questions:

1. How have mobile phones been used for health interventions that target older adults?
2. What is the level of evidence for the effectiveness of mobile phone based health interventions with older adults?

Relevant literature was identified via searching Pubmed and CINAHL. We searched PubMed with combinations of MeSH terms "Cellular Phone" and "Aged" as well as keyword terms, such as "Mobile devices" and "Older adults." Within CINAHL, we utilized the subject heading of "Aged" with other keywords of "elderly," "older adult," with keywords for mobile phones, including "mobile phone," "cell phone," "cellular phone," "cellular telephone," and "mobile telephone". Articles were included if they were published between 1965 and June 2012.

2.2 Inclusion/ Exclusion Criteria

The aim of this review was to survey the current state of the field, where mobile phone interventions were explored for the purposes of improving or managing the health of older adults. Consequently, in order to be eligible for the review, the projects needed to utilize a mobile phone as an intervention, involve or explicitly target adults that are 60 years of age or older, and have an aim that emphasizes the mobile phone's use in health or health issues. Within the initial search, abstracts were reviewed by the first author (JJ) to determine if they matched the aforementioned criteria. Once these articles were filtered, the remaining full text articles were analyzed by both authors for a more detailed review. Articles were eliminated if the focus of the project was on unrelated non-health aspects of a device or intervention, focused solely on the technology, or was not published in English. We also excluded reviews and other articles that did not contribute original research. Articles that were unclear on how they fit into the scope of the criteria were resolved via discussion. For each study included, we scored the level of evidence based on the Oxford Centre for evidence based medicine framework by both authors[16]. This framework introduces levels to help assess the strength of evidence of study findings. The framework includes 5 levels (Level 1: Meta analyses, Level 2: Randomized Trials, Level 3: Non-Randomized Studies, Level 4: Case studies, Level 5: Mechanism based reasoning). For our purposes, studies that included observations within a laboratory were classified as level 4. Per the framework, cohort studies of poor quality prognostic studies were classified as level 4.

3. Results

The initial searches on Pubmed and CINAHL yielded 310 articles, and 200 articles, respectively, for a total of 510 articles, before removing duplicates or filtering. Articles were eliminated based upon review of titles and abstracts, yielding 85 articles, 73 from Pubmed and 12 from CINAHL. The 85 remaining articles underwent full review and 63 articles were eliminated, leaving 21 articles were included in the final set. The 21 resulting articles from the filtered searches were categorized into 10 major clinical domains, which are discussed in more detail below. Table 1 summarizes the articles included in the review.

3.1 Activities of Daily Life

New mobile technologies, such as the mobile phone have opened new opportunities in rural homecare. Kotani et al. recruited 19 elderly participants in a rural area under home care for chronic disease and requested that they use a mobile phone camera to log activities of daily life, rather than writing it down on paper to demonstrate the practicality of the technology for elderly home care (Level of Evidence: 4) [17]. The trial was successful due to the technology's acceptance by older adults, including those who refused traditional instant cameras, with 16 out of 19 (84%) subjects agreeing to take photos with the mobile cameras. The study also suggests that using mobile phone cameras is a promising route especially when considering its facile operation and ability to transfer photos easily for the staff.

3.2 Alzheimer's / Dementia Care

Mobile phones have been used for different purposes in dementia care, including memory enhancement and wandering safety. The use of mobile phones to track wandering patients via the global positioning system (GPS) chips has been explored by both Fauconau (Level of evidence:4) et al and Miskelly (Level of evidence: 4) [18,19]. Miskelly reported on being able to successfully and accurately locate 11 persons who have wandered, and the mobile phone acted as a reliable tracking device, showing greater than 90% successful location concordance with description given by carer of participant (Level of Evidence: 4). Faucanau was interested in attitudes, barriers, and feelings of usefulness of the tracking device, and reported on a case study with 1 caregiver and 1 subject, and reported on the subject's dissatisfaction with the aesthetic of the device, and the caregiver's usage difficulties. However, both studies noted that compliance can be an issue, where it can be difficult to encourage or ensure that the patient carries the device so that they can be located. In addition, the studies identified that the caregiver and patient may have different acceptability criteria and wants that may conflict with each other.

De Leo et al requested that a single older adult with Alzheimer's disease wear a smartphone that was programmed to take photos every 5 minutes to assess satisfaction and recent events memory recall before and after completing the intervention (Level of evidence: 4) [20]. Once completed, a slideshow was generated, which was shown to improve the recall of events during the day significantly. At baseline, the subject remembered 12/47 (26%) events, and after the intervention, the subject remembered 26/47 (55%) events. The passive, unobtrusive use of a smartphone to take photos helped the project achieve its goals of taking photos at regular intervals to improve memory recall of recent events without patient intervention.

3.3 Chemotherapy Symptom Management

A patient undergoing chemotherapy as a treatment may experience many undesirable side effects that can negatively affect their quality of life[21]. Prompt intervention at the first appearance of side effects can minimize the negative effects of chemotherapy. Both Weaver et al. (Level of evidence : 3) and Larsen et al. (Level of evidence : 3) performed symptom management feasibility studies concerning the use of mobile phones to report adverse chemotherapy symptoms[22,23]. Weaver et al. sought to assess and analyze the feasibility of alert generation, patient satisfaction and acceptability, while Larsen et al. sought to assess patient compliance, types of symptoms reported, acceptability, and the types or alerts generated. Both studies involved 6 subjects with colon cancer, and the mobile phone intervention issued an alert to clinical staff when moderate to severe symptoms were submitted, which allowed them to contact the patient and give them advice as needed. These systems also included a patient diary and automatic self-care advice, which did not overwhelm the patients. The systems were found to be feasible, with alerts being successfully acknowledged with 24/25 (96%) red alerts acknowledged by staff (Weaver et al.) and the patients exhibiting high data entry compliance with both Weaver and Larsen's study showing 98% compliance for the diaries. All subjects (6/6) found the system to be acceptable and felt positively about the system in both studies. There were no comparator groups for the selected studies.

3.4 Palliative Care Symptom Management

Effective palliative care requires the knowledge of, and changes in the symptoms of the patient, to minimize symptom distress and increase well-being. Consequently, mobile phones have the potential to remotely collect symptom data at regular intervals, which may not have been possible previously. McCall et al explored using a mobile phone platform for remote monitoring of symptoms via a patient's reported assessments (Level of evidence: 3) [24]. The study sought to assess the acceptability and usability of a mobile application via pre-post study questionnaires using 21 patients receiving palliative care and 9 health professionals. Automatic self-care advice was shown in response to patient input, and a healthcare provider remotely reviewed their symptoms daily. Both patients and healthcare providers reported that the tool was helpful or very helpful for symptom monitoring at baseline (Patients: 21/21, Providers: 9/9) and after the intervention (Patients:9/13 (69%), Providers: Majority). The healthcare providers also felt the early warnings of symptom issues could permit timely interventions. Consequently, the pilot study successfully demonstrated feasibility, usability, and acceptability of the system. However, studies with a larger number of subjects are needed to establish a stronger evidence base for these attributes, including studies involving a wider range of patients and tests of scalability of the system.

3.5 Congestive Heart Failure

Congestive heart failure (CHF) disproportionately affects older adults, and CHF patients have a high rate of hospital readmission [25]. The use of home telemonitoring has shown promise for heart failure patients in reducing the duration of hospital stays and mortality rate[26]. Consequently, there has been interest in using mobile phone technology as a way to monitor remotely patients at home (telemonitoring). Scherr et al. performed a randomized controlled trial with 120 participants to evaluate whether a mobile phone based telemonitoring platform could detect early symptoms of impending heart failure to prevent hospitalization (Level of Evidence: 2)[27]. The platform alerted the healthcare provider if a patient showed signs of worsening symptoms, so that the provider could act early. The study suggests that the platform significantly reduces the duration (median length of 6.5 days compared to 10.0 days with the control group) of heart failure hospitalization, and had a high acceptability rate among the patients (95% adherence by patients in intervention arm).

3.6 Chronic obstructive pulmonary disease (COPD)

Exercise training has been established to improve quality of life, including improvements in fatigue, emotions, and dyspnea for patients with COPD[28]. Consequently, adherence to such a training program can improve patient quality of life and help with pulmonary rehabilitation. The feasibility of mobile phones for entering exercise and symptom data has been studied by Nguyen et al, which found acceptable response rates (~83%) from patients using the program using 6 older adult patients with COPD (Level of evidence: 4)[29]. There have been further studies with more elaborate mobile phone interventions, including a mobile phone based exercise program by Nguyen et al (Level of evidence:2) and Liu et al (Level of evidence:2) [30,31]. Nguyen et al compared a self-monitored group (n=8) that used the mobile phone program versus another group (n=9) that had ongoing reinforcement and symptom monitoring. They found that the self-monitored group performed better than the coached group in a number of physical activity tests including increased total steps per day (p=0.04) and higher peak performance (p=0.002). Liu et al found that a mobile phone based exercise training program with reminders showed increased duration and distance via the Incremental Shuttle Walk Test (ISWT) from baseline for the cell phone group (n=24, p<0.001) but not the control group (n=24, p=0.078), rising to 324.2m after 12 weeks compared to baseline at 255.8m. In addition, the mobile intervention group showed improved exercise capacity (Inspiratory capacity: 12 weeks 1.75L, Baseline:1.59L, p<0.001), and quality of life (SF-12 at 12 weeks: 45.4, baseline: 38.7, p<0.01) with a reduction in worsening symptoms, along with good compliance. While both Nguyen and Liu both showed improvements in physical activity over time, it remains to be seen which parts of the interventions are essential to see the improved clinical outcomes in COPD patients.

3.7 Diabetes

Since self-management of diabetes requires patient adherence to best practice recommendations (e.g. dietary management, glucose monitoring, physical activity, etc.), there has been an interest in increasing compliance with self-care advice[32]. One method of increasing compliance is via reminders, which was explored by both Lim et al (Level of Evidence: 2) and Durso et al (Level of Evidence:3) [33,34]. While they both studied the effect of a rule-based reply based on health-related data entered via mobile phone, Lim performed a randomized controlled trial that used telemetric data from a glucometer used by the patient, along with other information from an EMR. In the Lim study, 144 subjects were randomized into several groups, and those who were given patient-specific messages (n=49) and reminders achieved better glycemic control with less hypoglycemia (AIC<7.0%, 30.6%), compared to those in the group who were who were self-monitored (n=47, 23.4%, p=0.027) or routine care groups(n=48, 14.0%, p=0.019). Durso et al (n=10 enrolled, 7 completed) used a mobile phone as a platform to enter personal health data, and as a way to get automated interactive voice messages for reminders in response and the study sought to ascertain usability and satisfaction via survey, as well as a pre/post test on diabetes knowledge. Their healthcare provider could also review the data, and the subjects in the study reported a positive perception of the system (Value in management of diabetes: 4.28/5). Similar to Lim, Durso reported that subjects had improved glycemic control and diabetes knowledge (3/7 (42%) subjects increased diabetes knowledge test scores) after using the system.

Reducing the barriers to use of self-management tools, such as by increasing ease of use can also increase compliance with the tool. Rollo et al (Level of evidence: 3) studied the feasibility of using a mobile phone camera to record dietary intake in diabetics with 10 participants by comparing the phone system to the standard food diary, and by using questionnaires to assess usability and acceptability[35]. When compared to a food diary, it was deemed an acceptable alternative, with some caveats. All patients reported the phone system was easier to use, and most subjects reported that it took less time than a written food diary (6/10). However, there was some underreporting of items eaten, with the energy intake on the phone being underreported on average by 649kJ (p=0.03) compared to the standard written food diary. This discrepancy needs to be mitigated in future studies. Another method to increase the ease of use is to allow data to be transmitted passively, rather than requiring a user to actively transmit the data. Lee et al (Level of evidence: 3) investigated the use of a low power protocol, Zigbee, to transmit blood glucose and ECG data via mobile phone to a central server with 29 older adults[36]. The data were successfully transmitted (78% blood glucose measurements successfully transmitted); thus, findings suggest that Zigbee may have a place in telemonitoring systems.

3.8 Falls and Fall Risk

Falls are one of the leading causes of accidental injury and death among older adults, and is a major care burden on social services[37,38]. Previous studies have investigated using wearable sensors to detect falls, which would hopefully minimize the amount of time between the fall and receiving medical attention[39,40]. More recently, there has been interest in using sensors already built into phones for the purposes of fall detection and fall risk. Lee and Carlisle (Level of evidence:4) investigated whether mobile phone accelerometers could detect falls compared to a standalone wearable accelerometer sensor[41]. The study found that there was agreement between the phone (Mobile sensitivity: 0.77, specificity: 0.81) and standalone accelerometers (Standalone sensitivity: 0.96, specificity: 0.82), which suggests that their method showed the feasibility of using the accelerometer within a mobile phone for fall detection.

Fall risk has also received attention, so that individuals at higher risk for falls can be monitored. Dual-task performance has previously been used to evaluate the risk of falls[42,43]. However, definite, repeatable conclusions could not be drawn via these tests due to lack of standardization, such as using a well-defined quantitative task for evaluation of the individual[43]. Yamada et al (Level of evidence: 3) assessed the viability of a smartphone-based dual tasking program as a measure to gauge fall risk via dual tasking lag when compared to single tasking[44]. The subjects (n=318) were assayed while walking, but the results only weakly correlated with other physical performance tests previously validated with risk of fall. Further, the application could not accurately predict which subjects would eventually fall during the study period. However, the application did have advantages over traditional dual task tests, including portability, simplicity and greater access since the application could potentially be downloaded worldwide.

3.9 Osteoarthritis

Self-reported health information has been used as a way to provide more opportunities to measure health-related quality of life metrics. For osteoarthritis, self-reported patient metrics have been developed, one of which is the Western Ontario and McMaster Universities Arthritis Index (WOMAC)[45]. The paper version of WOMAC has been successfully transferred into new electronic formats that can be accessed via computerized touchscreen devices[46,47]. With the growth of mobile phones, there has been more recent interest in testing a version of WOMAC on a mobile phone. Bellamy et al (Level of Evidence:4) tested a version of the mobile WOMAC index (m-WOMAC) with older adult patients (n=12), who regarded the system as easy to use (Very easy:11/12) and acceptable for use (Very confident in continued use: 11/12), with the index being transmitted successfully[48]. Other studies (n=62, n=12) found a high agreement between paper and mobile versions of the WOMAC index (Level of evidence: 4, 4; Correlation: 0.90+, 0.996), and found that the favorable reviews by participants and the effectiveness of the platform held across multiple phones[49,50].

3.10 Dermatology

Nonmelanoma skin cancers represent a third of all cancers within the United States[51]. It is estimated that one in six Americans will experience skin cancer in their lifetime, and early detection and identification can improve outcomes significantly[52]. In addition, older adults show higher rates of non-melanoma skin cancers than younger age groups[53]. Consequently, the ease of use and availability of mobile phones has garnered interest in applying it into teledermatology to diagnose skin lesions. Kroemer et al (Level of evidence: 3)used mobile phones as a platform for a clinician to take and transmit photos of skin lesions, which were then diagnosed by a dermatologist[54]. They compared teledermatologic evaluation using photos from a mobile phone camera (with and without a dermatoscope), with a histologic examination (gold standard) and face-to-face evaluation. The results were comparable (n=88 patients) between the gold standard and the mobile phone camera (90% agreement with histopathologic examination), suggesting that mobile teledermatology has potential for an acceptable diagnostic accuracy for skin tumor screening.

3.11 Overall State of the Field

It is important to not only look at the studies from individual disease states, but to look across broadly at the methods, outcomes, and processes of these studies to better understand the level of evidence currently available in aggregate for older adults. Several ideas have been shown to be technologically feasible, such as transmitting patient reported outcomes to a central server via the mobile device, or sending rule-based, patient specific feedback based on the data[19,24,29,34]. Rule-based feedback can be combined with healthcare provider alerts and review, which in some studies were considered useful by the acting healthcare provider[24,27,34]. In addition, several studies have shown high patient acceptability of mobile systems, along with patient satisfaction of the effectiveness of the system[22,23,48]. However, many of these studies were pilot or feasibility studies with small sample sizes of older adults, and consequently need to be replicated with larger samples to generate more generalizable results and establish a higher confidence in the evidence.

Across all studies, the most common study design was a pilot or feasibility study, constituting 11 of the 21 studies identified. The smallest number of participants were in case studies with 2 participants [18,20], and the largest number of participants involved in a single study was an evaluation study with 318 participants[44]. Of the 21 studies, 5 studies showed improved clinical outcomes [20,27,31,33,34], and 4 studies showed an equivalence between the intervention and a gold standard [35,49,50,54]. Many of the studies used the mobile phone as a way for the intervention to follow the participants throughout their day [17–19,22–24,29,30,34,35,48], while others primarily focused on the intervention being used in a lab [41,44,50], or at home[27]. Multiple studies also included a clinic component, where a healthcare provider would have access to or alerted by the intervention's data[23,24,27,31,34,36,49].

Many studies commented on issues and other considerations for older adults in design, usability, and function. Studies commented that interventions need to address assumptions or psychological barriers to be acceptable for use with older adults. For example, Kotani et al. reported success when using mobile phones to take photos even when older adults refused to be in photographs with traditional cameras[17]. Mobile phones and mobile phone cameras were seen as informal and pervasive, and thus seen as acceptable when traditional cameras are not. In addition, devices should be designed in a manner that is not stigmatizing to the individual using or wearing them, so as to not convey a lack of independence[18]. Mobile phones, due to their ubiquitous nature, could then be leveraged without stigma for clinical usage in a manner that other devices may not allow.

Individuals also want to keep control over devices to maintain their privacy and not feel like they are constantly being monitored or tracked[18,19]. However, while older adults want to be able to remove the device at will, this may create conflict with caregivers, who believe

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that it could become lost too easily, and could be problematic if the individual forgets or does not wish to use it. Lim et al. emphasized the need for sufficient education and training for individuals before implementation of a new intervention to maximize the effectiveness of the intervention among older adults, especially those who may not be as familiar with new technologies.[33]. This could be done via more detailed guidelines on the use of their device, and to design the device to minimize the intervention needed by the participant[20]. Physically, devices should not be too physically demanding, by being too large voluminous, or perceived as ugly[18,19]. Participants also responded positively when they felt the system allowed them to be less bothersome in contacting their healthcare provider and felt comforted that their status was being monitored[22]. However, ease of use could still be improved[19,34].

Caregivers also had opinions on how a device should operate or be designed, which may conflict with the wants and needs conveyed by the direct user of the intervention or device. Caregivers thought that a larger device may be easier to find, battery life could be improved, and worried that paid caregivers would be given extra work from the intervention[19]. They also felt that tracking interventions may not be useful or practical, and may want to be able to use a device without needing to subscribe to a telehealthcare service or need access to the internet for use[18].

4. Discussion

Most of the studies identified were pilot or feasibility studies, resulting in a lack of overall generalizability. Even though these studies focused on older adults specifically, they often did not compare their findings against other age groups. There is a clear need for a stronger evidence base for usefulness and effectiveness of these mobile tools, and future studies need to consider establishing criteria for a stronger level of evidence (e.g. Cochrane, STARE-HI[55]). While technical success rates are important to ensure that the technology works, more studies need to be done with a link to clinical outcomes. A good example of this is Lim and colleagues study regarding how a health management system that included mobile phones affected glycemic control[33], which correlated the mobile device's use to a relevant clinical outcome. More investigation is needed to confidently establish whether mobile phone technologies can meaningfully improve an older adult's health and well-being.

Several studies followed subjects for a relatively short time period and studies with longer follow-up periods may also be needed to better understand the role of technology in the long trajectory of a chronic disease or symptom management. For example, individuals that are diagnosed with type 2 diabetes are expected to live a decade or more after diagnosis[56], while studies identified in this review took place over 3 days[35], and 3 months [33,34]. Lifestyle changes to manage diabetes are ongoing, lifelong changes, rather than short term and temporary. In this context it is important to assess if users and healthcare providers have the same attitudes towards and perceptions of the mobile tool interventions over longer periods of time, and how time affects adherence and user satisfaction.

Rule-based alerts seem promising, but the ideal frequency, method, and type of alerts have yet to be determined. How often should a user or provider receive alerts to feel that the intervention is useful and effective, but not burdensome? Further investigation is needed to identify the optimal model of integrating the mobile phone platforms with healthcare and care systems, such as with clinical medical records systems or personal health records. Mobile phone interventions that generate alerts and notify the provider, or require providers to review the data regularly may be effective, but the scalability of the model should be explored. What incentives will a provider need to agree to be alerted or review data daily, when they are already pressed for time? Further studies can determine providers are more willing to adapt if they currently operate under a managed care model or a fee for service model, and how this affects the availability of these devices and interventions to patients. In addition, since mobile technologies allow providers and patients to reside far from each other, licensing, reimbursement, and availability issues need to be worked out, especially across state lines along with the payment model for these interventions.

These studies have also focused on a single condition or disease. Since the majority of older adults have multiple chronic conditions [10], we need to explore how the use of mobile technologies can help them manage and take control of their health in the context of managing multiple diseases simultaneously. Adding further complexity, as they age, older adults see decreases in dexterity, fine motor control, visual acuity and audio acuity[57,58]. Users with functional limitations, such as visual or motor impairment, or technologically unskilled older adults may not be able to utilize currently available mobile platforms to their fullest. The growing popularity of touchscreen smartphones may exacerbate these issues, which should be examined to determine ways to mitigate them and allow these older adults to improve their health and well-being. In addition, older adults are generally more risk averse and slow down more following an error than younger individuals. Consequently, they are not as willing to try new methods when old ones work for them, and they do not want to be a burden on others, so they would prefer not to ask for help in order to learn new methods [59]. Older adults have also shown a preference towards hardware buttons, and do not immediately notice information changes on the screen. While there have been some studies into mobile phone interface personalization for older adults[60], more work is needed to understand how older adults will interface with touchscreen smartphones with the considerations noted above in order to maximize their potential for use in this population.

In order to gain the full benefit of mobile interventions, users need to adhere to instructions given and carry the device with them. Adherence can be complex, as there are many ways that individuals cannot carry out all the tasks needed to gain the benefits of the mobile intervention, such as not entering data, not carrying the device, or not turning the device on. The methods of encouraging adherence should be explored, as this is a complex and critical issue affecting health care costs and quality of care[61–65]. One barrier to adherence may be that studies required the user to carry around another phone in addition to their personal device, which can be cumbersome. Developing platform-independent applications so that users can load it onto their personal device may increase adherence. In addition, mobile applications should be able to build off each other, so that common elements, such as inputting user data, will not have be rebuilt every time. Having common elements would reduce the amount of duplicate effort between groups. Further, understanding adherence issues where there may be differences in acceptability within a dyad are also important to explore further. In order to succeed, a product or intervention needs to find a way to balance and resolve these two sides, so that the users will feel that the intervention is useful and effective, while protecting their wanted level of privacy.

In addition, future work needs to be pursued in clinical-domain specific areas. For dementia care, the ability for mobile phones to be programmed to transmit data or perform tasks without direct input from the user has great potential in this area. Faucounau and Miskelly both reported on being able to track wandering patients via GPS, but before such technologies can be more widespread, there needs to be a way to resolve technological issues such as battery life, as well as any ethical and legal issues posed by the GPS tracking devices[18,19]. De Leo studied using a smartphone to automatically take photos in support of helping improve memory recall[20]. Since the patient wasn’t required to actively operate the device, and the photos were manually transferred, future work could study how to use the connectivity of the smartphone to automatically transmit and generate the photo slideshow. In the area of fall risk, using a smartphone to assess falls and fall risk is attractive due to their portability and increasing ubiquity. However, further studies are needed in the area to develop a smartphone-based system for fall risk, as well as studies to examine the generalizability of falls to older adults. In addition, studies are needed to determine how to ensure compliance of wearing fall sensors, since they are not effective if they are not being worn. The application of mobile phones to teledermatology has seen increased interest, and has shown comparable results to the histologic gold standard[54]. Further studies should focus on a larger sample sizes, as well as establishing the minimum specifications needed on a mobile phone's camera to achieve similar results. Several studies evaluated the use of m-WOMAC on mobile phones[48–50]. While the use of m-WOMAC is commendable, future studies should look at other ways to help osteoarthritic patients. For example, empowering osteoarthritic patients for their health via self-care merits further investigation. In addition, longer periods of study are needed with an application for osteoarthritic individuals on their personal phone to more closely emulate real world usage.

5. Conclusion

The study of mobile phone interventions for supporting the health of older adults is in its infancy, and is just now starting to expand. With the rapid growth of mobile phones, paralleled by the rapidly aging population, there exists a golden opportunity to utilize mobile phone technologies to help manage older adult health and to positively affect their quality of life and well-being. The field's infancy allows interested investigators take their research in any of a number of directions, while moving towards the same goal of improving the lives of older adults.

6. Limitations

There are limitations to this review that need to be acknowledged. The first major limitation is that the review is based on research literature from mainly the health sciences via PubMed and CINAHL. There could be other interventions published in other outlets not included in these two databases, as well as commercially available tools evaluated in reports not published in a peer-reviewed article. In addition, the use of English only language search may have excluded some non-US studies that fell within the subject area.

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References

1. Lu MC, Kotelchuck M, Hogan VK, Johnson K, Reyes C. Innovative strategies to reduce disparities in the quality of prenatal care in underresourced settings. Medical care research and review : MCRR. 2010; 67(5 Suppl):198S–230S. [PubMed: 20675351]
2. Detmer D, Bloomrosen M, Raymond B, Tang P. Integrated personal health records: transformative tools for consumer-centric care. BMC medical informatics and decision making. 2008; 8:45. [PubMed: 18837999]
3. Gustafson DH, Hawkins R, Pingree S, McTavish F, Arora NK, Mendenhall J, et al. Effect of computer support on younger women with breast cancer. Journal of general internal medicine. 2001; 16(7):435–45. [PubMed: 11520380]
4. Skeels, MM.; Unruh, KT.; Powell, C.; Pratt, W. Proceedings of the 28th international conference on Human factors in computing systems - CHI '10. ACM Press; 2010. Catalyzing social support for breast cancer patients; p. 173

5. Martínez A, Everss E, Rojo-Alvarez JL, Figal DP, García-Alberola A. A systematic review of the literature on home monitoring for patients with heart failure. Journal of telemedicine and telecare. 2006; 12(5):234–41. [PubMed: 16848935]

6. CTIA. Semi-Annual Wireless Industry Survey. 2011.

7. Smith, A. Americans and Their Cell Phones [Internet]. 2011.

8. Zickuhr, K.; Madden, M. Older Adults and Internet Use [Internet]. 2012.

9. US Census Bureau. The Next Four Decades: The Older Population in the United States: 2010 to 2050. 2010. p. 10

10. Anderson G, Horvath J. The growing burden of chronic disease in America. Public health reports (Washington, D.C.: 1974). 2004; 119(3):263–70.

11. Demiris G, Hensel BK. Technologies for an aging society: a systematic review of "smart home" applications. Yearbook of medical informatics. 2008:33–40. [PubMed: 18660873]

12. Skubic M, Alexander G, Popescu M, Rantz M, Keller J. A smart home application to eldercare: current status and lessons learned. Technology and health care : official journal of the European Society for Engineering and Medicine. 2009; 17(3):183–201. [PubMed: 19641257]

13. Magnusson L, Hanson E, Borg M. A literature review study of Information and Communication Technology as a support for frail older people living at home and their family carers. Technology and Disability. 2004; 16:223–35.

14. Culhane KM, O'Connor M, Lyons D, Lyons GM. Accelerometers in rehabilitation medicine for older adults. Age and ageing. 2005; 34(6):556–60. [PubMed: 16267178]

15. NíScanaill C, Carew S, Barralon P, Noury N, Lyons D, Lyons GM. A review of approaches to mobility telemonitoring of the elderly in their living environment. Annals of biomedical engineering. 2006; 34(4):547–63. [PubMed: 16550450]

16. OECBM levels of evidence working group. The oxford 2011 levels of evidence [Internet]. 2011

17. Kotani K, Morii M, Asai Y, Sakane N. Application of mobile-phone cameras to home health care and welfare in the elderly: experience in a rural practice. The Australian journal of rural health. 2005; 13(3):193–4. [PubMed: 15932491]

18. Faucounau V, Riguet M, Orvoen G, Lacombe a, Rialle V, Extra J, et al. Electronic tracking system and wandering in Alzheimer's disease: a case study. Annals of physical and rehabilitation medicine. 2009; 52(7–8):579–87. [PubMed: 19744906]

19. Miskelly F. Electronic tracking of patients with dementia and wandering using mobile phone technology. Age and ageing. 2005; 34(5):497–9. [PubMed: 16107453]

20. De Leo G, Brivio E, Sautter SW. Supporting autobiographical memory in patients with Alzheimer's disease using smart phones. Applied neuropsychology. 2011; 18(1):69–76. [PubMed: 21390903]

21. Dikken C, Sitzia J. Patients' experiences of chemotherapy: side-effects associated with 5-fluorouracil + folinic acid in the treatment of colorectal cancer. Journal of clinical nursing. 1998; 7(4):371–9. [PubMed: 9830978]

22. Larsen ME, Rowntree J, Young AM, Pearson S, Smith J, Gibson OJ, et al. Chemotherapy side-effect management using mobile phones. Conference proceedings :... Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Conference. 2008. 2008:5152–5.

23. Weaver, a; Young, aM; Rowntree, J.; Townsend, N.; Pearson, S.; Smith, J., et al. Application of mobile phone technology for managing chemotherapy-associated side-effects. Annals of oncology : official journal of the European Society for Medical Oncology / ESMO. 2007; 18(11): 1887–92. [PubMed: 17921245]

24. McCall K, Keen J, Farrer K, Maguire R, McCann L, Johnston B, et al. Perceptions of the use of a remote monitoring system in patients receiving palliative care at home. International journal of palliative nursing. 2008; 14(9):426–31. [PubMed: 19060793]

25. Bonow RO, Bennett S, Casey DE, Ganiats TG, Hlatky Ma, Konstam Ma, et al. ACC/AHA clinical performance measures for adults with chronic heart failure: a report of the American College of Cardiology/American Heart Association Task Force on Performance Measures (Writing Committee to Develop Heart Failure Clinical Performance Meas. Journal of the American College of Cardiology. 2005; 46(6):1144–78. [PubMed: 16168305]

26. Cleland JGF, Louis Aa, Rigby AS, Janssens U, Balk AHMM. Noninvasive home telemonitoring for patients with heart failure at high risk of recurrent admission and death: the Trans-European Network-Home-Care Management System (TEN-HMS) study. Journal of the American College of Cardiology. 2005; 45(10):1654–64. [PubMed: 15893183]
27. Scherr D, Kastner P, Kollmann A, Hallas A, Auer J, Krappinger H, et al. Effect of home-based telemonitoring using mobile phone technology on the outcome of heart failure patients after an episode of acute decompensation: randomized controlled trial. Journal of medical Internet research. 2009; 11(3):e34. [PubMed: 19687005]
28. Ries AL, Bauldoff GS, Carlin BW, Casaburi R, Emery CF, Mahler Da, et al. Pulmonary Rehabilitation: Joint ACCP/AACVPR Evidence-Based Clinical Practice Guidelines. Chest. 2007; 131(5 Suppl):4S–42S. [PubMed: 17494825]
29. Nguyen, HQ.; Wolpin, S.; Chiang, K-C.; Cuenco, D.; Carrieri-Kohlman, V. Exercise and symptom monitoring with a mobile device. AMIA... Annual Symposium proceedings / AMIA Symposium. AMIA Symposium; 2006. p. 1047
30. Nguyen HQ, Gill DP, Wolpin S, Steele BG, Benditt JO. Pilot study of a cell phone-based exercise persistence intervention post-rehabilitation for COPD. International journal of chronic obstructive pulmonary disease. 2009; 4:301–13. [PubMed: 19750190]
31. Liu WT, Wang CH, Lin HC, Lin SM, Lee KY, Lo YL, et al. Efficacy of a cell phone-based exercise programme for COPD. The European respiratory journal : official journal of the European Society for Clinical Respiratory Physiology. 2008; 32(3):651–9.
32. Schechter CB, Walker Ea. Improving Adherence to Diabetes Self-Management Recommendations. Diabetes Spectrum. 2002; 15(3):170–5.
33. Lim S, Kang SM, Shin H, Lee HJ, Won Yoon J, Yu SH, et al. Improved glycemic control without hypoglycemia in elderly diabetic patients using the ubiquitous healthcare service, a new medical information system. Diabetes care. 2011; 34(2):308–13. [PubMed: 21270188]
34. Durso SC, Wendel I, Letzt AM, Lefkowitz J, Kaseman DF, Seifert RF. Older adults using cellular telephones for diabetes management: a pilot study. Medsurg nursing : official journal of the Academy of Medical-Surgical Nurses. 2003; 12(5):313–7. [PubMed: 14608688]
35. Rollo ME, Ash S, Lyons-Wall P, Russell A. Trial of a mobile phone method for recording dietary intake in adults with type 2 diabetes: evaluation and implications for future applications. Journal of telemedicine and telecare. 2011; 17(6):318–23. [PubMed: 21844173]
36. Lee HJ, Lee SH, Ha K, Jang HC, Chung WY, Kim JY, et al. Ubiquitous healthcare service using Zigbee and mobile phone for elderly patients. International journal of medical informatics. 2009; 78(3):193–8. [PubMed: 18760959]
37. Oakley A, Dawson MF, Holland J, Arnold S, Cryer C, Doyle Y, et al. Preventing falls and subsequent injury in older people. Quality in health care : QHC. 1996; 5(4):243–9. [PubMed: 10164150]
38. Scuffham P, Chaplin S, Legood R. Incidence and costs of unintentional falls in older people in the United Kingdom. Journal of epidemiology and community health. 2003; 57(9):740–4. [PubMed: 12933783]
39. Tamrae T, Griffina M, Rupcica S, Taylor T, Barfield J. Operationalizing a wireless wearable fall detection sensor for older adults. 2012:297–302.
40. Bourke, aK; O'Brien, JV.; Lyons, GM. Evaluation of a threshold-based tri-axial accelerometer fall detection algorithm. Gait & posture. 2007; 26(2):194–9. [PubMed: 17101272]
41. Lee RYW, Carlisle AJ. Detection of falls using accelerometers and mobile phone technology. Age and ageing. 2011; 40(6):690–6. [PubMed: 21596711]
42. Lundin-Olsson L, Nyberg L, Gustafson Y. Attention, frailty, and falls: the effect of a manual task on basic mobility. Journal of the American Geriatrics Society. 1998; 46(6):758–61. [PubMed: 9625194]
43. Beauchet O, Annweiler C, Dubost V, Allali G, Kressig RW, Bridenbaugh S, et al. Stops walking when talking: a predictor of falls in older adults? European journal of neurology : the official journal of the European Federation of Neurological Societies. 2009; 16(7):786–95. [PubMed: 19473368]

44. Yamada M, Aoyama T, Okamoto K, Nagai K, Tanaka B, Takemura T. Using a Smartphone while walking: a measure of dual-tasking ability as a falls risk assessment tool. Age and ageing. 2011; 40(4):516–9. [PubMed: 21593058]

45. Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt LW. Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. The Journal of rheumatology. 1988; 15(12):1833–40. [PubMed: 3068365]

46. Bischoff-Ferrari, Ha; Vondechend, M.; Bellamy, N.; Theiler, R. Validation and patient acceptance of a computer touch screen version of the WOMAC 3.1 osteoarthritis index. Annals of the rheumatic diseases. 2005; 64(1):80–4. [PubMed: 15231508]

47. Theiler R, Spielberger J, Bischoff Ha, Bellamy N, Huber J, Kroesen S. Clinical evaluation of the WOMAC 3.0 OA Index in numeric rating scale format using a computerized touch screen version. Osteoarthritis and cartilage / OARS, Osteoarthritis Research Society. 2002; 10(6):479–81.

48. Bellamy N, Patel B, Davis T, Dennison S. Electronic data capture using the Womac NRS 3.1 Index (m-Womac): a pilot study of repeated independent remote data capture in OA. Inflammopharmacology. 2010; 18(3):107–11. [PubMed: 20422296]

49. Bellamy N, Wilson C, Hendrikz J, Whitehouse SL, Patel B, Dennison S, et al. Osteoarthritis Index delivered by mobile phone (m-WOMAC) is valid, reliable, and responsive. Journal of clinical epidemiology Elsevier Inc. 2011; 64(2):182–90.

50. Bellamy N, Wilson C, Hendrikz J, Patel B, Dennison S. Electronic data capture (EDC) using cellular technology: implications for clinical trials and practice, and preliminary experience with the m-Womac Index in hip and knee OA patients. Inflammopharmacology. 2009; 17(2):93–9. [PubMed: 19139830]

51. Gloster HM, Brodland DG. The epidemiology of skin cancer. Dermatologic surgery : official publication for American Society for Dermatologic Surgery [et al.]. 1996; 22(3):217–26.

52. Diepgen TL, Mahler V. The epidemiology of skin cancer. The British journal of dermatology. 2002; 146(Suppl):1–6. [PubMed: 11966724]

53. Staples MP, Elwood M, Burton RC, Williams JL, Marks R, Giles GG. Non-melanoma skin cancer in Australia: the 2002 national survey and trends since 1985. The Medical journal of Australia. 2006; 184(1):6–10. [PubMed: 16398622]

54. Kroemer S, Frühauf J, Campbell TM, Massone C, Schwantzer G, Soyer HP, et al. Mobile teledermatology for skin tumour screening: diagnostic accuracy of clinical and dermoscopic image tele-evaluation using cellular phones. The British journal of dermatology. 2011; 164(5):973–9. [PubMed: 21219286]

55. Talmon J, Ammenwerth E, Brender J, de Keizer N, Nykänen P, Rigby M. STARE-HI--Statement on reporting of evaluation studies in Health Informatics. International journal of medical informatics. 2009; 78(1):1–9. [PubMed: 18930696]

56. Leal J, Gray AM, Clarke PM. Development of life-expectancy tables for people with type 2 diabetes. European heart journal. 2009; 30(7):834–9. [PubMed: 19109355]

57. Hawthorn D. Possible implications of aging for interface designers. Interacting with Computers. 2000; 12(5):507–28.

58. Carmeli E, Patish H, Coleman R. The aging hand. The journals of gerontology Series A, Biological sciences and medical sciences. 2003; 58(2):146–52.

59. Akatsu H, Miki H. Usability research for the elderly people. Oki Technical Review (Special Issue on Human …. 2004; 71(199):54–7.

60. Olwal, A.; Lachanas, D.; Zacharouli, E. Proceedings of the 2011 annual conference on Human factors in computing systems - CHI '11. ACM Press; 2011. OldGen: mobile phone personalization for older adults; p. 3393[cited 2012 Nov 3]

61. Sokol MC, McGuigan Ka, Verbrugge RR, Epstein RS. Impact of medication adherence on hospitalization risk and healthcare cost. Medical care. 2005; 43(6):521–30. [PubMed: 15908846]

62. Ruppar TM, Conn VS, Russell CL. Medication Adherence Interventions for Older Adults: Literature Review. Research and Theory for Nursing Practice. 2008; 22(2):114–47. [PubMed: 18578221]

63. Schlenk EA, Dunbar-Jacob J, Engberg S. Medication non-adherence among older adults: a review of strategies and interventions for improvement. Journal of gerontological nursing. 2004; 30(7): 33–43. [PubMed: 15287325]

64. Campbell NL, Boustani Ma, Skopelja EN, Gao S, Unverzagt FW, Murray MD. Medication adherence in older adults with cognitive impairment: a systematic evidence-based review. The American journal of geriatric pharmacotherapy. 2012; 10(3):165–77. [PubMed: 22657941]

65. Sengstock D, Vaitkevicius P, Salama A, Mentzer RM. Under-prescribing and non-adherence to medications after coronary bypass surgery in older adults: strategies to improve adherence. Drugs & aging. 2012; 29(2):93–103. [PubMed: 22239673]

Highlights

- We review the use of mobile phones for health applied to older adults.
- The field emerging field contains many feasibility studies with smaller samples.
- A variety of clinical domains are appropriate for mobile phone interventions.
- Future work should address generalizability and establish a stronger evidence base.

Table 1

Included Articles in Review

Cite	LoE	Subjects	Technology	Study Outcome Aims
Kotani [17]	4	19 Elderly Patients under care for some chronic disease	Mobile Phone Cameras	Demonstrate practicality of technology for elderly home care; Subjective assessment on ease of use, simple transferance, etc
Faucanau[18]	4	1 84y Subject + Caregiver	Mobile Phone, GPS, SMS	Attitudes toward device, including usage difficulties malfunctions, and barriers to use and feelings of usefulness
Miskelly[19]	4	11 adults with dementia total (3 <70y, 2 71–80y, 6 80+ y)	GPS-enabled mobile phone with continuous tracking	Positive location requests to total location requests across a variety of environments in simulation, on older adults with dementia similar, but also tracking accuracy based on information given by carer/relative
De Leo[20]	4	1 Older adult with Stage 4 Alzheimer's (80y) and caregiver (73y)	Smartphone programmed to take photos at 5 minute intervals, webserver, dvd	Recent events memory recall test scores before and after viewing the DVD; Satisfaction scores after viewings
Larsen[22]	3	6 Subjects commencing capecitabine treatment for colon cancer (R:54–76y)	Mobile phone, webserver, pagers	Patient compliance, types of symptoms reported, number and types of alerts generated, progression of side effects, and system acceptability to the patients during their treatment; feasibility
Weaver[23]	3	6 Adults with Colon Cancer receiving adjuvant chemotherapy (A:64y)	Mobile phone with application, tympanic thermometer	Assessment and analysis of alert generation feasibility, patient satisfaction and acceptability, staff response time threshold
Mccall [24]	3	21 Patients receiving palliative care in advanced stages of illness (R:40–87, A:64y);	Mobile phone with Advanced Symptom Management for Palliative care	Acceptability and usability of mobile ASyMSp via Pre and post study questionnaires/interviews including usefulness, including healthcare provider perceptions towards usefulness
Scherr[27]	2	120 Adults (A:66y) with acute worsening of heart failure with an ACE inhibitor or ARB	Mobile phone, scale, automated sphygmomanometer, website with notifications	Cardiovascular mortality / reshospitalization for worsening heart failure, system availability, feasibility of transmission by patients for their daily doses of meds and vital parameters: cumulative transmissions and transmissions per patient and feasibility for patients to adhere to telemonitoring system via mobile phone equipment
Nguyen[29]	4	6 adults with moderate to severe COPD that were internet users (R:65–80y, A: 73y)	Mobile phone, website and email	Response rate and response times to automated prompts
Nguyen[30]	2	17 Adults with COPD	Palm Smartphone, webserver, automatic alerts, SMS	Feasibility: Adherence to data submission, barriers to exercise, adverse events, self-efficacy, exercise performance outcomes between the two groups before and after intervention, health related quality of life, steps
Liu[31]	2	48 Adults with moderate to severe COPD (A:71y)	Mobile phone with java application	Measure change in Incremental Shuttle walk test (ISWT) spirometry and SF12 and differences between cell phone intervention with control group.

Cite	LoE	Subjects	Technology	Study Outcome Aims
				Breathlessness and other pulmonary function tests
Lim[33]	2	144 Older adults (A:~67y); Control (n=48), Self-monitored (n=47), U-Healthcare (w/mobile phone, n=49)	Mobile phone SMS, glucometer, PSTN, internet based CDSS	Changes in A1C levels, Proportion of patients iwth A1c <7.0% without hypoglycemia; Comparison to other interventions
Durso[34]	3	10 Adults 60+y with Type 2 Diabetes	Mobile phone with personal diabetes management system, web	Test of usability via survey and satisfaction, pre/post test on diabetes health behaviors and general knowledge about diabetes, trends in glycemic control, exercise, etc
Rollo[35]	3	10 adults with type 2 diabetes (R:59–70y, A:~65y)	Mobile phone camera, application “Nutricam”	Energy intake on the phone system versus a standard food diary. In addition, usability and acceptability questionnaire of the mobile phone system.
Lee[36]	3	29 Adults (A:70.3y)	Mobile phone, zigbee+blood glucometer, ECG; webserver	Daily average transmission frequency, rate of transmission loss, error reasons; Patient satisfaction with U-healthcare service and sensors
Lee[41]	4	18 Adults (A:29y)	Mobile phone	Acceleration as measured by phone accelerometer when falling, compared to an external accelerometer
Yamada[44]	3	Older adults in a community dwelling (A:78.9y), categorized as high risk (n=90) or low risk (n=228) for Falls and Fall Risk	Smartphone, Application “RollingBall”	Scoring on both single-task and dual-task walking conditions based on phone application developed for assessment of fall risk. Compared to previously validated physical performance tests
Bellamy[48]	4	12 Adults with hip or knee osteoarthritis (A:63.4y, R: 52–81y)	Mobile phone with m-WOMAC, Webserver, SMS Reminder System	Feasibility of collecting WOMAC index scores, time to completion, patient ratings for ease of use
Bellamy[49]	4	62 adults with hip or knee osteoarthritis (A:68.5y, R: 47–85y)	Mobile phone with m-Womac	Concordance of scores between m-WOMAC delivered via mobile phone vs paper WOMAC; Comparison in completion times and user preference
Bellamy[50]	4	12 Subjects (R:55–82y) with hip and/or knee osteoarthritis	Mobile phone with WOMAC	(Not main purpose: Correlation between p-WOMAC and m- WOMAC scores), how patients felt about the 3 different phones used, ranked on ease of use, navigation, instructions, screen clarity, etc as well as time to completion
Kroemer[54]	3	88 Patients (R:3–93y, A: 69y) with skin lesions	Mobile phone camera, with and without dermascopic device	Concordance of teleevaluated “normal” and “dermatologic” photo diagnosis accuracy with gold standard diagnosis

*LoE: Level of Evidence