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## The Use of Mobile Applications in Preventive Care and Health-Related Conditions: A Review of the Literature

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# The Use of Mobile Applications in Preventive Care and Health-Related Conditions: A Review of the Literature

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**ABSTRACT:** The purpose of this review of literature is to understand the role of mobile device applications (apps) in health-related conditions and to analyze their effects on health outcomes related to the management of chronic illnesses. The author also explores implications for the future use of apps in patient-centered care and interpretation of the data by health care providers. Peer-reviewed, English-language research articles published from 2008 to present are included for synthesis. Study results reveal positive outcomes when health-related mobile apps were used in practice and support clinicians' use of mobile apps as a tool for monitoring symptoms and communicating with individuals. The literature indicates nurses play a significant role in providing feedback, which reinforces self-care strategies and adherence with the potential for improving outcomes. Additional research is needed to evaluate the long-term effects of apps on patient outcomes, nurses' perspectives, and feasibility of implementation into practice.

**KEYWORDS:** nursing, chronic conditions, mobile devices, smartphones, tablets, applications, apps

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## INTRODUCTION

Patient-centered care is rapidly evolving as new technologies emerge with the potential to increase communication, efficiency, and accessibility with health care providers. Smart phones integrate many technological functions into one device capable of changing the delivery of health care (Putzer & Park, 2010). Patients and providers are increasingly using smartphones and tablet computers in daily health care practice (Sevetson & Boucek, 2013). Smartphone owners who use health-related applications (apps) can readily track and manage their health care encounters and needs (Fox & Duggan, 2012).

A Pew Research Center study shows smartphone ownership is most prevalent among 18 to 49-year old adults, but nearly half of 50 to 64-year olds currently own a smartphone (Pew Research Center's Internet & American Life Project, 2014). In addition, individuals living with chronic conditions or those seeking preventive health strategies are most likely to participate in mobile health activities (Fox & Duggan, 2012). In 2012, 19 percent of smartphone users had at least one health-related app, with exercise, diet, and weight management among the most popular apps (Fox & Duggan, 2012). Research is thus needed to discover how clinicians use health-related apps to engage individuals and improve outcomes of chronic illnesses.

### *Problem*

The number of health-related, mobile applications focusing on chronic disease management is expected to greatly increase as consumer demand and as the incorporation of patient data trending into health-related outcomes becomes a performance-based, reimbursement incentive for health care providers (Blake, 2008). However, there is a paucity of research exploring consumers' use of health-related applications and integration into the health care setting. This review of literature will establish a better understanding of how patients use apps to track health statuses and progress toward health improvement. Mobile device technologies have great potential as a basic means for tailoring patient-centered care to improve individual health outcomes (Kratzke & Cox, 2012).

### *Background*

Mobile device applications, or end-user software

applications, first became available to consumers with the Apple iPhone release in 2007 (Purcell, 2011). Apps have become a fundamental feature of smartphones, tablets, and handheld devices as patients have moved from traditional computers to mobile computing (Purcell, 2011). Portable mobile devices give individuals opportunities to interact with clinicians outside of the traditional health care setting. Apps are unique tools due to their ability to store data and upload data to the Internet (Aungst, Clauson, Misra, Lewis, & Husain, 2014).

Chronic diseases are among the most common and costly of health problems in the United States (Centers for Disease Control and Prevention, 2012). Yet, heart disease, stroke, diabetes, and obesity may be preventable by modifying health behaviors related to physical activity, nutrition, tobacco use, and alcohol consumption (Centers for Disease Control and Prevention, 2012).

Clinicians face many challenges in caring for patients with complex chronic illnesses. A coordinated approach in which health care professionals engage patients, families, policymakers, and other interdisciplinary professionals is needed to modify health behaviors and outcomes (U.S. Department of Agriculture, 2010). Health care professionals now have the ability to educate and engage patients through mobile device technology, which allows patients to become partners in their care (Weaver, Lindsay, & Gitelman, 2012).

### *Purpose*

The purpose of this review of literature is to examine current research regarding health-related, mobile device apps and understand how apps can be implemented into the management of chronic disease conditions to prevent, maintain, or improve an individual's health. Kratzke and Cox (2012) propose health-related apps as convenient tools for individualizing interventions to improve self-management of chronic illnesses and health behaviors. The secondary purposes of this review will be to apply findings to nursing practice and identify areas for future research.

## METHOD

A search of published literature was carried out using EBSCOhost, Cumulative Index to Nursing and Allied Health Literature, Education Information Resource Center, MEDLINE, and PsychINFO databases.

Inclusion criteria extended to peer-reviewed articles written in the English language and articles focusing on feasibility or use of apps in health care, chronic condition management, and health promotion. Exclusion criteria extended to studies in which full-text articles were unavailable, articles discussing psychiatric-related diagnoses, articles where interventions did not focus on chronic conditions or apps, or articles describing clinician-specific apps. Keywords included smartphone, smart phone, app, and disease.

## RESULTS

Sixteen studies were included and an additional three articles provided further analyses in this review (see Table 1 in Appendix A). Participants used questionnaires or surveys related to app use in 15 of the studies. Four of the studies included interviews; two studies included focus groups; three studies described pain and app use; five studies related to diabetes; four studies related to physical activity; three studies related to diet; and one study discussed potential uses for health-related apps.

### *Pain*

Vanderboom, Vincent, Luedtke, Rhudy, and Bowles (2013) found a pain diary app to be valuable, useful, and easy to use for fibromyalgia patients. Vanderboom et al. concluded nurse-provided feedback and interactions had the potential to positively influence outcomes, but did not examine improvements in pain levels. In a study by Kristjánsdóttir et al. (2013b), participants wrote smartphone-based pain diaries and received personalized feedback from study authors. Participants had significantly improved pain immediately, followed by moderate results at 5 months, and no significant difference at 11 months. Stinson et al. (2013) found an increased compliance among adolescent participants who rated pain on a game-based app. Stinson et al. concluded mobile apps had the potential to improve pain and quality of life after participants reported app enjoyment, found it easy to use, and did not find it intrusive in daily life.

### *Diabetes*

In a randomized controlled trial, type 1 diabetic patients uploaded blood glucose levels, insulin dosages, medications, diet, and physical activity to an app and received individualized feedback (Kirwan, Vandelanotte, Fenning, & Duncan, 2013). Participants had significantly

decreased HbA<sub>1c</sub> over nine months; however, researchers did not identify a significant relationship among app engagement, text messages, and HbA<sub>1c</sub> change. Kirwan et al. proposed a higher baseline HbA<sub>1c</sub>, allowing more potential for improvement.

Charpentier et al. (2011) randomized diabetic participants to study improvements in HbA<sub>1c</sub>. Those using an app and receiving telephone consultations had significantly lower HbA<sub>1c</sub> ( $8.41 \pm 1.04\%$ ) compared to the control group HbA<sub>1c</sub> ( $9.10 \pm 1.16\%$ ), which used a paper log and in-person consultations (Charpentier et al., 2011). Nes et al. (2012) found HbA<sub>1c</sub> levels decreased from a mean of 7.39 percent prior to intervention to a mean of 6.9 percent at the end of intervention, but HbA<sub>1c</sub> alone was not found to be indicative of behavioral change. Participants reported the app to be meaningful and motivational, and nurse-supplied feedback reinforced strategies to manage diabetes (Nes et al., 2012).

Lyles et al. (2011) evaluated diabetic participants' use of a smartphone app and Wii console to upload blood glucose readings and collaborate care with a nurse. Lyles et al. concluded smartphone technical issues frustrated participants, but nurse interactions had potential to influence participants' self-care behaviors. Logan (2013) found hypertensive diabetic participants who used Bluetooth-enabled sphygmomanometers to transmit data to a smartphone app and received automated self-care messages had significantly decreased mean daytime ambulatory systolic blood pressure (SBP) and mean 24-hour SBP. Fifty-one percent of the intervention group and 31 percent of the control group reached the blood pressure goal of less than 130/80 mm Hg (Logan, 2013).

### *Physical Activity*

Verwey et al. (2014) evaluated app use among patients with type 2 diabetes or chronic obstructive pulmonary disease (COPD). Physical activity increased 29-39 minutes per day on average, and health-related quality of life scores increased. Verwey et al. indicated the app and clinician-provided feedback helped to improve participants' self-efficacy. Pfaeffli et al. (2013) found an app-based questionnaire to be relatively reliable and valid in measuring and tracking physical activity among participants with cardiovascular disease. Results supported mobile device use to assess physical activity regardless of cardiac rehabilitation attendance.

Nguyen, Gill, Wolpin, Steele, and Benditt (2009) compared efficacy of a website and app-based program to a face-to-face dyspnea self-management program for COPD. Both groups had improved dyspnea. The six-minute walk test improved in the intervention group but declined in the face-to-face group (Nguyen et al., 2009). Kirwan, Duncan, Vandelanotte, and Mummery (2012) examined health behaviors by comparing usage of an app to a website resource. Those who self-selected into the app group had 71 percent overall usage compared to 29 percent usage among the website group (Kirwan et al., 2012).

#### *Diet*

Welch et al. (2013) found an app had no statistical significance on improvements in diet or self-efficacy among hemodialysis patients. Perceived control significantly increased immediately after the study but returned to baseline at eight weeks, which led researchers to conclude that self-efficacy might have improved if participants used the app more frequently (Welch et al., 2013). Eleven participants stated the app caused diet changes and 17 thought about making changes (Connelly et al., 2012). Carter et al. (2013) found app users had significantly higher adherence, decreased BMI, and decreased body fat compared to those using a paper diary or website. App and paper diary users had significant weight loss, although some participants reported use of an additional weight-loss tool (Carter et al., 2013).

A separate study found adherence to be more important than method used to lose weight (Burke et al., 2011). App users who received feedback had small, statistically significant weight loss ( $p=0.02$ ) compared to participants using only the app or paper diary (Burke et al., 2011). Feedback significantly increased adherence, and mobile technology had potential to enhance adherence (Turk et al., 2013).

#### *Other Potential Uses*

Dennison, Morrison, Conway, and Yardley (2013) described adult perspectives on apps used to modify health behaviors. Participants did not participate in an intervention but instead discussed uses to monitor diet, exercise, and medications, or as an adjunct to psychological therapy (Dennison, Morrison, Conway, & Yardley, 2013).

## DISCUSSION

The studies reviewed explore the role and potential of mobile device technology in managing chronic health conditions. While the literature shows mixed results, the use of apps exhibited several positive effects on patient outcomes. The literature suggests apps allow patients to self-monitor progress and to communicate with clinicians who also monitor progress, which may result in modifying health behaviors.

Patients with chronic conditions may benefit from the use of apps (Kratzke & Cox, 2012). Apps discussed in the studies allowed patients to input, upload, track progress, and receive feedback on pain symptoms, blood pressure, HbA<sub>1c</sub>, physical activity, and diet. Mobility may provide convenience for patients who wish to input data in real-time; however, studies did not examine how portability influences adherence or health-related outcomes. Many studies included apps designed specifically for the purpose of research and did not discuss how patients would download apps in the future or potential costs.

Several studies reported positive outcomes, but findings were not linked directly to apps (Burke et al., 2011; Carter et al., 2013; Charpentier et al., 2011; Kirwan et al., 2013; Kristjánsdóttir et al., 2013b; Logan, 2013; Nguyen, 2009). Diabetic patients using an app had improved HbA<sub>1c</sub>, but one group received telephone feedback while the other did not (Charpentier et al., 2011). Thus, it cannot be concluded the app rather than the method of feedback was responsible for decreased HbA<sub>1c</sub>. Further analysis of the Nguyen et al. study suggests support and feedback rather than the method may be linked to improved dyspnea in COPD patients. Logan indicates diabetic patients with uncontrolled SBP may benefit from an app, but the study did not examine the direct role of the app.

#### *Relationship between Feedback and Apps*

Research describes use of mobile device apps solely or in conjunction with feedback, yet the relationship among feedback, apps, and positive outcomes is unclear. App use in conjunction with provider feedback resulted in greater weight loss compared to app use alone (Burke et al., 2011). Patients reported less chronic pain after writing diaries on an app and receiving feedback; however, the relationship of feedback and outcomes was not analyzed (Kristjánsdóttir et al., 2013a; Kristjánsdóttir et al., 2013b). While Vanderboom et al. (2013) found

feedback to be valuable reinforcement with potential to influence patients with pain, Kirwin et al. (2013) did not find a relationship between feedback and improvements in diabetic patients' HbA<sub>1c</sub> levels. Given these mixed results, it is difficult to determine how beneficial patients will find apps with automated or clinician-generated feedback.

### *Barriers to Implementation*

Barriers to implementation are technical difficulties and a lack of app usability or usefulness. Although technical difficulties led to one study ending early, participants found nurse support to be helpful and showed improvements in symptoms (Nguyen et al., 2009). Nurses have the potential to mitigate patients' technical difficulties, but app reliability should be addressed prior to implementation.

Useful applications may be a key factor in engagement and may indirectly influence outcomes (Kirwan et al., 2012). Dennison et al. (2013) suggests usefulness depends on patients' existing motivation to change health behaviors, and patients will not benefit unless they have a foundation of knowledge regarding their health. In addition, results are limited in generalizability due to the small sample size and participants who may have exhibited bias in self-selecting into studies.

Determining relevant and usable apps is another challenge to implementation. Methods include reviewing current research and existing app store databases (Aungst et al., 2014). Clinicians may use patient adherence, engagement, or perceived value to evaluate feasibility but are limited by inconclusive research findings. Participants using a diet-tracking app, for example, demonstrated no significant improvements and provided limited data, which does not provide substantial evidence to draw conclusions about app feasibility (Connelly et al., 2012; Welch et al., 2013).

### *Limitations*

This review has several limitations. Initial search results revealed numerous findings on keywords such as health, application, tech, and mobile; however, fewer original studies remained relevant to the purpose of this investigation. Keyword searches were expanded to include smartphone, app, and disease in order to provide more relevant results. This limitation may be indicative of the relative novelty of apps and potential for future

research.

In addition, many studies were limited by timeframe, location, and small sample sizes. Only one study collected data from multiple sites over 1.5 years (Charpentier et al., 2011). The majority of studies included small but targeted populations, which limits generalizability of findings. The largest sample size (n=210) was limited by a population of mostly educated and employed Caucasian females (Burke et al., 2011). Most studies were descriptive in nature, with only four studies out of the 16 studies including power analyses (Charpentier et al., 2011; Kirwan et al., 2013; Kristjánssdóttir et al., 2013b; Logan, 2013).

Response and retention rates in two studies further limit findings. One study experienced a 30 percent withdrawal rate from the intervention group, followed by response rate of less than 70 percent (Kristjánssdóttir et al., 2013b). It is not uncommon in projects to find poor retention rates when data collection extends over a longer period of time.

### *Additional Comments: A Nursing Perspective*

Mobile technology is a tool that allows healthcare professionals to modify an individual's health behaviors and outcomes (U.S. Department of Agriculture, 2010). As part of the healthcare team, nurses play a significant role in the implementation of mobile device apps into practice.

Communication with individuals seeking to manage their health-related conditions was a common topic among the studies reviewed. Mobile technology is a vehicle for communication and enhances daily feedback, which in turn increases self-monitoring adherence (Turk et al., 2013). The literature suggests an individual's motivation is a key factor in successfully implementing apps (Dennison et al., 2013). The use of apps to educate and reinforce health behaviors can motivate a person with a chronic condition that requires self-monitoring to maintain current health status and achieve positive outcomes. Thus, communication between nurses and individuals who seek health-related interventions promotes self-care.

Another strategy to improve health outcomes is through education (Weaver et al., 2012). Mobile devices provide the functionality and convenience for individuals to track their health through the use of apps. Nurses can educate

patients on how to implement applications into daily living. Furthermore, nurses can use apps as a delivery tool for succinct and tailored educational messages.

### Further Research

Further research is needed on the perspectives of nurses related to uses, implementation, and outcomes of mobile device apps. Verwey et al. (2014) found nurses dedicated more time to counseling on technical issues rather than study objectives. Nursing resources and time allocation affect the feasibility of implementation; therefore, future research on issues that impact the nurse workforce are important to better understanding efficiency and effectiveness of health-related apps.

Research reviewed during this investigation revealed perceptions of patients but lacked substantial data on nurses' viewpoints. One study concluded nurses perceived data gained from the app helped to assess patients, lower barriers, and facilitate change (Verwey et al., 2014). Studies are needed to evaluate nurses' perspectives in order to understand how apps can be implemented into practice.

This review uncovered a lack of long-term, large-scale research studies related to chronic conditions. Four of the studies included lasted at least one year, but only one study was conducted at multiple research sites (Charpentier et al., 2011; Kristjánsdóttir et al., 2013a; Logan, 2013; Stinson et al., 2013). Because nurses perform a variety of vital roles, including recruiting participants and managing app-generated data, nurses are in a position to carry out future investigations.

### Education

Education of nurses is essential for nurses to successfully implement mobile device apps into practice and provide quality care. The literature findings suggest patients' first-line communication occurs with nurses on issues ranging from technical difficulties to health behaviors. Therefore, nurses can become barriers to implementation if they are not knowledgeable about apps. Nurses should be educated on mobile device technology and be confident with their roles in troubleshooting technical issues, handling patient data, and communicating to patients. Employers must also consider incentives for nurses to assimilate apps into clinical practice.

Nurses must be knowledgeable about which apps are appropriate for their patients as nurses may be expected to make recommendations. Aungst et al. (2014) proposes clinicians use mobile app store databases to first identify apps. Clinicians who use this method will depend on taxonomy determined by the mobile app stores or by the app developers, which may not reflect medical expertise. Clinicians may find searching online databases dedicated to health-related medical apps to be more efficient in selecting apps for their patients (Aungst et al., 2014).

### Nursing Practice

Research findings have many implications for nursing practice. In addition to direct patient care, nurses are involved in organizational initiatives that contribute to changes in healthcare practice. As workplace leaders, nurses may be expected to be knowledgeable about current research in order to develop protocols and best practices for integration of mobile device apps. Nurses may also use apps to modify patient care. The literature suggests the principal functions of apps are to allow patients to input and track symptoms, diet, weight, or screening measurements. Nurses have the ability to monitor data linked from patients' devices and to send feedback based on nursing judgment or preset goals. This feedback mechanism, which provides an opportunity to educate and reinforce self-management strategies, is a significant factor in tailoring care. However, patients must be committed to using apps if these methods are to be effective.

### CONCLUSION

Mobile device technology has the potential to influence nursing practice and patient outcomes. In summary, apps may be used as tools for improving adherence, which in turn has the potential for improving self-care among patients with chronic conditions. Patients who use apps more consistently may have improved health-related outcomes.

Nurses' roles may include choosing apps to implement, monitoring trends in patient-generated data, and providing individualized-feedback to increase patients' motivation and knowledge regarding their health. The literature suggests patients' knowledge and motivation influence health outcomes (Dennison et al., 2013; Kirwan et al., 2012). However, it is unclear whether the apps or nurses who utilize the apps are the key component in improving patients' motivation.

## APPENDIX A

Table 1: Table of Evidence

Author, Year	Study Design, Purpose	Sample Size	Intervention Protocol	Population	Key Findings, Limitations
Burke et al., 2011	Prospective, randomized controlled trial  Evaluate relationship of feedback and adherence in weight loss	n=210	All received reduced energy intake and attended intervention meetings  PDA = Diet software  Daily feedback for PDA+FB; others weekly/biweekly	18-59 years old; BMI 27-43 kg/m <sup>2</sup> ; no major medical or psychiatric conditions	Self-monitoring adherence associated with weight loss; more important to sustained weight loss than method used. Mobile technology has potential for reducing burden. Feedback enhanced outcomes; technology may play role in weight loss  Limitations: 86% retention rate; 21% minority representation
Carter et al., 2013	3-arm parallel group randomized controlled trial  Acceptability and feasibility of app	n=128	Baseline measurements and self-completed questionnaires. 1 group had smartphone app; 1 group had weight-loss website; 1 group had paper diary with calorie-counting book. Evaluated at 6 weeks and 6 months	18-65 years old; BMI >27 kg/m <sup>2</sup> ; employed; no weight-loss surgery; not pregnant or planning pregnancy; not breastfeeding; not taking anti-obesity medications, insulin for diabetes, or sertraline	App group had significantly higher adherence than others. 16% smartphone users recorded dietary intake every day; other groups recorded none. Smartphone and diary groups had significant weight loss (p<0.01). Smartphone group had significant decrease in BMI and body fat. Diary and website groups had higher attrition rates (p<0.001)  Limitations: Mostly white female sample; reported intervention use in addition to assigned one; unequal dropout rate
Charpentier et al., 2011	Randomized open-label parallel-group multicenter study  Demonstrate smartphone software combined with telesupport significantly improves HbA1C in poorly-controlled type 1 diabetics	n=180	Control (G1) paper log, in-person follow up at 3 and 6 mos.  Smartphone app (G2) without teleconsultation; in-person follow up at 3 and 6 mos.  Smartphone app (G3) and teleconsultation every 2 weeks and 6-mos.; data uploaded from smartphone	Recruited from 17 hospital sites; 18 years or older; T1DM for at least 1 year; treated with basal bolus insulin for at least 6 mos. with MDI or pump; HbA1c ≥8.0%	Diabeo led to 0.9% decrease in HbA1c. G3 had significantly lower 6-mos. mean HbA1c compared to G1 (p=0.0019). 17% of G3 reached target goal of HbA1c <7.5%  Limitations: Two groups received software; participants had history of poorly-controlled T1DM
Connelly et al., 2012	Continuation of Welch et al. (2013)  Describe design, evaluate usage and user perceptions	n=18	PDA with DIMA home to record intake. Downloaded app data at each subsequent dialysis session. Administered questionnaires at end of self-monitoring intervention	See Welch et al. (2013)	Two-thirds able to and continued to monitor food and fluid intake; Participants recorded average of 56% of fluid intake. Generally unable to scan items but could use icon interface. All participants felt feedback was applicable  Limitation: Difficulty obtaining consumption data; proxy used for literacy



Dennison et al., 2013	Qualitative, inductive thematic analysis  Explore adult perspectives on apps and changes in health behavior	n=19	4 focus groups discussions with images showing health-related apps to trigger discussion	18-years-old; recruited from university campus	App usefulness and appeal depends on existing motivation to change health behavior. Participants liked apps to help monitor improvements in health behavior. Best suited for those with chronic conditions to monitor diet and exercise, elderly who need med reminders, or psychological therapy  Limitations: Small, self-selected sample; retrospective accounts and hypothetical discussion of app uses
Kirwan et al., 2012	2-arm matched case control trial  Determine app potential to improve physical activity health behaviors	n=200	Intervention group given allowed to use app or website to log steps. Given questionnaire on usability and usefulness	Recruited via email; matched with comparable ages, gender, membership length, average number and frequency of steps logged in past 3 mos.	App assisted program engagement. Matched group had significant decline in frequency and steps logged. 71% smartphone app usage vs. 29% website usage suggests convenience, usefulness, and usability  Limitations: Matched-case; small sample; short duration; not representative of wider population; self-selected; may have been more self-motivated than control group
Kirwan et al., 2013	2-group randomized controlled trial  Evaluate effectiveness of app and feedback in improving glycemic control of type 1 diabetics	n=72	Groups continued care from diabetes PCP every 3 mos. Intervention group used app to upload blood glucose levels, insulin dosages, medications, diet, and physical activity. Certified diabetic educator provided feedback	Age 18-65; Type 1 diabetes > 6 months; HbA <sub>1c</sub> >7.5%; multiple daily injections or insulin pump treatment	Intervention group had significant decrease in HbA <sub>1c</sub> (p<0.001) over 9 months. Control group had non-significant increase. No significant differences between groups for other outcomes. No significant relationship of text message and app engagement and HbA <sub>1c</sub> change  Limitations: Baseline differences in glycemic control and gender; small sample; short study period; patient dropout; possibility of some control participants using app during study
Kristjánsdóttir et al., 2013b	Parallel group, randomized controlled trial  Evaluate efficacy of smartphone intervention for chronic pain	n=140	1-hour face-to-face session with nurse; 3 diaries per day on smartphone. Daily therapist feedback for 4 weeks, excluding weekends. 4 audio files with mindfulness exercises	18 years or older; female; participant in chronic pain multidimensional rehabilitation program; chronic pain >6 months with or without fibromyalgia diagnosis; not participating in another research project; use of smartphone; no major psychiatric diagnoses	Intervention group reported less catastrophizing than control (p<0.001); moderate results at 5-month follow up  Limitations: 30% withdrawal rate; younger participants had less pain, less sleep disturbance, better baseline function. Follow-up response rate <70%
Kristjánsdóttir et al., 2013a	11-month follow up to randomized controlled trial  Evaluate long-term effects of smartphone intervention for chronic pain	n=82	See Kristjánsdóttir et al. (2013b)	See Kristjánsdóttir et al. (2013b)	No significant differences of catastrophizing, acceptance, functioning, and symptom level between intervention and control groups evident (p>0.10). More improvement within intervention group of catastrophizing scores compared to control group (p=0.045). Small positive effect (d=0.33) on catastrophizing from baseline to 11 months in intervention group; no change in control group. Positive effect on acceptance found within intervention group (p<0.001).  Limitations: Response rate <70%; those who did not complete follow-up had generally more admission symptoms

Logan, 2013	Prospective, open, randomized primary end-point controlled trial  Examine self-care and measures to lower blood pressure (BP) of hypertensive diabetics	n=110	Self-care group taught to use app and Bluetooth-enabled BP monitoring device. PCP reviewed data, indicated values for critical alert messages. No contact with researchers during study	Patients familiar with computers; access to Internet	BP significantly decreased only in self-care group. BP readings declined despite reminders.  Limitations: Interventions not masked; no analysis of support group mechanisms or adherence to home BP readings in control; no analysis of weight or HbA <sub>1c</sub>
Lyles et al., 2011	Qualitative, randomized pilot  Evaluate disease management of type 2 diabetics	n=14	Smartphone and website browser on videogame console used to upload glucose readings via Bluetooth interface and app. Nurse provided feedback and clinic visits. Interviews at end of study	18-75 years old; type 2 diabetics; at least 1 visit between 2007-2008; HbA <sub>1c</sub> >7% in past year	Increased self-awareness; provider connection increased self-care behaviors. No value in accessing web-based elements. Some receptive to mobile communication services to manage diabetes  Limitations: Small sample size; limited comparison among age groups; technical literacy
Nes et al., 2012	Pilot study  Evaluate feasibility of smartphone intervention for self-management of type 2 diabetes	n=15	Smartphone with secure Internet connection, individualized nurse therapist-written feedback based on ACT, audio files with mindfulness and relaxation exercises, app to transfer blood glucose from meter to smartphone. Daily diaries with feedback for first month, then weekly after	Males and females 49-71 years old	Most perceived experience to be supportive, meaningful, and motivating. High satisfaction with feedback content; helped reinforce coping strategies. Majority found smartphone user-friendly; main issues were display; size too large; Internet connection. HbA <sub>1c</sub> indicative of behavioral changes. Nurse felt participants not knowledgeable about diabetes  Limitations: Small sample; time-consuming in beginning; lack of nonverbal communication
Nguyen et al., 2009	Randomized, repeated pilot study  Compare dyspnea programs	n=50	Nurse consultations, assessments, app training; reviewed submissions, provided feedback, reinforced strategies. Face-to-face group did not receive PDA	COPD; clinically stable for at least 1 month; spirometry results of at least mild obstructive disease; ADL limited by dyspnea; internet use and checking email at least 1x/wk with Windows OS; O <sub>2</sub> sat < 85% on room air or < 6L/min nasal cannula after 6-min walk test	Both groups showed meaningful improvement in dyspnea with ADL and at 0-3 mos and at 6 mos. 6-min walk test declined in eDSMP and improved in eDSMP with marginal group by time difference (p=0.05). 100% eDSMP agreed or strongly agreed they received nurse support. HRQOL improved over time for both groups (p<0.001)  Limitations: Study ended early; technical difficulties; self-reported measures

Pfaeffli et al., 2013	Convergent validation study  Determine validity of smartphone questionnaire against accelerometry in cardiovascular disease (CVD) patients	n=30	Demographics questionnaire and 6-minute walk test at first visit. Smartphone questionnaire preloaded on app for responses to 2 questions daily for 7 days, while wearing accelerometer. 1-week follow-up visit	49-85 years old; exercise-based cardiac rehabilitation clinic; CVD history	App-based questionnaire relatively reliable and valid measure of physical activity, as good as existing self-report measures. Findings support mobile questionnaire to assess physical activity. Little within-day variability for mobile phone questionnaire.  Limitations: Small sample; mostly New Zealand European men
Stinson et al., 2013	Qualitative usability testing and thematic analysis  Design and test smartphone pain app for adolescents with cancer	n=14	Interviews for usability testing. Users alerted to record pain in game-based app, rewarded with ranks; completed surveys. Compliance and satisfaction data collected after trial	9-18 years old; hematology/oncology center patients; self-reported pain at least once in last week; no severe cognitive illness or comorbidities	App appealed overall to adolescents. Compliance high from week 1 to week 2 (p=0.55) due to app notifications resulting in internal motivation. Pain diary has potential to improve pain management and QOL in adolescents with cancer  Limitations: Small sample from one oncology program
Turk et al., 2013	Secondary analysis Burke et al. (2011)  Evaluate feedback role in weight loss	n=210	See Burke et al. (2011)	See Burke et al. (2011)	Daily feedback significantly increased self-monitoring adherence. Feedback has potential to enhance self-monitoring adherence  Limitations: Existing data for secondary analysis; sample of mostly educated, employed White females
Vanderboom et al., 2013	Feasibility, descriptive  Evaluate app monitoring in fibromyalgia patients	n=20	Rated pain, fatigue, and activity 3 times per day for 7 days app. App-generated emails for RN review and feedback. 1-hour focus group at end of study	Outpatients of fibromyalgia treatment program from 4/2011 to 7/2011	Perceived interactions nurse as valuable and reinforced self-management strategies. Interactions have potential to impact outcomes  Limitations: Small sample size; lack of diversity; limited technology; knowledge level
Verwey et al., 2014	Pilot study  Test performance, acceptance, and satisfaction of app	n=20	Accelerometer and app use for daily life. Nurses assessed baseline activity, helped patient set daily goal, provided feedback based on data from tool	10 adults >40 years old with type 2 diabetes and BMI > 25kg/m <sup>2</sup> ; 10 adults with COPD stage 2-3 who would benefit from more physical activity	3 themes: Awareness of physical activity performance; stimulating effect of daily target goal; positive effect on self-efficacy. Nurses spent more time on technical issues than physical activity but stated tool useful for obtaining objective data; stated it was easier to discuss when looking at data with patient. Once technical issues resolved, tool feasible in primary care  Limitations: Small sample size; possible selection bias; no control group; accelerometer not validated
Welch et al., 2013	Randomized, pilot study  Examine feasibility of app, changes in weight, self-efficacy, and perceived benefits	n = 44	Scanned food packages or selected food icons from database; received individualized feedback. Researchers collected app data at baseline, 6 and 8 weeks, recorded questionnaire responses	18+ years old; outpatient hemodialysis patients; alert and oriented; receiving treatment for 3 months or longer; self-reported difficulty following diet or fluid prescription	No effect based on group assignment. No statistical significance in improvements of diet or self-efficacy; those who used app 50% of time had significant sodium reduction. Significantly increased perceived control at end of study returned to baseline at 8 weeks  Limitations: Data not entered as instructed; small sample size; predominantly African American; lack of direct self-efficacy statements; potential interaction among groups

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