Mobile Health, Self-Management, Diabetes & the Impact of Self-Efficacy:

A Systematic Review of Literature

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Abstract

The purpose of this systematic review was to analyze mHealth trials designed to assist diabetics with the challenges of self-managing their illness through technologically-based and theoretically-informed health interventions, in order to examine both physical and psychological outcomes and to determine the potential impact of technology on these factors.

Using Albert Bandura's theory of self-efficacy, this research addressed whether mHealth technology may impact diabetic patient's self-reported levels of efficacy when used to assist in the self-management of their illness. Search efforts yielded 263 initial articles, 15 studies were selected for analysis. Results indicate a strong correlation between technology-use and improved patient self-efficacy.

Evidence supports mHealth trials can also have a positive, statistically-significant impact on physical health outcomes (i.e. HbA1c), and therefore (even with differences in trial design and duration) communication technology can be a useful tool for facilitating improvements to self-efficacy for diabetics over non-technological healthcare models.

Introduction

i. Examining the Problem

The World Health Organization (WHO) predicts that by 2020 chronic illness will be responsible for approximately 60% of the total global burden of disease (WHO, n.d). Diabetes is reported to be one of the fastest growing chronic diseases in the world, currently affecting more than 346 million people (WHO, 2011b, p.1). WHO estimates that diabetes is responsible for one-in-twenty deaths globally (Farmer & Avard, 2008), and predicts that it will "become the seventh leading cause of death in the world by the year 2030 [with the] total deaths from diabetes projected to rise by more than 50% in the next 10 years" (WHO, 2011b, p.2).

In response to these statistics, diabetes has been flagged as a significant health priority among international health organizations that recognize diabetes as a serious global health issue (i.e. International Diabetes Federation, WHO). Although these predictions provide some indication of the rapid pace at which this chronic illness is impacting the global population, understanding the growing complexities associated with the prevention, diagnosis, and management of this disease continues to present significant challenges for both healthcare professionals and their patients.

ii. Defining Diabetes

In simple terms, diabetes can be defined as "a chronic condition that stems from the body's inability to sufficiently produce and/or properly use insulin, which the body needs [in order] to use sugar as an energy source" (Public Health Agency of Canada, n.d.). According to the Canadian Diabetes Association, there are three main types of diabetes namely: type 1, type 2, and gestational (Canadian Diabetes Association, n.d.). Gestational diabetes is a temporary form of diabetes that occurs in pregnancy and is "defined as high blood sugar (hyperglycemia) with onset or first recognition (occurring) during pregnancy" (Canadian Diabetes Association, n.d.). This temporary type of diabetes can indicate a heightened risk for developing diabetes later in life for both the mother and the child (Canadian Diabetes Association, n.d.).

Type 1 diabetes (T1D) is an unpreventable form of this disease that "[…] occurs when an individual's pancreas does not produce the hormone insulin, which is required to convert sugar into energy" (Canadian Diabetes Association, n.d.). This type of diabetes is often diagnosed in patients before the age of 30 and requires a lifelong regime of insulin to be administered by syringe, pen or pump in order to help regulate the patient's blood glucose levels (Canadian Diabetes Association, n.d.).

Type 2 diabetes mellitus (T2DM) is the most common form of diabetes in the world, affecting between 90-95% of Canadians living with this chronic illness (Public Health Agency Canada, 2011), and about 90% of the global diabetic population (WHO, 2011b). These rates are particularly troubling when viewed with evidence that some cases of type T2DM may be prevented, or the onset delayed, through better diabetes education, regular physical activity, maintenance of a healthy body weight, and healthy food intake (WHO, 2011b). However, both the prevention and proper management behaviour is far more complex than these factors would appear to illustrate.

iii. Importance of Disease Self-Management

In terms of the daily management of diabetes, the burden-of-care often falls most heavily upon the individual patient. Though trials targeting diabetics vary greatly by design, duration, sample population and methodological rigor, a common trend within the research demonstrates an interest in programs which may influence positive changes to self-care behaviour and self-monitoring routines as evidence suggests these have a direct and corresponding positive impact on diabetic health outcomes (Arsand, Tufano, Ralston & Hjortdahl, 2008; Mirza, Norris & Stockdale, 2008). For example, in a systematic review and meta-analysis of 25 randomized control trials (RCT) for T2DM patients, McIntosh et al. (2010) found that patients self-monitoring behaviour had a significant and direct positive impact on improvements in glycemic control. This is an important finding, as blood glucose monitoring and improvements in HbA1c levels are a primary objective in most diabetic research and essential to the overall health of a diabetic patient.

In terms of the basic self-care requirements for Type 1 diabetes, patients undertake the daily responsibility of monitoring and administering their own insulin. This presents its own series of challenges, taking into account the fact that a large majority of T1D's are diagnosed while under the age of majority. In such cases, the burden-of-care can be managed by parents and guardians, however this can make the eventual transition from supervised management to self-care an overwhelming and isolating experience for adolescents (Scott, Vallis, Charette, Murray & Latta, 2005).

With T2DM self-management, health issues can arise when excess glucose builds up in a patient's blood stream instead of being converted to energy (Canadian Diabetes Association, n.d.). Like T1D, this requires patients to monitor their own blood glucose (blood sugar) in order to ensure their levels remain within the targeted range (Canadian Diabetes Association, n.d.). Thus, the demanding nature of diabetic self-management provides some explanation as to the increasing interest in research for diabetes programs that may assist patients in their self-care efforts.

iv. Burden to Healthcare System & Challenge for Primary Care Providers

However, beyond assisting individual patients this research also has the potential to make a larger impact. "In many countries diabetes consumes between 5% and 10% of the healthcare budget, and more than 50% of that cost is due to diabetic complications" (World Health

Organization & International Diabetes Federation, 2004, p.17). Increasingly complex, costly and time-consuming medical care for chronically-ill patients is a growing global problem (WHO, n.d.). In Canada, results from the National Physician Survey (NPS) polling 12,000 practicing physicians reported that doctors are finding it increasingly challenging to meet the healthcare requirements for their growing roster of chronically-ill patients (College of Family Physicians of Canada, June 27 2011). “Nearly three-quarters (72%) reported that the complexity of their patient caseload is placing increasing demands on their time” (College of Family Physicians of Canada, June 27 2011), and two-thirds (63%) identified managing patients with chronic conditions as a key factor influencing those increased demands (College of Family Physicians of Canada, June 27 2011).

These factors combined with the rapid increase in global diabetes rates re-enforce the need for a review of tools and programs that may help to ease the burden-of-care associated with both the prevention and management of this disease. Pilot-projects and clinical trials have become increasingly focused on the potential of leveraging technology in order to assist patients in their self-management tasks (Preziosa, Grassi, Gaggioli & Riva 2009; Patrick, Griswold, Raab, & Intille 2008). This field is often referred to as mobile health (mHealth) research.

v. Mobile Health (mHealth)

Mobile health, referred to throughout this paper by the abbreviated terminology mHealth, can be defined as “the use of mobile and wireless technologies to support the achievement of health objectives” (WHO, 2011a, p.9). mHealth falls under the broader umbrella of electronic health (e-health) as well as, wireless telemedicine as it frequently involves leveraging mobile phones features and web-enabled devices to provide medical healthcare services and information (Yadav & Poellabauer, 2012).

Due to its broad and evolving definition mHealth technology now refers to a range of wireless and mobile devices including, but not limited to: mobile phones, mobile tablets, laptops, computers, personal digital assistants (PDA), and a growing number of wireless, portable medical devices including sensors and monitors.

While mHealth programs involving computers have become well-established within the literature, investigations involving mobile phones are a growing and particularly promising area of mHealth research. Studies have demonstrated that factors such as the global penetration of mobile communication technology as well as adoption habits of mobile phone users make it a particularly practical tool for assisting in the daily transmission, monitoring and dissemination of health information to diverse populations, even within relatively resource-poor communities (Quinn et al., 2011; Piette et al., 2011; Fan & Sidani 2009; Kaufman & Woodley, 2011, Katz, Mesfin & Barr, 2012).

mHealth is an increasingly relevant and timely area for health communication research, as reports indicate that over 85% of the world's total population now have access to wireless signals extending far beyond the reach of the electrical grid and there are currently more than five billion wireless mobile subscribers worldwide (WHO, 2011a, p.9). In fact, according to a recent Times Magazine survey of 5000 people "84% worldwide say they couldn't go a single day without their mobile device in their hand" (Duerson, NYdailynews.com, 2012). This survey included a varied and diverse cultural, demographic and economic population sample from eight key countries, namely the United States, United Kingdom, China, India, South Korea, South Africa, Indonesia and Brazil. Interestingly, five of eight countries used in this survey also rank within the top 10 countries with the highest global diabetes prevalence rates (WHO, 2011).

This survey also found that "1 in 4 people check their phones about every 30 mins [and] 1 in 5 people check it every 10 mins" (Gibbs, techland.time.com, 2012). Polling results such as these help to demonstrate the importance of mobile technology in our daily lives and support the potential for mobile phone-based health programs.

Purpose of Study

Consequently, the purpose of this paper was to critically and systematically review existing literature on mHealth diabetes trials designed to assist participants in the self-management of their illness in order to gather a better understanding of the potential impacts of communication technology (specifically computers and mobile phones) on *both* physical and psychological health outcomes for diabetics. Based on the intended scope of this paper, investigations and analysis of mHealth interventions for diabetes focused only on randomized control trials[1] (RCT) and pilot projects that utilized web-enabled computer technology or mobile phones functionality as the primary tool for their program. Both RCT and pilot projects were chosen in order to allow for the most inclusive research parameters and review potential variants that resulted from the differences in design and program duration of these two types of trials. Mobile phones and computers were selected because a review of the literature indicated these tools were most frequently utilized technologies harnessed for mHealth research.

[1] A randomized control trial is defined by Sibbald & Roland (1998) as: "the most rigorous way of determining whether a cause-effect relation exists between treatment and outcome and for assessing the cost effectiveness of a treatment. They have several important features: Random allocation to intervention groups, patients [...] should remain unaware of which treatment was given until the study is completed—although such double blind studies are not always feasible or appropriate, all intervention groups are treated identically except for the experimental treatment, patients are normally analysed within the group to which they were allocated, irrespective of whether they experienced the intended intervention (intention to treat analysis), the analysis is focused on estimating the size of the difference in predefined outcomes between intervention groups" (p. 201)

Therefore, this review will help close gaps within the current literature by providing a research synthesis of the impact of this technology as demonstrated in diabetes trials, focusing on comparing both physical and psychological outcomes while evaluating the way factors such as age, sex, ethnicity and socio-economic status have been handled by researcher.

In order to better conceptualize mHealth diabetes research, evaluate the psychological impact of patient self-efficacy on health outcomes, and explore the role of mHealth technology in diabetes self-management, we will now turn to previous studies that have examined important diabetes risk factors, explored the significance of common barriers to care and discussed the potential role of technology.

Diabetes Risk Factors, Barriers-to-Care and Technology: A Review of Previous Studies

i. Key Influencers & Risk Factors

Based on the higher prevalence for T2DM and with the understanding that T1D is an unpreventable form of this disease, the primary emphasis of this literature review will remain largely on T2DM-related material. As such, it is essential to identify some key contributing factors that have been linked to an increased risk for developing T2DM. WHO outlines some of the most relevant factors for increasing an individual's risk for T2DM as: advancing age, ethnicity, high body mass index (BMI), unhealthy diet, inactivity, tobacco, and the harmful use of alcohol (WHO, n.d.(b)). From a clinical perspective, it is difficult to isolate any single factor as the primary or most significant contributing catalyst for heightening risk. It is also important to note that each factor comes with its own complex sets of variables, several factors may occur simultaneously, each may behave unpredictably based on the individual's health history, and (as with age and ethnicity) some risk factors are simply unavoidable. This may provide some indication of why detection, diagnosis and treatment of T2DM is an increasingly complex health challenge.

Within this research report, age and ethnicity were highlighted as important factors for further investigation, particularly because they are elements that represent both pre-determined and unavoidable risk (Oldroyd et al., 2005; van den Berg et al., 2012)

In terms of sex-based statistics, research indicates that T2DM affects men and women at relatively equal rates with slightly higher incidences occurring in men under the age of 60 and in women over the age of 65 (WHO, n.d.(b)). In terms of age, the International Diabetes Federation's (IDF) fifth edition of the *Diabetes Atlas* states that, "the greatest number of people with diabetes are between the ages of 40 and 59" (International Diabetes Federation, 2011, p. 27), with the second highest incidences found in people between 60 and 79 years of age (International Diabetes Federation, 2011).

Interestingly, the Public Health Agency of Canada reports that the risks for T2DM steadily increases with age after 40, despite the fact that 50% of the affected Canadian population actually fall between the ages of 25 and 64 (Public Health Agency Canada, 2009). The next largest segment of the population affected are those over the age of 65, with approximately one-in-three people living with diabetes in Canada falling between the ages of 55 and 69 (Public Health Agency Canada, 2009). In terms of diabetes mHealth research these are relevant statistics to highlight, as research also indicates there can be age-related limitations to the use of technology. More specifically, researchers suggest "cognitive and visual impairment, communication barriers, [and] hearing problems" (van den Berg et al., 2012) can have a significant impact on the reported preferences, usability, and acceptability of such tools particularly in elderly populations. As T2DM greatly affects the elderly population and more mHealth programs are being designed to assist in T2DM management age-related research and technological preference are an increasingly important area of health research that needs further investigation.

It is important to note, that not all research has indicated that age-related preferences and technology-use are met with barriers, negative feedback or poor health outcomes. In fact, a recent review by van den Berg, Schumann, Kraft & Hoffmann (2012) suggests technology may be an extremely effective and increasingly practical tool for assisting in the care and monitoring of chronic illnesses in elderly patients. Results from their analysis of 68 telemedicine intervention studies conducted on patients 60 years of age and older found that even those studies using relatively complex technological features such as videoconferencing yielded predominantly positive results. Specifically, this research suggests that these technology-based interventions can actually result in greater improvements in behavioural outcomes such as self-efficacy, and in the case of diabetes-specific trial research 11 of the 16 studies analyzed also reported achieving positive physical clinical health outcomes (including specific improvements in HbA1c, LDL cholesterol, and blood pressure) (van den Berg et al., 2012). This is particularly encouraging as it presents evidence that indicates technology may not only be an effective tool for improving diabetes care in one particular age group, but that it lends more support to the use of technology for the purpose of improving behavioural and psychological outcomes as well.

a.) Ethnicity

Another factor that can have a significant impact on the prevalence of diabetes, is ethnicity. “Ethnicity refers to common cultural traditions, geography, ancestry, religion, and history […] common culture typically includes language, religion, and diet” (Oldroyd, Banerjee, Herald & Cruickshank, 2005). Cultural commonalities, such as diet and lifestyle habits have become a significant linking factor connected with increased rates of T2DM among certain ethnic groups, specifically: Aboriginal communities, South-East Asians, Hispanics, Latin Americans, and the Black African and Caribbean populations (Oldroyd et al., 2005). In addition to evidence of an increased risk for diabetes among these ethnic groups, studies have found that ethnicity can also be a relevant factor in terms of assessing barriers to self-care behaviour in diabetic patients (Pun, Coates & Benzie, 2009). According to Pun, Coates & Benzie's (2009) who analyzed 16 original studies covering 28 countries and surveying over 8900 patients, results suggest that when directly comparing feedback from African American diabetic participants with white Caucasian patients, perceived barriers had specific ethnic and cultural foundations (Pun, Coates & Benzie, 2009). More precisely, the authors state "the quantitative data showed that the African American women were more likely than their white counterparts to indicate financial, painful (e.g. neuropathic pain) and/or visual barriers to self-care" (Pun, Coates & Benzie, 2009, p. 7). Thus, ethnicity may be a relevant factor to examine in a review of mHealth trials aimed at assisting patients in their diabetes self-management tasks particularly if researchers want include an ethnically-diverse sample. Researchers must be aware of the potential barriers that participants may experience in order to design program strategies and alternatives that may help mitigate these barriers. If ethnicity can be linked to both the increased risk for diabetes, and as a significant linking factor in assessing barriers to self-care behaviour, it should be considered an essential variable in mHealth research specifically for programs targeting and including at-risk populations and diverse population samples. For this reason, ethnicity was a specific factor of interest highlighted in this research synthesis.

b.) Socioeconomic Factors

It is important to note that although age and ethnicity are significant factors associated with an increased risk for T2DM they are not the only relevant factors this paper has considered in the analysis and review of diabetes mHealth trials. According to research conducted by Dinca-Panaitescu et al. (2011) diabetes risk factors are becoming an increasing complex issue and though “some of these factors are physiological and genetic as well as health behaviours related, […] social and economic statuses are also important” (Dinca-Panaitescu et al., 2011, p.118). More precisely, socioeconomic factors have been found to have a significant impact on both the risks and prevalence of T2DM. In a study of the impacts of socioeconomic factors on diabetes prevalence conducted by Dinca-Panaitescu et al. (2011) results suggest that personal income has a direct and statistically significant impact on prevalence rates for diabetes in both men and women. Interestingly, this significance remained consistent across various adult age groups (Dinca-Panaitescu et al., 2011). The results from this research were gathered using population-based survey data from across Canada and indicate that more research is needed particularly in terms of determining the impact of other socioeconomic factors and their contribution to heightening the risks for developing this chronic illness. Dinca-Panaitescu et al. (2011) state that in reviewing numerous studies that examine the role between income and education on diabetes, both factors had a similar effect on prevalence rates but when adjusted for variants including physical activity, BMI, age, sex and ethnicity the effects of education varied and in some cases became insignificant, whereas income remained both a consistent and significant predicting factor. Thus, this project chose to highlight age, ethnicity and socioeconomic factors in combination and to include an investigation into both education and income in order to gain a better understanding of the trends and highlight potential gaps in the current literature.

Beyond these risk factors there are several other issues to consider before analyzing trials designed to assist diabetics manage their illness. In particular, we must address specific management requirements and the common barriers associated with self-care activities must be established before research can determine how technology may impact these efforts.

Pun, Coates & Benzie (2009) state that the burden of T2DM "requires patients to perform self-care activities by modifying their lifestyle on a long-term basis"(p.5), which may be an extremely daunting task. As defined by Funnel et al. 2007, "the self-care regimens [can] include diet modifications, adherence to medication, regular exercise, foot [and eye] care and self-monitoring of blood glucose (Pun, Coates & Benzie, 2009, p.6). For this reason, many intervention studies focus their primary objectives and outcome measures on these activities, and most often specifically on improving the frequency and consistency of glucose levels (HbA1c). The recommended guidelines of which are reported to be <7% glucose or sugar in the blood (Costa et al. 2009). Each health and lifestyle modification may present its own unique challenges for patients but, they are not the only party-of-interest when it comes to addressing challenges and barriers to proper diabetes self-management.

General practitioners and primary healthcare providers can have an essential role in promoting self-care and improving overall diabetic health. Their attitudes, knowledge, and technical literacy can all have an impact on how a patient's self-care routine may be approached.

ii. Barriers-to-Care

Therefore, critical to a study of the potential impacts of interventions targeting diabetes is a fundamental understanding of the common barriers contributing to poor self-care behaviour and adherence beyond the perspective of the patient. Pun, Coates & Benzie (2009) offer a useful systematic review of studies exploring the main barriers to self-care for T2DM gathered from the perspective of both patient and provider. This review provides a broad overview of the challenges associated with traditional clinical diabetes care and results demonstrate that the barriers identified by patients and their providers are not necessarily consistent with one another.

For example, patient-reported barriers focused mainly on socioeconomic, psychosocial, physical and environmental factors perceived to be influencing their ability to perform adequate self-care activities. Some of these barriers included: the lack of family/social support and relevant health information, challenges related to restrictive dietary options and exercise regimens, requirements for self blood-glucose testing, cost associated with self-care activities (from both a personal and financial perspective), and inadequate health resources (trained professionals). However, for healthcare providers, barriers focused primarily on physical, environmental and cultural challenges, as well as larger policy issues that they associated with impeding proper care. Specifically, these included barriers related to understanding and translating the complexities of the disease and its complications to patients, social and personal attitudes towards the disease, limited management options, and communication barriers (including cultural and language differences) each leading to poor adherence and substandard disease management. Costa, Fitzgerald, Jones & Dunning (2009) support a similar assessment in their discussion of the barriers that face general practitioners, conducted in Australia. Costa et al. (2009) state "many of these barriers relate to insufficient time, knowledge and inadequate communication among HPs [health professionals]" (Costa et al., 2009, p.2), and therefore acknowledge that the challenges associated with the translation of essential health information is not solely an issue impacting patient and provider communication but, also may exist between the providers themselves. Costa et al. (2009) go on to state that "a structured approach to care planning, which could be facilitated by IT, could begin to address barriers associated with time constraints, knowledge deficits and inadequate communication among HPs" (p.2). In their research they see the potential for technology to enhance the flow of communication with patients, and to encourage the dissemination of health knowledge among healthcare professionals, as well.

In terms of the application of this research for this project, it demonstrates a significant barrier impacting effective diabetes management, specifically the need for better communication channels and tools to bridge the gaps in self-care. From a health communication perspective, it is therefore essential to determine ways to better facilitate the patient-provider/ provider-provider communication processes. The effective integration of technology may be one practical means for enhancing communication. For example, a systematic review of cell phone interventions for diabetes by Krishna & Boren (2008) discovered that cell phones and text messaging were particularly successful tools for improving communication between patients and their providers, because when compared to other technologies they were the preferred and most successful tool for "facilitating regular treatment advice and support between in-person clinical visits" (p.516).

However, there are still large gaps within the literature in terms of preferences for technology with effective long-term positive health outcomes and the ability and potential for technology to assist in overcoming reported barriers-to-care. In particular, the following barriers may be assisted by mHealth: tracking and adapting new regime requirements for patients, streamlining communication processes and building potential social support networks, as well as improving access to resources (including availability of personnel and information).

iii. Overcoming Barriers: Opportunities Provided by Technology

Let us explore more in depth how mHealth technology can be leveraged to overcome such barriers. Pun, Coates & Benzie's (2009) have addressed this question and offer three key guidelines that they believe must exist in order to help healthcare providers overcome perceived barriers and successfully achieve more effective self-management behaviour in their diabetic patients. Despite the fact that the authors main objective for their review was to identify and explore major barriers to care, the identification of the key factors necessary for overcoming these barriers presents a strong case for the value of incorporating technology into diabetic self-care. For example, the first key to overcoming barriers was to provide patients with a sufficient base of knowledge and diabetes-specific education to enhance their understanding of this disease (Pun, Coates & Benzie, 2009). Interestingly, several studies have substantiated the potential for technology (specifically mobile phones and computers) to encourage (statistically) significant improvements in diabetes knowledge through pilot projects and RCT's where intervention groups actually have shown greater improvements in knowledge than control groups (Balamurugan et al., 2009; Goodarzi et al., 2012; Pacaud et al., 2012). More specifically, a review published in the Canadian Journal of Diabetes entitled the *Effectiveness of Diabetes Self-Management Education Intervention Elements: A meta-analysis* compared 50 RCT's for T2DM self-management education programs and found that between traditional face-to-face clinical trials and those utilizing technology such as computers, phones and video features, "phone contact appeared to be an effective method for delivering DSME [diabetes self-management education] and supporting patients, particularly with respect to improving self-management behaviour and metabolic control" (Fan & Sidani, 2009, p.24).

The second strategy offered to help overcome barriers involves requiring patients to perform all of the recommended activities to reduce risks associated with T2DM and prevent complications (Pun, Coates & Benzie, 2009). Many psychological factors may influence a patients self-care adherence, but successful self-care routines and programs encourage, motivate educate and support patients in these endeavours. Several studies suggest that factors such as motivation, frequency and consistency of self-care activities, as well as overall patient activation and regime adherence may be improved through the use of technology-based programs (Goodarzi et al., 2012; Nundy et al., 2012; Lorig et al., 2010; Balamurugan et al., 2009; Wangberg, 2008). In the words of one patient participating in a text-based T2DM mobile trial conducted by Nundy et al. (2012), the text message reminders were particularly helpful for adherence. "[…]Prior to the beginning of the study, I was very forgetful about taking my medication; I wasn't taking it in a timely manner. By actually being in the study [receiving text message reminders] it made me become more aware of how important it was for me to take my medication at the same time everyday on a regular basis, at a specific time" (Nundy et al., 2012, p.4). In the patient's own words, this is one primary example that helps to illustrate a trend within the research. Patients were often encouraged to improve their self-care behaviours simply through being enrolled in such programs. Unfortunately, the long-term application and implications of such research is still relatively lacking within the current literature and will be an important area for future mHealth research.

Pun, Coates & Benzie's (2009) final strategy for overcoming barriers, suggests that diabetes programs need to be tailored to teach and support patients in acquiring and applying the skills that will help to facilitate positive psychosocial functioning. According to the article, *Assessing Psychosocial Distress in Diabetes: Development of the Diabetes Distress Scale*, Polonsky et al. (2005) state that psychosocial issues associated with diabetes can include all manners of emotional distress and can often lead to a heightened risk for developing depression. In Ali et al.'s (2010), *The association between depression and health-related quality of life in people with type 2 diabetes: a systematic literature review*, researchers state "[…] depression in people with diabetes and adverse outcomes including poor HbA1c control, adherence to medication and mortality have been examined and confirmed" (p.75). This final strategic recommendation by Pun, Coates & Benzie (2009) provides an indication of how the current systematic research synthesis may be relevant at the clinical level, as many previous reviews of mHealth technology-based trials have neglected to include an in-depth examination of psychosocial factors particularly looking at the potential links between patient self-efficacy, diabetes self-management outcomes and the use of technology. Therefore, the strategies suggested by Pun et al. (2009) not only serve to highlight the importance of patient self-management behaviours for diabetes, but the authors also provide suggestions for a useful strategy that may address a number of the common barriers to self-care and more significantly, demonstrate specific areas where technology may offer a useful tool for improving diabetic self-management and overall health outcomes.

Clearly, technology is one way to improve the communication between patient and provider. With reports indicating that over 85% of the world's total population now have access to wireless signals extending far beyond the reach of the electrical grid and there are currently more than five billion wireless mobile subscribers worldwide"(WHO, 2011a, p.9) the potential for mHealth programs to assist diabetes management continues to improve.

There are significant opportunities for leveraging the capabilities of technological tools such as mobile phones and computers for medical interventions. Particularly using features such as: SMS text messaging and mobile applications, websites, as well as instant chat and video capabilities on computers.

Technology-based mHealth tools enable the instantaneous customization of programs, both in terms of design and delivery based on preference and feedback measures. A review by Mulvaney, Ritterband & Bosslet (2011) supports this assessment particularly for diabetes in their review of 22 mobile diabetes intervention programs conducted to determine recommendations in effective electronic trial design. The authors state "studies with the greatest impact on hemoglobin

A1c integrated patient feedback and a role for clinicians" (Mulvaney, Ritterband & Bosslet, 2011, p. 486). Feedback may be easier to attain and assess through electronic participation and technology-based trials. Electronic records and usage can also be measured to capture user data and behaviour while on a website or mobile application without the participants direct input. In contrast with a clinical-setting or approach, this type of feedback may not be as easily accommodated, acknowledged or improved upon by primary-care providers conducting a tradition program in a clinical setting.

In the article *Healthcare in the pocket: Mapping the space of mobile-phone health interventions*, Klasjna & Pratt (2012) present a brief summary of the current mobile health landscape that was particularly relevant for this paper. In this article, which focused exclusively on intervention designed for mobile phones, literature was used to identify emerging opportunities within this growing medical field. The authors identify four potential reasons for the growing interest and use of mobile phones in health intervention state: "(1) the widespread adoption of phones with increasingly powerful technical capabilities, (2) people's tendency to carry their phones with them everywhere, (3) people's attachment to carrying their phones, and (4) context awareness features enabled through sensing and phone-based personal information" (Klasjna & Pratt, 2012, p.185). In addition, this research identifies the five most common technical features used in mobile interventions including: text messaging, cameras, applications, automated sensing, and internet access. Through these features the authors then identified common strategies most often used to guide the design and objectives of mobile interventions. "Specifically, we have identified five key intervention strategies: (1) tracking health information, (2) involving the healthcare team, (3) leveraging social influence, (4) increasing the accessibility of health information, and (5) utilizing entertainment [features] (Klasjna & Pratt, 2012, p.186).

Current mHealth programs leveraging mobile phone technology have allowed T2DM patients to receive regular health reminders regarding appropriate dietary options, recipes, exercise tips, and appointment reminders for prescription renewals, foot checks, and eye care appointments in an effort to promote healthy lifestyle changes and improve blood glucose control, even in low income countries (Ferrer-Roca, Cãrdenas, Diaz-Cardama & Pulido, 2004; Trief et al. 2008; Rotheram-Borus et al. 2012). Mobile technology can also allow patients to track health information through mobile applications (apps) that monitor and record patient glucose levels and lifestyle habits in order to allow patients to better self-manage their disease while sharing this information with their health-care professionals (Arsand et al. 2008). Text messaging features have already proven helpful to the improvement of patient attendance rates at appointments using targeted text reminders (Branson, Clemmey, Mukherjee, 2011), aiding in the smoking cessation (Berkman, Falk, Dickenson & Lieberman, 2011), adherence to drug therapy particularly for HIV treatment (Lewis et al. 2012), as a tool for enhancing aspects of cognitive behavioural therapy in depressed patients from low-income populations by improving the likelihood of patients attending sessions and increasing feelings of closeness between the group and the therapist (Aguilera &Munoz, 2011).

Many mHealth trials still emphasize the challenges related to implementing technology-based programs, citing that technical glitches, high drop-out rates, unrepresentative samples, and overall poor technological literacy have had a significant effect on the potential for their programs to positively impact patient health (Katz, Mesfin & Barr, 2012; Istepanian et al. 2009; Faridi, Liberti, Shuval, Northurp, Ali & Katz, 2008). Despite these challenges, other studies have focused on the important benefits associated with the use of technology for healthcare.

In terms of diabetes self-management using technology, Kaufman & Woodley (2011) offer three main benefits to the use of self-management support interventions that are both clinically-linked and technologically-enabled. According to Kaufman & Woodley (2011), the benefits can be seen to affect three distinct players, 1) the patient, 2) the clinician, 3) the overall healthcare system/community. Benefits for the patient include: an engaging medium for information collection and dissemination which may be tailored to individual learning, encourage regular personal assessments, goal-setting, and tracking relevant clinical health measurements (i.e. weight, activity, diet, glucose levels). Access to such technology can provide an instant connection to information, social support networks and medical care team advice at a time and place convenient to the patient. In terms of clinician benefits these include: support for long-term follow-up, reduced patient travel and scheduling conflicts, improved tracking and review of patient activities and performance as well as frequent, efficient online communication opportunities (i.e. email/video conferencing).

With regards to healthcare system benefits, Kaufman & Woodley (2011) focus on the resource saving potential of technology-enabled interventions, specifically, the potential to decrease acute and intensive health service costs, increase the efficiency of transferring medical information, and improving patient/physician communication channels to streamline the care required for chronically-ill patients (p.801). In fact, research supports the acceptability, usability, effectiveness of patients keeping electronic records when compared to traditional handwritten methods during trials (Dale & Hagen, 2007; Lane, Heddle, Arnold & Walker, 2006; Demidowich, Lu, Tamler & Bloomgarden, 2012). However, they also stipulate ten essential conditions must take place in order to achieve these benefits, specifically: “identify patients [with or at risk of diabetes], encourage program participation, assess baseline status, provide teaching and learning [opportunities], set goals, motivate towards goal attainment, measure results toward goals, receive and provide social support, find needed help, and provide coaching support" (p.800).

Azar & Gabbay (2009) suggest the benefits may also extend to time and cost savings for both patients and clinicians. In particular, the authors found through a review of web-based telemedicine interventions that patients benefited most in the savings associated with travelling and waiting room time and costs including missed work (Azar & Gabbay, 2009). Clinicians benefited most in gaining valuable time through the increase of succinct electronic data allowing for easier analysis and facilitating faster treatment alterations and consultation times through direct patient feedback and reporting. Though the authors speculate that in some cases the healthcare provider may have spent the same, if not additional time on patient analysis using such programs, as often the time of nurses and dieticians who also may have been consulted by patients were not considered. Therefore, though mHealth programs may have time and cost benefits associated with the integration of technologically-based care models, the benefits are largely dependent upon technical literacy, the complexity of the intervention, design of the program, as well as preferences and needs of the specific patient.

iv. mHealth Technologies: Psychological Component

The potential of mHealth technology for diabetic health becomes more interesting when looking beyond the clinical health physical outcomes and considering the potential psychological implications of such tools. According to Aujoulat, Marcolongo, Bonadiman & Deccache (2008), for patients with a chronic illness like diabetes, in order to achieve positive health outcomes "[…] the need for change occurs not only at a behavioural level, but also at a psychosocial level" (Aujoulat, Marcolongo, Bonadiman & Deccache, 2008, p. 1229). As with most illnesses even the psychological perception of barriers to proper care (which can include depression, low self-esteem, lack of confidence and poor self-efficacy) may have a negative impact on the likelihood of any lasting behaviour change (Ali et al. 2010). In fact, in some cases low self-efficacy has been shown to be a primary barrier impeding adequate self-management behaviour (Dick et al. 2011). "Patients might know what should be done and be motivated to change by the management program, but they may relapse back to their 'unhealthy' behaviours if they encounter problems or barriers to achieving self-care activities" (Pun, Coates and Benzie, 2009, p. 5). More precisely, the potential for avoiding relapse and sustaining efforts despite problems can be connected with their perceived confidence or personal self-efficacy (Bandura, 1986). Therefore, the inclusion of an investigation into psychological elements of treatment (i.e. patient self-efficacy) is a central component for any study of diabetes mHealth trials that are aimed at assisting patients in their self-management activities.

In terms of diabetes research, studies have demonstrated that building confidence, self-esteem and improving a patients feelings of self-efficacy can influence not only the execution of proper self-management behaviours, but, ultimately also result in positive physical health outcomes (Mishali, Omer & Heymann 2011; Senecal, Nouwen & White 2000; Quinn et al. 2011). Despite this evidence, the medical community has been relatively slow to put this knowledge into practice within a clinical trial setting. In recent years, more studies have begun to investigate the potential correlation between diabetes self-management and improved clinical health outcomes (on a physical and psychological level). At the heart of this correlation lies the concept of self-efficacy, which has been extensively studied by Albert Bandura (1986).

Self-Efficacy: Bandura's Theoretical Perspective

Bandura's (1986) theory of self-efficacy is derived from social cognitive behavioural theory and has most commonly been applied to research in the fields of psychology, sociology, nursing, education and more recently health communications (Riley et al., 2011, p. 61). Bandura (2004) describes the concept of self-efficacy as the personal judgment of an individual regarding their own personal capabilities, which directly impacts one's ability to "[…] exercise control over one's health habits" (p. 144). More precisely, "self-efficacy theory offers a link between self-perceptions and individual actions. According to this theory, individual beliefs about personal capabilities predict later behaviour" (Jeng & Braun, 1994, p. 427).

It may be important to note that within the clinical literature reviewed for this project, the term self-efficacy is often used interchangeably with patient empowerment (Aujoulat, d'Hoore & Deccache, 2006), and can be closely connected with the concepts of perceived competence, confidence and self-esteem (Gecas, 1989; Williams, Glasgow & Lynch, 2007). For example, in a telemedicine computer-based pilot project conducted by Balamurugan et al. (2009), the authors refer to their psychological results as patient self-efficacy but make a primary attitude marker for their assessment tests, confidence (i.e. specifically how patients measured their ability to control/manage their disease). One explanation for the overlap of these concepts, beyond their closely related definitions, could be that many of the popular assessment tools and scales used for measuring a patients perceived competence, confidence, self-esteem, empowerment and self-efficacy often rely on the fundamental elements of Bandura's theory. One particularly popular assessment tool used for measuring self-efficacy that illustrates these elements is the diabetes empowerment scale (DES) (Anderson, Funnell, Fitzgerald & Marrero, 2000). In their paper *The Diabetes Empowerment Scale: a measure of psychosocial self-efficacy*, Anderson et al. (2000)

describe this test as a 28-item psychometric analysis which evaluates efficacy in three distinct subcategories, namely: "Managing the Psychological Aspects of Diabetes (alpha= 0.93), Assessing Dissatisfaction and Readiness to Change (alpha= 0.81), and Setting and Achieving Diabetes Goals (alpha= 0.91)" (Anderson, Funnell, Fitzgerald & Marrero, 2000, p. 739).

Due to the interconnectivity and mixed use of these terms within the trial literature, studies explicitly aimed at measuring patient empowerment, perceived competence, patient confidence and diabetes self-efficacy were all included in the preliminary search efforts for this research paper.

i. The Impact of Empowerment

In terms of Bandura's (1986) description of the theory of self-efficacy he states that a strong belief, or confidence, in one's capabilities can have an empowering effect. Aujoulat, d'Hoore & Deccache (2006) provide a useful definition of empowerment that helps to highlight some of the benefits empowered patients may experience:

> Empowerment may be defined as a complex experience of personal change. It is guided by the principle of self-determination […] As they get empowered, patients may develop a greater sense of self-efficacy regarding various disease and treatment-related behaviours, and may express changes in life priorities and values. As a result of their empowerment process, patients are expected to better self-manage not only their illness, but their lives as well (Aujoulat, d'Hoore & Deccache, 2006, p. 6).

Alternatively, if an individual feels that they lack the ability to change, control, master and manage their illness, that stress can make them less likely to monitor their daily activities and actions, which in turn, impairs their ability to adequately maintain their health and manage a chronic illness like diabetes. Bandura states that individuals often "interpret their stress reactions and tension as signs of inefficacy" (Bandura, 1986, p. 625). Self-doubt about one's efficacy can ultimately lead to poor emotional and often negative physical health outcomes (Bandura, 2004). This may be one reason Bandura's theory is so applicable to mHealth diabetes research. The theory suggests that the levels of self-efficacy an individual reports can have a significant and direct impact on their resulting physical health, behaviour, motivation, cognitive functioning, and overall personal experience (Jeng & Braun, 1994). It may also assist primary care physicians and researchers in predicting future intentions and eventual adoption of specific behaviour (Jeng & Braun, 1994). More precisely, a patient's reported levels of self-efficacy can accurately predict several health-related behavioural outcomes including: 1) whether participation in health changing behaviour will be initiated, 2) how much effort will be exerted towards a specific goal, and 3) the length of time and effort that such activities will be sustained despite potential barriers and obstacles (Jeng & Braun, 1994).

Bandura's self-efficacy theory implies that the higher the levels of self-efficacy in a patient, the more potential there may be to accurately predict and positively impact their health. Clinical research substantiates these claims. For example, a study aimed at encouraging more consistent physical activity in participants over the age of 50, used daily electronic messages delivered to personal handheld computers, and the outcomes demonstrate that greater patient self-efficacy was a significant predictor of the successful initiation and consistent execution of the resulting physical activity adopted by participants (Dunton, Atienza, Castro & King, 2009).
One explanation for this phenomenon offered by Bandura (2004) is that patients with low-efficacy "[…] make half-hearted efforts to change and are quick to give up when they run into difficulties. They need additional support and guidance by interactive means to see them through tough times"

(Bandura, 2004, p. 148); patients experiencing higher levels of self-efficacy are more likely to sustain efforts despite challenges (Bandura, 2004).

In terms of improving low self-efficacy levels, technology-based health programs may present a particularly strong area of opportunity. As Bandura discovered that a majority of "[…] guidance can be provided through tailored print or telephone consultation[s]" (Bandura, 2004, p. 148). Bandura (2004) goes on to state:

> The revolutionary advances in interactive technology can increase the scope and impact of health promotion programs. On the input side, health communications can now be personally tailored to factors known to affect health behaviour.[…] On the behavioural adaption side, individualized interactivity further enhances the impact of health promotion programs (Bandura, 2004, p.149).

Therefore, if improving patient efficacy can assist researchers in accurately predicting behaviour initiation, adoption and sustainability, it may reasonably have the potential to aid in the development of effective messaging and trial design as well. In its ideal application, the theory of self-efficacy should allow clinical researchers to predict patient behaviour (both the initiation and sustainability of efforts), target key messages and program objectives, while also providing a framework for assisting in the mitigation of potential perceived obstacles in order to successfully motivate positive and lasting behavioural change.

For diabetes, research has already substantiated that patient self-efficacy is a relevant and determinant factor impacting physical (blood pressure, LDL, HbA1c) and psychological (diabetes distress and depression) health outcomes across a diverse sample of patients (in terms of ethnicity, income range, education level, and health literary) (Sarkar, Fisher & Schillinger, 2006). Specifically, positive "self-efficacy in Type 2 diabetes is associated with higher self-rated adherence, metabolic control, and treatment satisfaction (Kavanagh, Gooley & Wilson, 1993; Padget 1991; Skelly, Marshall, Haughey, Davis & Dunford, 1995, Xu, Toobert, Savage, Pan &

Witmer, 2008) as well as dietary self-care (Aljasem, Peyrot, Wissow & Rubin, 2001; Kind et al. 2010)" (Nouwen et al., 2011, p. 772). This is particularly significant research as growing evidence of a specific connection between reported levels of self-efficacy and glycemic control (i.e. higher self-efficacy influencing improved HbA1c levels) is a primary objective of most diabetes-related interventions and an essential factor in improving the overall health and quality-of-life for diabetic patients (McIntosh et al. 2010).

A growing library of empirical evidence is likely a primary reason for the increased emphasis on self-efficacy testing in clinical diabetes research. While clinical interventions targeting diabetes remain largely focused on physical health outcomes (such as HbA1c levels, body mass index (BMI), weight, and blood pressure) as the primary measurements in their trials, more diabetes interventions have given greater emphasis to psychological measures in concert with physical, clinical health assessments to gather a better understanding of how each factor may influence the other. Though numerous reviews have highlighted the potential for mHealth technology to positively impact diabetic health (Liang et al., 2010; Verhoeven et al., 2007; Fjeldsoe et al., 2009; Ramadas, Quek, Chan & Oldenburg, 2011; Siriwardena et al. 2012; Mulvaney, Ritterband & Bosslet, 2011), far fewer have limited their reviews of such studies to trials that incorporate psychological (self-efficacy) assessments in their research objectives. This is an essential and significant area for further investigation because despite the fact that the impact of self-efficacy on diabetes has been well-established, and the potential for mHealth technology to assist in diabetes self-management efforts has growing empirical support, *evidence of the impact of mHealth technology on self-efficacy is still needed*. Therefore, to further explore the role of technology as a potential catalyst for self-efficacy, this systematic review of literature has been guided by the following research questions:

Research Questions

RQ1) Does mHealth technology (specifically the use of computers and mobile phones) have an impact on diabetic patient's self-reported levels of efficacy when used to assist in the self-management of their chronic illness?

And, if so...

RQ1a) How do factors such as age, sex, education and socioeconomic status, impact the levels of efficacy among participants?

Methodology

i. Research Design

To answer these research questions, a systematic and critical review of scholarly literature was conducted which allowed for a full exploration of empirical evidence in respect to the impact of mHealth technology on feelings of self-efficacy among diabetes patients. As such we were able to summarize and analyze past research findings with the objective of identifying trends, highlighting unresolved issues and drawing overall conclusions from both qualitative and quantitative investigations that addressed related or identical hypotheses (Cooper, 2010, p.4). To do this a 'problem-driven' qualitative and quantitative content analysis was conducted, which according to Krippendorff (2013) "[is] motivated by epistemic questions"(p.355), most often concerned with real-world problems and undertaken because of a belief that those questions may reasonably be answered through a systematic reading, coding and analysis of the available, relevant texts (Krippendorff, 2013).

The research process was guided by a simple six-step approach as outlined by Krippendorff (2013): 1) formulate the research questions, 2) locate relevant texts, 3) define inclusion and exclusion criteria and identify relevant units within available texts, 4) extract sample units of text for coding, 5) develop coding categories and recording instruments, and 6) select an analytical procedure and standards for recording and interpreting coded data (Krippendorff, 2013).

ii. Location of Relevant Texts

After defining the main research questions guiding this study, an intensive systematic review was performed on three major electronic academic databases (Pubmed/Medline, Science Direct, PsychINFO). These search efforts were conducted with two major objectives. The primary goal and strategy was to locate all relevant studies examining self-efficacy in relation to the use of mHealth technology, specifically, for the management of diabetes.

The available research was examined in order to gather literature and previous reviews that would provide significant background information in several distinct areas (including: age, gender, ethnic and socioeconomic information and statistics) related to this mHealth investigation. Ultimately, this information became the basis for the literature review presented earlier in this paper, but also helped to enrich the analysis and discussion sections.

In the next research phase, a broad list of key search terms was identified as relevant for this project and applied to each database. Key words included: *diabetes, mobile health, mobile apps, mobile phones, health apps, text messaging, computers, mobile healthcare, chronic illness, type 1 diabetes, type 2 diabetes, chronic illness self-management, self-management, diabetes management, diabetes care, diabetes self-management, mobile diabetes monitoring, mobile diabetes management, self-efficacy, patient self-efficacy, diabetes self-efficacy, patient empowerment,* and *diabetes empowerment.* As each term yielded over 5000 results, a secondary search strategy was then developed in order to extract the most relevant results from each database using a series of combined search terms. For example, the term *mobile* was combined with *diabetes management* and *self-efficacy* (i.e. mobile + diabetes management + self-efficacy) to better target results. A full list of the specific word combinations and the resulting number of articles were recorded to add to the validity of this search strategy. This record can be found in the appendices of this paper. In addition, search criteria was limited to journal articles and narrowed further by year (2000-2012) in order to filter unrelated material from the results.

A total of 300 articles were initially extracted from the Pubmed/Medline database, 2832 from Science Direct and 1130 from PsychINFO using the aforementioned search strategy. During search efforts, articles were initially assessed for eligibility based on the relevancy of their title. A second round of analysis and brief review of their abstracts was performed on the combined 4262 articles. From this reading, abstracts suggesting potential relevance to this project were extracted, numbered and filed electronically along with a record of the database, specific search terms, and article information in order to ensure validity of results and ease of future retrieval.

Based on abstract information, 263 articles were read beyond the abstract and searched for several key terms, specifically: self-efficacy, empowerment, self-care, and mastery. Two hundred of these articles contained one or more terms. These studies were read in their entirety using the following specific eligibility criteria to determine their inclusion or exclusion from this analysis.

iii. Defining Inclusion Criteria

Types of Articles

All articles included in this review were drawn from Pubmed/Medline, Science Direct, and PsychINFO electronic databases, and strictly included peer-reviewed journal articles, published in English, between 2000 and 2012.

Types of Studies

Studies were limited to pilot projects and randomized control trials (RCT). Trials had to test participant's self-efficacy in conjunction with diabetes-related outcomes. Trials were only included if they incorporated computers or mobile phone technology into the design of their programs and the project lasted for a minimum of four weeks. This approach was chosen specifically in order to be inclusive of both pilot projects and RCT's, as well as to allow the scope of this review to cover two of the most popular technologies used in mHealth diabetes research (i.e. computers and mobile phones).

Participant Factors

Studies included in this review were aimed at patients diagnosed with T1 and T2 diabetes and had to involve at minimum of 15 participants T1 and T2 diabetes trials were both included specifically to examine the potential differences between the impacts of self-efficacy experienced by type 1 and type 2 diabetic patients within a mHealth context. An earlier review of mHealth diabetes trials by Holtz & Lauckner (2012) focusing on mobile phone interventions found a trend within the research results from trials with few statistically significant findings and suggested that "the small number of significant findings could be due to the small sample sizes;[…]" (Holtz & Lauckner, 2012, p.176). The authors state that among the studies and pilot projects analyzed in their research, some trials were conducted with as few as six participants but the median number was 30 (averaged from the 21 articles reviewed for their analysis) (Holtz & Lauckner, 2012). With this in mind, this research chose a strategy that opted for a middle ground approach in terms of participant size, making 15 (half the average sample (30) found by Holtz & Lauckner (2012), in order to accommodate both smaller pilot projects and larger clinical trials within this review while ensuring methodological rigor was upheld.

Types of Outcome Measures

Outcome measures of interest for this review were both psychological and physical. Trials had to incorporate a qualitative or quantitative assessment of patient self-efficacy in order to be included. At a minimum, this required participant self-efficacy to be assessed and reported at baseline and again at the conclusion of the trial. Clinical health measurements for blood glucose (HbA1c levels) were also an outcome measure of particular interest to this review, though no trials were excluded for not reporting participant glucose levels among their primary results.

iv. Defining Exclusion Criteria

Trials published in languages other than English and those taking place before the year 2000, were excluded, regardless of the published date of the article. Similarly, diabetes trials not using computers and/or mobile phone technology, involving fewer than 15 participants, and/or lasting less than three weeks were eliminated. Trials that used strictly home-based, land-line phones as the sole technological tool for the intervention were not included. mHealth trials that did not assess self-efficacy or patient empowerment were eliminated. Articles outlining proposed mHealth trials for diabetes and those involving gestational diabetes or focused on the management of related diabetic conditions and targeting foot or eye care routines as the primary outcome measures were ultimately also excluded.

Based on this inclusion and exclusion criteria, 154 articles were ultimately eliminated completely. Thirty-one other articles were saved but re-categorized as reference material. These trials did not meet inclusion criteria but, were found to support other sections of this paper for material related to their theoretical foundations, diabetes knowledge and material to support discussion points. The remaining 15 trials met all inclusion criteria and became the final dataset for this project.

v. Data Analysis Procedure: Coding

A coding sheet was created and tested with a few randomly selected studies to ensure all the necessary information would be extracted and recorded for analysis from each trial (Cooper, 1989). The coding categories were translated into an excel spreadsheet and analysis was conducted in a two-part process over the course of several months.

Research was synthesized in a table that organized data into 30 distinct categories[2]. Categories included information such as: outcome measures, type of study (design and duration), technological tools used in study, statistical analysis conducted, assessment tests used, study results, theoretical content, and themes presented within the study.

Analysis was conducting using excel software. A second round of coding was conducted to categorize similar findings within the dataset using representative numbers, letters and colour coding in order to visually identify and count trends, where possible. For example, within the statistical analysis column of the coding sheet, a green highlight was used to identify RCT's that showed significant improvements in self-efficacy among the intervention group over the control group, while those that showed no difference in the improvements made by intervention and control groups were left white (clear). During the analysis this made identifying and comparing the eight trials that found significant improvements in self-efficacy among their intervention groups much easier and more efficient.

[2] The full list of categories include: author, study title, journal, year of publication, type of diabetes, number of participants, male/female breakdown, age(s), ethnicity, education, socioeconomic factors (employment, marital status, income), location, inclusion criteria, design of trial, technological tool, methodology, statistical analysis, program summary, duration of trial, outcome measures, desired outcome, efficacy measurement tool, outcome results, efficacy results, healthcare contact, frequency of contact with healthcare provider, theoretical framework, participant feedback, themes/keywords, quotes

Results & Discussion:

This research has synthesized evidence related to mHealth technology-based trials for diabetes through an in-depth content analysis of 15 representative trials taking place between 2000 and 2012. This section will highlight significant results through an in-depth discussion of: self-efficacy; technology; sex, ethnicity and socio-economic factors; trends in participant selection, location and duration of studies, the structure and design of trials, publication data trends, and important outcome objectives. An in-depth summary of the final 15 studies has been presented in a comprehensive analysis chart that appears in the appendix of this paper (Table A).

Self-Efficacy

Each of the 15 articles analyzed in this review tested for self-efficacy using various test measures including non-specific efficacy tests informed by Bandura's theory, as well as tests for perceived competence where self-efficacy was tested indirectly. However, as stated in the theory section of this paper, due to the links between competence, confidence and efficacy those studies have been included in this review. Thirteen trials specified their self-efficacy assessment tools. Nine used one of two scales, namely the Diabetes Empowerment Scale (DES, short form version DES-SF), or Diabetes Self-Efficacy Scale (DSES). Two other studies relied on the perceived competence scale (PCS), and four used unspecified testing apparatuses informed by Bandura's theory of self-efficacy.

Across the 15 studies analyzed for this review, each indicated some level of improvement in participant self-efficacy or perceived competence. However, seven studies found statistically significant improvements in efficacy over the course of their trials, and three noted (moderate) improvements using qualitative non-statistical test comparisons from baseline to follow-up. Interestingly, of the seven studies indicating statistically significant improvements in self-efficacy, five indicated there were also greater improvements in efficacy among the intervention group using technology when compared to the usual care control groups. This finding is consistent with existing literature and earlier review that also support similar outcomes (Quinn et al. 2009; Harno et al. 2006; Montori et al. 2004; Yoon 2008; Ralston et 2009). More specifically, results from Samoocha et al.'s (2010) analysis of 14 web-based RCT's for diabetes confirms that not only do web-based intervention participants develop improved self-efficacy scores but, experience a significantly higher positive effect in terms of improved empowerment when directly compared with those in usual care and/or no care groups. This is further evidence of the strong potential for technology to act as a catalyst for improving self-efficacy beyond basic clinical care models or unassisted self-care routines.

Furthermore, within the seven studies that found significant improvements in patient self-efficacy, five also supported the link between self-efficacy and the improvement of other physical health outcomes measured within their study (specifically HbA1c [glucose] levels). This is particularly significant in terms of clinical measurements because maintaining healthy glucose levels is a primary and essential component for improving and sustaining a diabetic's health.

It may be relevant to note that in five of the trials where improvements in self-efficacy were reported as statistically significant, participant samples were predominantly female (Trief et al. 2009; Nundy et al. 2012; Balamurugan et al. 2009; Faridi et al. 2007; Lorig et al. 2010; Goodarzi et al. 2012). This may be significant, but requires further sex-based analysis to determine whether female self-efficacy may benefit from mHealth programs more than their male counterparts.

In terms of the integration of theory (and specifically self-efficacy principles), within these trial's design it is important to note that although both self-efficacy and competence were considered relevant and important outcome measures, most of the trials were not targeted specifically to increasing feelings of self-efficacy in their participants. This may have had a significant bearing on how the trials were designed in terms of being theoretically-informed, but not necessarily using specific theoretical components at a tactical level for their programs. For example, Trief et al. (2008) state clearly the fundamental principles of Bandura's theory throughout the introduction of their article as well as the importance of investigating the concept as it applies to elderly diabetes patients. However, the authors provide no specific details on its application within their trial design beyond the incorporation of educational features and personal goal-setting, which they believe will help to empower intervention participants.

Similarly, Nundy et al. (2012) describe several theoretical models they considered in the development of their intervention's behavioural program but, neglect to explain how this new model has been translated into any specific tactics, strategies and key messages used in their text message-based mobile pilot project. Instead, Nundy et al. (2012) explore self-efficacy in greater detail within their results and discussion section in order to help explain participant feedback. For example, Nundy et al. (2012) identified specific themes related to Bandura's theory of self-efficacy that emerged from qualitative interviews stating, "*mastery experience* or enactive attainment describes how success raises self-efficacy. As participants experienced fewer symptoms such as less hypoglycaemic events, the program reinforced positive behavioural changes" (Nundy et al., 2012, p.5). As one participant explained:

> But I feel much better. And it's not good having those low sugar reactions. And so I think that these 4 weeks have helped me to see the benefits of being on a regular schedule. I wanted to be able to answer [the text query about adherence] in the affirmative that, 'Yes, I had already done that.' So I think it helped me (Nundy et al., 2012, p.4).

The authors explain that positive changes in behaviour that lead to positive outcomes (such as fewer hypoglycaemic reactions) reaffirm feelings of mastery and thus build patient self-efficacy. Translating results through a theoretical lens in this manner is extremely effective for a pilot project, as it allows the authors to use their understanding of self-efficacy in order to present the specific benefits of their pilot program in qualitative terms and alter future programs in response to this feedback.

In other studies such as Pacaud et al. (2012), Becker et al. (2011), Arora et al. (2012), Balamurugan et al. (2009), Wagnild et al. (2008), Faridi et al. (2008), Franklin et al. (2006), Lorig (2012), Williams et al. (2007), and Goodarzi (2012) the concept of self-efficacy was strictly used as a psychological marker and tested as a secondary outcome objective to be measured and reported. As such, these interventions did not target their programs specifically to enhance patient efficacy, but rather focused on simply observing the phenomenon as it occurred. Thus, discussions of the methodological application of the theory of self-efficacy to elements of these programs and their strategic designs were relatively vague.

However, several other trials did present a broader discussion of the specific methodological application of the theory of self-efficacy beyond the description of their testing measurement tool (i.e. DSES). Specifically in Glasgow et al. (2012), the authors outline their first patient assessment plan and website strategy in order to demonstrate how the theory of self-efficacy was integrated into their trial through specific targeted tactics. Intervention participants were assessed for perceived self-efficacy during their first online session, based on initial scores participants were then prompted to set appropriate personal goals. The authors specify that if scores were to fall within a low range, participants were encouraged to reassess more attainable goals in order to ensure success and the ultimate improvement in feelings of confidence and efficacy through positive mastery over their chosen goals. During the second online session feedback and rewards were provided for the successful achievement of goals in order to further reinforce actions or positive behavioural change and help to build a patient's feelings of self-efficacy through continued goal-setting and effective self-care. The discussion of these tactics in relation to Bandura’s theory not only indicates that Glasgow et al. (2012) understood the importance of patient efficacy in motivating positive behavioural change and self-care adherence, but also that the authors acknowledged the potential impact efficacy may have on clinical health outcomes thus integrated the theory into their programs design through tactics to enhance and improve feelings of efficacy in intervention participants.

In another study, Wangberg (2008) presented an in-depth discussion of the theory of self-efficacy and used a baseline assessment of participant self-efficacy to create two intervention groups, a high and low-efficacy group. Wangberg (2008) compared each group using his web-based intervention to determine the impact that different baseline levels of self-efficacy may have on a diabetic’s specific health outcomes. Using this strategy, Wangberg (2008) discovered “that SE can function as a moderator in a behavioural intervention for diabetes self-care, and hence that initial level of SE provides relevant information for tailoring such interventions” (p.170). Specifically, higher initial SE group participants were found to experience the greatest improvements in self-care over the lower SE participants, further solidifying the connection between positive feelings of self-efficacy and improved self-care. However, beyond this initial strategy for separating participants, he was not explicit in the application of this theory in terms of his intervention design model. More importantly, he did not offer any specific guidelines or provide specific suggestions for further areas of research and the application of these results beyond validating that SE is a useful moderator for mHealth interventions.

Finally, Bond et al. (2010) describe their intervention design as "[…] using cues to modify perceptions of self-efficacy, and using cues to modify personal beliefs regarding the subject's ability to affect the progress of the disease and change his or her personal behaviour" (p.448). However, the cues for modifying self-efficacy are not discussed in great detail, though the authors do mention using educational information and communication between nursing staff and fellow participants to promote feelings of social support, improve disease-specific knowledge, assist in problem-solving, and encourage goal-setting/achievement. Each of these tactics described elements targeted at building feelings of empower and efficacy among participants.

Ultimately, despite incorporating brief outlines of the test measures and tools used to assess efficacy and competence, and brief discussions of the significance of perceived confidence, competence and self-efficacy in terms of diabetic health, few studies explained their specific methodological approach for incorporating the fundamental theoretical principles into their intervention designs. Therefore, future research should not only present a deeper analysis of the application strategies and specific tactics used to incorporate the self-efficacy theory into an mHealth programs but, should also take a more critical approach in terms of analyzing trial results considering specific variables such as: age, sex, ethnicity and socio-economic status separately and in concert in order to determine the potential for mHealth technology to build patient efficacy across diverse patient samples.

Future investigations would also be greatly assisted by a mixed methodological approach that included qualitative interviewing in order to allow participants to provide more in-depth feedback on the impact of a trial's psychological strategy.

It may also be important to note that the majority of trials only reported self-efficacy test results at baseline and upon the completion of the trial. However, one study did presented results from a follow-up measurement taken six months after the conclusion of the trial (Lorig et al. 2010). These findings were particularly interesting and relevant for future investigations of the long term potential for technology to impact feelings of self-efficacy. In Lorig et al.'s (2010) follow-up results, self-efficacy was reported to have continued to improve at a statistically significant rate during the follow-up assessment. Unfortunately, few trials have conducted such lengthy follow-up assessments for self-efficacy and therefore these results could not be considered significant in the content analysis conducted for this review. However, this is a significant area for further research, as the use of mHealth technology can only be validated and improved through an exploration into its long-term potential.

Notably, of the seven trials that made specific reference to the theory of self-efficacy (including those that did not specifically outline the methodology for incorporating the theory into their intervention design), five actually demonstrated statistically significant improvements and one other found improvements based on a qualitative analysis. This may provide some indication of the usefulness of this theory for not only informing mHealth diabetes programs but, also for interpreting and evaluating trial results particularly at a pilot project phase. The significance of improved self-efficacy among intervention participants over control groups is also an extremely encouraging finding indicating technology (i.e. cell phones and computer-based interventions) not only may affect feelings of self-efficacy but, may have the potential to make a positive and statistically significant impact on diabetic health.

Technology

In terms of technological trends, technical literacy became a relevant theme during a review of the recruitment inclusion criteria specified for each trial. Six trials determined and reported the technical literacy of participants (with the specific technology and tools being used in the trial) prior to enrolment. However, two of these trials specified that this literacy information had not been gathered for the purpose of pre-screening and disqualifying potential participants, but simply to add richness to the studies results. In analyzing trial results based on those that assessed technical literacy, only one study that required participants to have a pre-existing technical literacy with the technology being utilized actually yielded statistically significant results (Goodarzi et al. 2012). This may indicate that a pre-existing technical literacy with the technology being used in mHealth interventions may not be a significant and determinant factor in the resulting health outcomes of such a trial.

The other four trials required participants to be comfortable with the technology being used, prior to enrolment. Similarly, seven or nearly half of the trials analyzed in this review required participants to either owe or have access to the specific tool being used for the trial (i.e. web-enabled computer, mobile phone with SMS text messaging capabilities). This may have limited and potentially biased the participant samples for these studies, as participants from low income, resource-poor communities may not have been able to afford or gain access to such technology in order to qualify.

From a clinical perspective, the comfort and acceptability of technology not only applies to patients but also to their healthcare providers. As Costa et al. (2009) suggests, “GP’s initial level of computer literacy and experience with the technology may influence their acceptance and use of new informatics-based interventions” (p.5). Therefore, pre-existing preferences for patients and healthcare providers, as well as technical literacy may be seen as relevant factors biasing these trials.

The technology used in the design of these trials was primarily divided between web-enabled computers (nine studies), mobile phones (five studies), and a combination of the two (one study). Each trial leveraged specific features of their chosen tool and applied it towards their specific diabetes program objectives. These included combinations of the following features: the strategic use of SMS text messaging (five studies), a dedicated trial website (six studies), web camera and video conferencing sessions (three studies), electronic diaries or journaling activities (two studies), online chatrooms and message boards (three studies), and email correspondence (one study). However, three of the seven trials that reported statistically significant improvements in self-efficacy specifically used mobile phone and SMS text messaging program strategies. Three other statistically significant trials, also shared common program designs, namely: video conferencing tools and a trial-specific website for their participants. However, none of these trials reported any pre-post test assessment of the technology to determine whether there were existing preferences to this specific technology among their participants and therefore an analysis of the potential for attitudes towards technology to be altered throughout the course of a mHealth program is an area for further investigation.

Sex, Ethnicity & Socioeconomic Factors

Though most studies tried to divide participation equally between the sexes, within the thirteen trials that specified the breakdown of these divisions, six had samples where the female participants outnumbered the male sample by at least fifteen per cent. This may not be surprising in terms of common participation breakdowns, but is worth highlighting as the uneven division of the sexes was not considered in reporting of results in nearly all of the studies under investigation.

In terms of ethnicity, six studies left the ethnic breakdown of their participants unspecified or ambiguous (i.e. German). Among the other nine studies providing ethnic demographic information, five studies reported their participant sample was predominately Caucasian (Trief et al. 2009; Glasgow et al. 2007; Franklin et al. 2007; Lorig et al. 2010; Bond et al. 2010) and one trial had a predominately Latino/Hispanic sample. Two other trials enrolled only Caucasian participants (these samples were consistent and representative of the community being studied), and one trial strategically limited recruitment to Black African American participants for research purposes. These trials highlight an important area in need of further research. Most of the mHealth trials reviewed for this report did not only lack ethnic diversity within their participant samples but, ethnicity largely did not appear to be a variable of specific interest within the research. This is surprising, given evidence that ethnicity can have an impact on diabetic prevalence, as well as potential complications, thus further research should examine the potential for ethnic preferences for technology-based trials. In fact, only one trial indicated a deeper ethnic-specific analysis had been conducted (Trief et al. 2009) and interestingly, this trial also reported that there were age-specific, ethnically-relevant trends related to higher drop-out rates among their young African-American participants. Lorig et al. (2010) found similar trends in their trial non-completers recorded at 6 and 8-month milestones. However, Lorig et al. (2010) also found some psychological commonalities. The authors state: “noncompleters were younger, less likely to be married, and less likely to be non-Hispanic white. They had higher mean baseline A1C and higher levels of health distress”(Lorig et al., 2010, p.1278). This remained consistent for the non-completers that dropped-out at the 18-month mark as well (Lorig et al. 2010). Though neither study offer a direct explanations for this phenomenon, it may have potential links to patient self-efficacy and barriers to care, that (as discussed in the review of literature) may be ethnically-specific.

Faridi (2008) explains, “self-efficacy is considered a significant predictor of adherence to management plans” (p.465). Therefore, in cases where participants have lower reported self-efficacy, adherence (i.e. continued participation) to a mHealth self-management program may be negatively impacted as well. Though, this is only one possible explanation and Lorig et al. (2010) provides support for the benefits of entering a mHealth program particularly for those willing to persevere despite lower baseline self-efficacy. The authors specifically state: "baseline self-efficacy also had significant interactions with randomization and appears to be a moderating variable, suggesting that lower baseline self-efficacy was associated with better outcomes" (Lorig et al., 2010, p.1278). Wangberg (2008) actually may be able to provide an explanation for this phenomenon. Wangberg (2008) theorizes that those with lower baseline self-efficacy may simply have more room for improvement than those that begin an intervention with a higher level of self-efficacy.

From a clinical perspective, a greater understanding of preferences and outcomes that may be sex, age or ethnicity-based may enable healthcare providers and communication professionals to make better recommendations for programs that would better target specific sample populations based on solid empirical evidence that is still lacking within the academic literature.

Interestingly, ethnicity was not the only variable that was not explored in-depth within most of the available mHealth research reviewed for this paper. Among the 10 trials reporting education, only one reported that a majority of their participants had less than ten years education (Becker et al., 2011), meaning that the majority of participants in the trials however none provided any specific reference or made allowances within their program design for the potential impact that education may have had on reported self-efficacy outcomes. It is notable that Becker et al. (2011) is also the only trial within this analysis that was conducted in Germany and the mean age of participants was reported to be 64.5 years of age. Across the other nine trials including an educational assessment, four reported that a majority of participants had at least a high school level education, two studies had an equal number of participants with high school education and with 'some college', and in three studies the majority of participant had at least a college education or higher. Even within the studies reporting on education, little reference to its potential impact has been made within the literature. This is surprising given that research demonstrates a strong correlation between socio-economic factors such as education and health outcomes in diabetics, particularly because this correlation can be directly linked with health literacy (Schillinger, Barton & Adler, 2006). As Schillinger, Barton & Adler (2006) found in their paper *Does Literacy Mediate the Relationship Between Education and Health Outcomes? A Study of a Low-Income Population with Diabetes*, "inadequate literacy has been found to be associated with demographic characteristics and markers of socioeconomic status, such as older age, non-White race/ethnicity, immigrant status, and lower educational attainment and income" (p. 246). More precisely, the authors found that "in a low-income population with diabetes, literacy mediated the relationship between education and glycemic control" (Schillinger, Barton & Adler, 2006, p. 246). Therefore, not only can socio-economic status be a factor influencing health literacy but, it may ultimately also impact the potential for a positive health outcome in diabetics.

Further investigations into additional socio-economic factors such as marital status, annual income and employment status also yielded disappointing results within this literature. Nine studies neglected to provide any information on participant martial status, and eleven studies omitted information regarding income and employment. This is potentially significant, as previously stated, Lorig et al. (2010) found marital status a common factor in program drop-outs. According to their study non-completers were more likely to be unmarried. Studies have also indicated that patients that were married or living in a partnership (particularly in a relationship they rate as highly satisfactory) reported better health outcomes and improved glycemic control (Trief, Himes, Orendorff & Weinstock, 2001). Rabi et al. (2006) state "in patients with diabetes, low income is associated with an increased rate of hospitalization for acute diabetes related complications" (p. 124). Therefore, it would be relevant to explore how different income groups may have been affected by a particular intervention. This was lacking in the literature analyzed for this review and represents an important area for future investigation.

Participant Selection

In terms of participant samples, the smallest sample among the 15 studies involved 18 subjects (Nundy et al. 2012), while the largest enrolled 1,665 (Trief et al. 2009). However, the majority of trials had a participant sample that fell between 51 and 250 participants (Pacaud et al. 2012; Becker et al. 2011; Franklin et al. 2006; Wangberg et al. 2008, Bond et al. 2010, Goodarzi et al. 2012). In terms of participant recruitment and selection, studies recruited participants mainly through online registration, advertisements and primary healthcare clinic referrals. Participants were screened and those meeting basic age and health requirements were randomized for each of the trials reviewed. Across the final 15 trials analyzed for this paper, 10 studies focused strictly on T2DM (Trief et al. 2009; Nundy et al. 2012; Pacaud et al. 2012; Glasgow et al. 2007; Faridi et al. 2007; Lorig et al. 2007; Wangberg et al. 2008; and Williams et al. 2007; Bond et al. 2010; Goodarzi et al. 2012). Only one study that met all the inclusion criteria focused solely on T1D (Franklin et al. 2006), three allowed both participants with T1 and T2 diabetes (Arora et al. 2012, Balamurugan et al. 2009; Wagnild et al.), and the final study targeted chronically-ill patients (living with any type of diabetes, coronary heart disease, and both) (Becker et al. 2011). This trial was ultimately included in this analysis because it met all inclusion criteria and the majority of trial participants (75%) were diabetics (Becker et al. 2011). It may be relevant to note that four trials made no distinction in terms of narrowing the scope of research to a specific type of diabetes. Becker et al. (2011), Arora et al. (2012), Balamurugan et al. (2009), and Wagnild et al. (2008) each included T1 and T2 diabetics in their trials and though all found improvements in patient self-efficacy over the duration of their programs only one had statistically significant findings

(Balamurugan et al. 2009). The initial research strategy for this paper chose to include both T1 and T2 diabetes trials with the intention of examining potential differences in the impact of self-efficacy. Unfortunately, the other inclusion criteria for this project eliminated all but one trial that focused solely on T1 diabetes and therefore a comparison between T1 and T2-specific trial results for self-efficacy could not be determined. However, it may be important to note that among the four trials that did include both T1 and T2 patients, no attempt to further evaluate and compare results based on this medical distinction were reported. Therefore, diabetic participant improvements were considered for the entire sample group. This could suggest that based on the existing evidence of the positive impacts improved self-efficacy can have on many chronically-ill patients, researchers from these diabetes trials chose not to use the specific type of diabetes as a determinant factor within their studies. Using this as a guideline and based on the available literature, this project could not determine distinguishing trends based on diabetes type among mHealth trial participants though this may be an interesting area for future investigation.

Location & Duration

In terms of geographic location, eleven studies were conducted in North America, ten based in the United States and one in Canada. Three studies originated in Europe (Netherland, Norway and Scotland), and one was conducted in the Middle East (Iran). Despite research intentions, the psychological-emphasis on patient self-efficacy limited the potential for a larger dataset that may have provided a better global perspective on mHealth diabetes trials.

Unfortunately, but perhaps not surprisingly, most mHealth research conducted in lower and middle-income countries continue to focus their primary trial objectives strictly on measurable, physical health outcomes (i.e. HbA1c). Thus, investigations for this paper of the potential links between the use of technology and diabetic self-efficacy were inevitably limited to a North American perspective by this gap within the global health literature. In terms of trial duration, eight trials were placed in the category of three months or less, five trials lasted for between six and twelve months, one ran for one year and six months, while the longest trial was conducted over a two-year period.

Structure and Design of Trials

With the exception of one trial that was solely qualitative in design, and three that used a mixed method approach that included interviews, the majority of trials analyzed for this paper were quantitative. Each quantitative study used questionnaires to gather data on the psychological state of their participants. Clinical measurements were most often gathered by medical professionals or attained from self-reported results.

Publication Data

In terms of trial dates, a trend emerged when comparing trials before 2009 with those published after 2009. In the eight studies published prior to 2009, all but two set their primary objectives on clinical health outcome measures (namely HbA1c improvements). However, after 2009 the interest in psychological and behavioural outcomes may demonstrate new knowledge encouraged a shift in focus, as only three of seven studies placed their primary emphasis on clinical measures (namely, HbA1c) while the other four were interested in behavioural and attitudinal changes as their primary objectives (Nundy et al. 2012; Becker et al. 2011; Arora et al. 2012; Bond et al. 2010). This may indicate that increasing empirical evidence of the impact and link between psychological outcomes (namely self-efficacy) and improved overall diabetic health has fostered a growing acknowledgement of the value of incorporating measures for psychological outcomes as a primary objective in clinical mHealth trials for diabetes.

Outcome Objectives

The overall research objectives of interest could be classified into three basic types: 1) clinical physical health outcomes, 2) psychological/behavioural and attitudinal changes, 3) educational/knowledge-based objectives. The majority of trials (10) primarily used physical health outcomes, specifically HbA1c glucose levels, as a targeted outcome measure. A total of 11 of the 15 studies, reported on HbA1c. This finding remained consistent across earlier mHealth reviews, suggesting physical health outcomes (specifically HbA1c measurements) are still the most popular and relevant objective of clinical trials for diabetes (Siriwardena et al., 2012; Costa, Fitzgerald, Jones & Dunning, 2009; Welch & Shayne, 2006). However, five trials analyzed for this review did set other primary outcome objectives specifically: improving reported self-efficacy, quality of life, depression scores, increasing diabetes knowledge, improving self-care behaviour adherence, increasing physical activity, improving diet (specifically increasing the daily consumption of fruits and vegetables), and measuring changes in attitudes about their disease and perceived social support.

Limitations

As is the case for any research process, this paper has limitations. For example, research was limited to studies published in English peer-reviewed journals between 2000 and 2012. Search efforts yielded only those articles available through University of Ottawa access, using the aforementioned search strategy on three major electronic databases (i.e. Pubmed/Medline, Science Direct, PsychINFO). Based on the scope of this study research focused solely on RCT or pilot projects aimed at assisting diabetics in various aspects of managing their illness by incorporating the use of computer technology or mobile phone functionality. mHealth trials using other communication technology were not included in this review. In addition, it should be noted that despite in-depth search efforts the majority of trials meeting inclusion criteria and ultimately included in this review originated in North America. As in earlier reviews, it is also important to acknowledge the potential for publication bias in the review of available literature for mHealth diabetes trials, as positive and statistically significant results may often be favoured over those without statistical significance. Thus, results and discussion of this research must be examined while keeping these factors in mind.

Conclusion

The overall results of this review indicate there is significant potential for mHealth technology to improve both physical and psychological health outcomes for diabetics. Evidence from this analysis reinforces the positive impact that self-efficacy can have on diabetic patient outcomes, indicating the need for further investigations into the use of this theoretical framework in terms of informing both the design and strategy of an intervention program. This research also supports the need for continued exploration into effective strategies and reporting on the effect of implementing the theoretical concepts of self-efficacy directly into diabetes programs through technology and the usefulness of developing self-efficacy objectives as an important and primary health outcome for both pilot projects and clinical trials.

More significantly, this analysis indicates there is a strong link between greater improvements in self-efficacy and the use of mHealth technology (specifically mobile phones and computers), when compared with more traditional (non-technologically enhanced) care models. Though the research does not explicitly present findings on why this may be the case, it is possible that providing participants with an on-demand technological support tool allows them to feel empowered about their own self-care and equips them with resources to enhanced their regular care regimes. Consistent with earlier reviews, results from this analysis support the need for trials that explore broader and more diverse participant samples in longitudinal trial settings that prioritize extensive follow-up strategies to better determine the long-term implications of mHealth programs on both the physical and psychological health of diabetic participants. Though trials that included both T1 and T2 diabetics neglected to make distinctions between these two patient groups within their results, this presents an interesting area for future investigation as further evidence is needed to determine whether making this distinction is relevant to the overall potential for technology to impact self-efficacy. Further research is also needed to explore the potential of technology and self-efficacy in relation to several other important variables that may have an impact on technological preferences, levels of self-efficacy and perceived barriers-to-care experienced by patients participating in mHealth trials. These include: age, sex, ethnicity and socio-economic factors and should be examined as potential determinate factors in mHealth research.

The gaps within the current literature that were highlighted by this analysis reinforce that this field is still largely unexplored territory. However, the future opportunities for mHealth are greatly enhanced by our increasing reliance upon technology, constant improvements in the technical literacy of both patients and primary healthcare providers, advancements in wireless mHealth tools (i.e. wireless heart sensors), increasing support and investment from both the public and private sectors, and the broadening accessibility of global wireless signals. These factors coupled with the growth of empirical evidence supporting the positive impacts of mHealth programs are strong indications that mHealth research is only in its fledging state and represents a rapidly-evolving field filled with opportunities and challenges that will continue to need of further investment and health communications-focused research.

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Appendix:

Table A:

AUTHOR (DATE)	STUDY DESIGN (Diabetes Type)	DURATION & LOCATION	PARTICIPANT (N)	AGE	ETHNICITY	SOCIO-ECONOMIC FACTORS
Trief et al. (2009)	RCT, Type 2	2 years (New York, USA)	1,665	Over 55, mean age 70.82	Caucasian = 49%, Black = 15%, Hispanic = 35% Other =.48%	**Income:** Equal 1 & 2 **Marital Status & Employ:** N/S
Nundy et al. (2012)	Pilot Project, Type 2	1 month (Illinois, USA)	18	Between 18-74, mean age 55	100% African American	**Income:** N/S **Marital Status:** B **Employ:** U/R
Pacaud et al. (2012)	RCT, Type 2	1 year (Calgary, Canada)	68	Between 35-79, mean age 54.2	Not Specified	Not Specified
Glasgow et al. (2007)	RCT, Type 2	1 year (Colorado, USA)	463	Between 25-75, mean age 58.4	American Indian/Alaska = 6.7% Native Asian = 1.6% Black or African American = 15.4% Caucasian = 72% Latino = 21.8%	**Income:** 1 **Marital Status & Employ:** N/S **Tech:** 5.9% were considered to have low-moderate health literacy

Table A (continued)

Becker et al. (2011)	Pilot Project, Both and/or CHD	1 month, 2 weeks (Marburg, Germany)	79 (57 had diabetes)	Over 18, mean age 64.5	German, Unspecified	**Income:** N/S **Marital Status:** A **Employ:** U/R **Tech:** 38% had no previous PC experience
Arora et al. (2012)	RCT, Both	3 weeks (California, USA)	23	Over 18, mean age 45.4	Latino/Hispanic = 70% Non-Latino/Non-Hispanic = 30%	Not Specified
Balamurugan et al. (2009)	RCT, Both	3 months (Arkansas, USA)	25	Over 18, mean age 67	100% Caucasian	**Income:** 1 **Marital Status & Employ:** N/S
Wagnild et al. (2008)	RCT, Both	6 weeks (3 months) for each group, conducted a year apart (Montana, USA)	31	Over 21, Group 1 (mean age 61.8 years) Group 2 (mean age 59.2)	100% Caucasian	**Income:** N/S **Marital Status:** A **Employ:** E
Faridi et al. (2007)	RCT, Type 2	3 months (Connecticut, USA)	30	Over 18, mean age of 55.3 intervention group and 56.7 for control	Not Specified	Not Specified

Table A (continued)

Franklin et al. (2006)	Pilot Project, Type 1	1 year (Tayside, Scotland)	92	Between 8-18, (Intervention group 1 mean age 14.1); (12.6 intervention group 2); (12.7 control)	Caucasian = 89% Non-Caucasian = 3%	Not Specified
Wangberg et al. (2008)	RCT, Type 2	1 month (Norway)	64	Between 17-67, (Low Self-Efficacy group mean age 37.3); (High SE group mean age 42.9)	Norwegian, Unspecified	Not Specified
Lorig et al. (2010)	RCT, Type 2	1 year, 6 months (USA)	761	Over 18, mean age 54.3	Non-Hispanic White = 13% American Indians/ Alaska Natives = 87%	**Income:** N/S **Marital Status:** A **Employ:** N/S
Williams et al. (2007)	RCT, Type 2	1 year (Denver, USA)	866	Over 25, mean age 64.63	Not Specified	Not Specified

Table A (continued)

Bond et al. (2010)	RCT, Type 2	6 months (Washington, USA)	62	Over 60, (mean age for intervention group 66); (68 for control)	Caucasian = 87% African American = 2% Native = .33% Hispanic = .33% Other = .33%	**Income:** Equal 1 & 2 **Marital Status:** A **Employ:** N/S
Goodarzi et al. (2012)	RCT, Type 2	3 months (Tehran, Iran)	81	Over 30, (mean age for intervention group 50.98); (56.71 for control)	Not Specified	**Income:** N/S **Marital Status:** A **Employ:** Housewives
	RCT = Randomized Control Trial					Income: 1) Below 50,000 2) Above 50,000 Marital Status: A (Married, Living in a Partnership) B (Single, Divorced, Widowed, Separated)Employ: E= majority employed U/R= Unemployed/Retired

Table A (continued)

Continued… AUTHOR (DATE)	TECH TOOL	PROGRAM
Trief et al. (2009)	Computer (C)	Two year, web-based RCT with software for uploading blood glucose (BG) and blood pressure (BP) readings, videoconference with a dietitian/nurse case manager and access to educational data. Regular televisits included discussions on basic diabetes education, nutrition and activity counseling, and collaborative goal setting. The patients and CDE collaboratively formulated a plan to address patient concerns, especially about BG, BP and lipid control. The patients set specific, attainable behaviour change goals. Summary was sent to the primary care physician and other medical specialists as needed
Nundy et al. (2012)	Mobile Phone (SMS Text)	Four week text message-based pilot project for diabetes self-management, designed to provide daily-automated self-care reminders to African American patients with Type 2 diabetes and low literacy levels. Project used to determine preferences in design features, health messages and overall potential for this technology to improve health outcomes within this specific community
Pacaud et al. (2012)	Computer (B, D, E)	One year, RCT to improve self-care education for Type 2 diabetics used to compare potential changes in hemoglobin (A1C), self-efficacy and diabetes knowledge between face- to-face or electronic educational group settings. Educational material and information was provided to the three groups in the following ways (control group: face-to-face/paper-based education), (Intervention #1 [web static group]: email/electronic journals, electronic educational material, website), (Intervention #2 [web interactive]: email, private/public chat features, bulletin board access, virtual appointment chats, electronic journals and online educational materials)
Glasgow et al. (2007)	Computer (B)	One year, web-based RCT for improving health behaviors (significantly) over usual care. Program involved two intervention groups and one control (usual care group). 1) Intervention Group 1 [CASM+]: Internet-based diabetes self-management program, with additional medical support 2) Intervention Group 2 [CASM]: Internet-based self- management, without additional support; and 3) Control - Enhanced Usual Care group [EUC] (no technology). Intervention group used a website to log goals in three areas over 12-month period (medication adherence, activity, and food choices), received automated feedback, resources for education and nutrition, quizzes and periodic calls. CASM+ group received additional calls and were invited to group sessions with other patients as well

Table A (continued)

Becker et al. (2011)	Computer (B)	Six week, computer-based counseling system (CBCS) for the improving attitudes towards physical activity and pilot efficacy/acceptance in primary care environment. Used in the waiting room the program mixed audio and minimal text to support general practitioners in counseling patients with coronary heart disease (CHD) and/or diabetes on physical activity (PA) with the goal of increasing activity, changing attitudes towards PA, and building patient's self-efficacy
Arora et al. (2012)	Mobile Phone (SMS Text)	Three week, pilot project of daily text message-reminders and prompts for self-care activities aimed at a low resource population with diabetes with the goal of improving both knowledge and motivation to adhere to proper self-care requirements. Automated text messages were delivered three times daily (9 a.m., 12 p.m., and 6 p.m.). Reminders were meant to encourage proactive self-care behaviour and motivate participants
Balamurugan et al. (2009)	Computer (C)	Three month, interactive telemedicine video-conference educational pilot study for diabetics in an under-serviced community focused on improving clinical health measures (HbA1c, cholesterol, weight or blood pressure, foot and eye care), knowledge, patient self-efficacy, self-management, preventive behaviours, and self-care practices. Six bi-weekly interactive video lectures/ counseling sessions were conducted by experts (covering various relevant topics) using computer videoconferencing technology
Wagnild et al. (2008)	Computer (C)	Three month, video conference intervention for remote community of diabetics, six videoconference educational classes were offered every 2 weeks for approximately 3 months at a remote classroom location. Each class was 2 hours focused on improving blood glucose monitoring, medication adherence, daily health habits including exercise and nutrition, and knowledge of diabetes.
Faridi et al. (2007)	Mobile Phone (SMS Text) (G, H)	Three month, pilot control trial using mobile phone technology and website program to assist T2D in self-care and improve clinical outcomes, as well as SE beyond the outcomes of a usual care model. Intervention participants received daily tailored text messages prompting them to execute various self-care activities and requiring them to transmit glucose levels, as well as pedometer readings daily in order to receive tailored feedback and reminders. Records were shared and reviewed by patients and providers for personalized tracking and goal setting.

Table A (continued)

Franklin et al. (2006)	Mobile Phone (SMS Text)	One year, automated, daily SMS text-messaging program for Type 1 diabetics designed to offer regular support and optimize their self-management behaviours including insulin therapy, while improving self-efficacy and adherence. Sweet Talk software allows goal- setting from clinical visits to determine personalized messages tailored to a patient's age, sex and specific insulin regimen in order to help patients stay on track. In addition to daily tips and reminders, as well as weekly goal reinforcement, this program also uses text newsletters to inform and educate patients regarding self-care. Emergency hotline was also available to participants
Wangberg et al. (2008)	Computer (B)	One month, RCT using online educational website for diabetes with both high and low baseline self-efficacy in order to improve self-care behaviour and determine potential for technologically-based program to impact clinical outcomes based on baseline self-efficacy ratings. Web content included interactive virtual exercises, quizzes, educational articles, informative videos from peers, expert video lecture series/interviews about overcoming common barriers to self-care.
Lorig et al. (2010)	Computer (B, D, E, F, G)	Six month, RCT (with 18 month follow-up) for weekly Virtual Education/ Support program to compare online intervention group self-management success with usual-care (particularly impact of program on HbA1c, health distress, activity, depression, patient activation, self- efficacy). Online interactive learning resources, bulletin board, program-specific website, email, tracking features were used by participants. All website activities were moderated by a facilitator who provided weekly personalized responses during each virtual session.
Williams et al. (2007)	Computer (B)	One year, computer-assisted intervention assessment during (six month) primary care visits in order to measure perceived autonomy support, perceived competence and improve diabetes distress, depression, HbA1c levels, and lipids. Touch screen automated program was used to generate a patient's individualized action plan, summarize personal self- management goals, create a needs assessment, highlight issues the patient should discuss with their physician. Print-out was provided to personal-care worker who made regular calls over next six months to follow-up/mitigate issues prior to next visit

Table A (continued)

Bond et al. (2010)	Computer (B, D, E, F)	Six month, Web-based RCT for adults over 60 with diabetes to improve depression, quality of life, social support, and self-efficacy. Intervention participants accessed a website were they tracked and transmitted their blood glucose readings, exercise, weight changes, blood pressure, and medication data for nurses to monitor. They also had contact with nurses through email and instant chat features in order for nurses to give personalized feedback when changes were needed. Weekly educational discussion sessions happened through the online forum (MSN messenger features) attached to the program website in order to get real-time feedback from professionals and build social support with other participants
Goodarzi et al. (2012)	Mobile Phone (SMS Text)	Three month, RCT using mobile phone SMS text-messaging for Type 2 diabetics over 30, in order to improve self-care behaviour, HbA1c levels, knowledge, attitude, practice (KAP), and self-efficacy (SE). Participants received 4 targeted automated text messages weekly consisting of educational information about exercise, diet, medication, monitoring of glucose levels in an effort to enhance feelings of self-efficacy and improve self-care adherence
	B) Web Portal / Specific Program C) Web Camera/ Video Conferencing D) Electronic Diaries E) Chatrooms/ Message Boards F) Email G) Wireless Device Connected to phone. Records and Transmits Information H) Other (i.e. Wireless	

Table A (continued)

Continued… AUTHOR (DATE)	**OBJECTIVES**
Trief et al. (2009)	To measure changes in diabetes self-efficacy attitudes and behaviour in relation to glycemic control; Secondly to measure blood pressure and cholesterol to determine if change in diabetes self-efficacy relate to change in these medical outcomes (particularly for a group of older, ethnically diverse individuals.)
Nundy et al. (2012)	To gather feedback on perceived feasibility, barriers and acceptability of pilot program; Secondly to measure impact of program on self-care behaviours, diabetes knowledge, health beliefs, self-efficacy and social support
Pacaud et al. (2012)	To compare measurements of HbA1c (glucose levels), Diabetes Self-efficacy, self care behaviour, QofL, knowledge in relation to usage of program website to determine potential impact of this program design on physical and psychological health outcomes
Glasgow et al. (2007)	To compare and measure changes in internet self-management intervention groups (one with support, one without) with that of enhanced usual care to examine biological, behavioural, and psychological outcomes

Table A (continued)

Becker et al. (2011)	To influence physical activity levels by building and measuring attitude change (cognitive and affective) and self-efficacy throughout a web-based counseling intervention for chronically- ill patients with CHD, diabetes, or both.
Arora et al. (2012)	To assess perceived feasibility of the program, efficacy levels. Gather feedback on the different types and frequency of text messages that are most effective, the appropriateness of text message content, and willingness of participants to continue with or recommend the TExT-MED program to family or friends.
Balamurugan et al. (2009)	To determine the impact of diabetes self-management education (DSME) on physical and psychosocial health in a rural community setting through telemedicine as an avenue to empower patients with the knowledge and skills required to deal with the complexities of managing diabetes.
Wagnild et al. (2008)	To determine whether the telecommunications DSM intervention would improve health-related outcomes and study any differences in pre/post physical and emotional test levels in the diabetic patients participating in this diabetes self-management (DSM) telehealth educational program (conducted in a small frontier community in Montana)
Faridi et al. (2007)	To measure clinical and self-care activities/outcomes (specially BMI, weight, HbA1c level, glucose level and blood pressure, physical activity, self-care behaviours and self-efficacy) by comparing differences in program approaches to determine the impact of a mobile program

Table A (continued)

Franklin et al. (2006)	To study the ability to reinforce self-management behaviour, improve self-efficacy, increase adherence to insulin injections, and improve blood-glucose testing (for better glycemic control HbA1c) without significantly increasing traditional patient contact and health professional resources.
Wangberg et al. (2008)	To determine if IT- delivered, tailored diabetes self-care education would be more effective among people with low SE than with high SE. Also to measure if diabetes education can increase SE, regardless of initial SE levels.
Lorig et al. (2010)	To compare online diabetes self-management program with usual-care control subjects to discover if either group: 1) demonstrated reduced A1C at 6 and 18 months, 2) had fewer symptoms, 3) increased exercise, and 4) had improved self-efficacy and patient activation.
Williams et al. (2007)	To determine if the incorporation of computer technology into primary care visits could increase perceived autonomy, perceived competence, patient satisfaction, lower glycemic control (HbA1c), ratio of total to HDL cholesterol, diabetes distress, and depressive symptoms in T2DM patients.

Table A (continued)

Bond et al. (2010)	To re-enforce patients role in their health, emphasize importance of goal setting and problem solving skills by improving self-management behaviour and psychosocial well-being of participants
Goodarzi et al. (2012)	To improve glycemic control (HbA1c levels), and Knowledge, Attitude, Practice (KAP), and Self-efficacy (SE) scores

Table A (continued)

Continued… AUTHOR (DATE)	OUTCOME MEASURES	EFFICACY MEASUREMENTS TOOL / TEST
Trief et al. (2009)	**HbA1c (glucose levels), self-efficacy, blood pressure (BP), lipids cholesterol (LDL)**	DSES
Nundy et al. (2012)	**barriers and facilitators of the program, self-care behaviours, diabetes knowledge, health beliefs, self-efficacy and social support (No HbA1c tests at all)**	Self-Efficacy Test (unspecified)
Pacaud et al. (2012)	**HbA1c, diabetes self-efficacy, self-care behaviour, quality of life (QofL), knowledge scores**	DSES
Glasgow et al. (2007)	**HbA1c, body mass index (BMI), lipids, and mean arterial pressure, eating habits, fat intake and physical activity, self-efficacy (SE), problem-solving, health literacy, QofL**	DSES

Table A (continued)

Becker et al. (2011)	**regular physical activity levels, affective & cognitive attitudes and behaviour, patient efficacy**	DSES
Arora et al. (2012)	**daily consumption of fruits and vegetables, exercise, participation in foot exams, adherence to medication and efficacy**	DES-SF
Balamurugan et al. (2009)	**self-management behaviour - skills to manage diabetes, feelings of helplessness, confidence in ability to control diabetes (SE), diabetes self-care practices (daily glucose monitoring, daily foot examination), HbA1c, blood pressure, cholesterol, knowledge to manage diabetes**	Self-Efficacy Test (unspecified)
Wagnild et al. (2008)	**HbA1c, self-efficacy, blood pressure, knowledge of diabetes, understanding of diabetes self-management, monitoring behaviours**	DES-SF
Faridi et al. (2007)	**HbA1c, body mass index (BMI), weight, blood pressure, self-efficacy, self-care activities**	DES

Table A (continued)

Franklin et al. (2006)	**HbA1c, self-efficacy, diabetes knowledge, and social support**	DSES
Wangberg et al. (2008)	**self-efficacy, HbA1c, diet management, physical activity**	Perceived Competence Scales (PCS)
Lorig et al. (2010)	**HbA1c, health distress, activity limitations, depression, patient activation, self-efficacy, aerobic exercise, physician visits**	Self-Efficacy Test (unspecified)
Williams et al. (2007)	**HbA1c levels, lipids, depressive symptoms, perceived autonomy support, perceived competence for diabetes self-management, motivation, QofL**	Perceived Competence Scale (PCS)

Table A (continued)

Bond et al. (2010)	**depression, social support, QofL, self-efficacy**	DES
Goodarzi et al. (2012)	**HbA1c levels, LDL cholesterol, knowledge, attitude, practice (KAP), and self-efficacy**	Self-Efficacy Test (unspecified)

Table A (continued)

Continued… AUTHOR (DATE)	**RESULTS**
Trief et al. (2009)	Statistically significant improvements in self-efficacy related to changes in A1c (*P* < 0.0001), Change in self-efficacy not related significantly to changes in BP or LDL. Gender, race/ethnicity did correlate with baseline self-efficacy, with females and whites reporting lower self-efficacy. Poor glycemic control over time was associated with longer duration of diabetes, and being younger, male and black or Hispanic. Older age, diabetes duration and being black was related to worsening BP.
Nundy et al. (2012)	Technology-use increased reported self-efficacy in patients through improved feelings of mastery and self-management. Consistent daily communications reduced denial of diabetes and reinforced the importance of self-management behaviours. Participants responding positively to questions about self-management abilities increased their mastery experience throughout the program thus improving perceived self-efficacy (no statistical measurements were taken, based on qualitative interviews only SE was improved.
Pacaud et al. (2012)	Non-statistically significant improvement to self-efficacy was found in all 3 groups. High total web use resulted in improved diabetes self-efficacy (p 0.008). Across total sample (all groups) saw an improvement in self-efficacy (p=0.019). Improvements were reported to be higher in males than in females in all three groups both at baseline and after 1 year (though not a statistically significant difference). Overall, the second intervention group (web static group: email/electronic journals, electronic educational material) was most improved.
Glasgow et al. (2007)	Non-statistically significant improvements in self-efficacy were achieved (particularly with two web intervention groups slightly more than with usual care). For the behavioral outcomes (healthy eating, physical activity, and medication taking) both intervention groups improved significantly more than the control group. On biological outcomes, there were modest improvements across treatment groups, but no indication that the intervention groups were superior to control. For psychosocial variables, diabetes distress improved significantly for intervention groups and self-efficacy scores were slightly higher for intervention groups than control.

Table A (continued)

Becker et al. (2011)	Patients using the system for 12 min on average showed significant changes in their affective and cognitive attitudes. Self-efficacy was improved (p=.81) but this change was not statistically significant. Patient's cognitive and affective attitudes towards PA were positively impacted, and results demonstrated a statistically significant improvement (p<0.05).
Arora et al. (2012)	Improved health behaviour, encouraged eating fruit/vegetables, exercise, foot checks, improved efficacy, medication adherence, diabetes knowledge. Participants saw a modest but not significant improvement (3.9 to 4.2) in self-efficacy.
Balamurugan et al. (2009)	Increases in knowledge of self-care practices and improvements in self-efficacy were statistically significant (self-efficacy [p = .016] & knowledge [P=.012]). Statistically significant improvements to self-efficacy measures were specifically evident in areas such as 'the possession of knowledge and skills to manage my diabetes' and 'improvements in feelings of helplessness'.
Wagnild et al. (2008)	Self-efficacy scores improved from pre-to-post test, but were not statistically significant. A modest improvement was reported [Group 1: 32.6 to 34.4], [Group 2: 32.8 to 34.9], the highest potential score being 40. Positive improvements were also made to HbA1c, blood pressure, and knowledge. However, groups were felt to be too small to demonstrate statistical significance in this phase 1 project.
Faridi et al. (2007)	Intervention group had statistically-significant improvement in self-efficacy and improvement in HbA1c (not significant). Usual Care saw deterioration in HbA1c and no improvement in self-efficacy. Self- efficacy scores in the intervention group (P = 0.0080) compared with no improvement in the control (P = 0.9060). Non-significant improvement in HbA1c levels were reported (P = 0.1534) in the intervention group and compared with a deterioration in the control (P = 0.3813).

Table A (continued)

Franklin et al. (2006)	Statistically significant improvements in diabetes self-efficacy ($P = 0.003$), self-reported adherence ($P = 0.04$) and diabetes social support ($P < 0.001$) were reported in both intervention groups using Sweet Talk, over the control group using conventional therapy. The second intervention group did also see significant improvements in HbA1c (HbA1c for second intervention group (intensive therapy + sweet talk was $P<0.001$).
Wangberg et al. (2008)	Self-efficacy did improve ($P = .17$), but it was not statistically significantly in either study group after one month. The intervention did have a positive impact on self-care scores for those with lower baseline self-efficacy scores, they had a slightly higher improvement in self-care scores than those with high self-efficacy. However, no statistically significant changes in self-efficacy were reported over this one-month intervention in either the High SE or Low SE groups.
Lorig et al. (2010)	Statistically significant improvement in HbA1c ($P=0.01$), patient activation ($P=0.021$), and self-efficacy ($P=0.001$) in intervention group compared to control group at 6 months and 12 months. These improvements were particularly significant for participants who had lower baseline HbA1c scores. At 18 month follow-up self-efficacy ($P=0.007$) was further improved in intervention group over control (HbA1c not observed).
Williams et al. (2007)	Improved perceived competence ($p>.10$) not statistically significant, however autonomy support improved significantly ($p<0.05$), this change had a mediating effect on changes in lipids, diabetes distress, and depression but not HbA1c. There was a trend for the patients to experience greater perceived competence at the 6-month mark then at the 12-month mark, but neither increase in perceived competence was significant.

Table A (continued)

Bond et al. (2010)	Statistically significant improvement in self-efficacy (P=.007) and social support in intervention group over control. Significant improvements also demonstrated in depression and quality of life scores.
Goodarzi et al. (2012)	Statistically significant improvements in intervention groups: HbA1c ($p = 0.024$), LDL ($p = 0.019$), cholesterol ($p = 0.002$), micro albumin ($p \leq 0.001$), knowledge ($p \leq 0.001$), practice ($p \leq 0.001$) and self-efficacy ($p \leq 0.001$) over control group.
	Blue Highlight = Statistically significant improvements, Yellow Highlight = Improvements that were not statistically significant

Table A (continued)

Continued… AUTHOR (DATE)	THEORY
Trief et al. (2009)	Social Cognitive Theory - Self-Efficacy Theory (Bandura, 2001)
Nundy et al. (2012)	Rosenstock Health Belief Model, Bandura Self-Efficacy, Theory of Social Support
Pacaud et al. (2012)	N/S
Glasgow et al. (2007)	Social Cognitive Theory, Social-Ecological Model Transtheoretical Model of Behaviour Change (TTM), which comprises Self-Efficacy and Elaboration Likelihood Model

Table A (continued)

Becker et al. (2011)	N/S
Arora et al. (2012)	Social Cognitive Theory
Balamurugan et al. (2009)	Chronic Care Model for self-management support in primary care settings (Wagner, 1998; Glasgow et al., 2005). Self-Determination Theory
Wagnild et al. (2008)	Social Ecological Model (Lewin, K.) Lewin suggests behavior is a function of personal competence combined with environmental demands and available resources.
Faridi et al. (2007)	Empowerment in Diabetes Scale (Anderson et al. 2000) based on Bandura

Table A (continued)

Franklin et al. (2006)	Social Cognitive Theory - Self-Efficacy Theory (Bandura, 1977, 1989)
Wangberg et al. (2008)	Social Cognitive Theory - Self-Efficacy Theory (Bandura, 2004)
Lorig et al. (2010)	Self-Efficacy Theory (Bandura, 1977)
Williams et al. (2007)	(SDT) Self-Determination Theory, Chronic Care Model (Wagner, 1998; Glasgow et al., 2005), Bandura's Social Learning Theory for Self-Efficacy

Table A (continued)

Bond et al. (2010)	Empowerment in Diabetes Scale (Anderson et al. 2000) based on Bandura
Goodarzi et al. (2012)	N/S

Appendix (Continued):

Research - Key Word Search Log & Records

September 28 - October 21 – 2012

Database: ScienceDirect
Keyword: mHealth
Results: 3 items

Database: ScienceDirect
Keyword: mHealth + chronic illness
Results: 3, 950

October 23 - November 28 – 2012

Database: ScienceDirect
Keyword: self-efficacy + diabetes
Results: 36,500

Database: ScienceDirect
Keywords: self-efficacy + diabetes + text messaging
Results: 4,040

December 1 – 2012

Database: PsychINFO
Keyword: mHealth
Results: not recognized

Database: PsychINFO
Keyword: mobile health + diabetes
Results: none

Database: PsychINFO
Keyword: mobile health
Results: 25

Database: PsychINFO
Keyword: mobile apps & health apps & mobile healthcare
Results: 1

Database: PsychINFO
Keyword: chronic illness
Results: 294

Database: PsychINFO
Keyword: non-communicable disease & NCD
Results: none

December 5 – 2012

Database: PsychINFO
Keyword: diabetes
Results: 186

Database: PsychINFO
Keyword: type 2 diabetes mellitus
Results: 13

Database: PsychINFO
Keyword: T2DM
Results: 2

Database: PsychINFO
Keyword: chronic illness self-management
Results: 13

Database: PsychINFO
Keyword: self-management
Results: 77

Database: PsychINFO
Keyword: type 2 diabetes care + monitoring
Results: 27

Database: PsychINFO
Keyword: Mobile + type 2 diabetes monitoring
Results: none

Database: PsychINFO
Keyword: mobile phones + diabetes + self-management
Results: 17

Database: PsychINFO
Keyword: cellular phones + diabetes + self management
Results: 19

Database: PsychINFO
Keyword: text messaging + diabetes + self management
Results: 8

Database: PsychINFO
Keyword: SMS + diabetes
Results: 12

Database: PsychINFO
Keyword: mobile phone interventions
Results: 1

December 8 - 16 – 2012

Database: PsychINFO
Keyword: self-efficacy
Results: 1, 000

December 18 – 2012

Database: PsychINFO
Keyword: Patient-efficacy
Results: 100

Database: PsychINFO
Keyword: diabetes + efficacy
Results: 23

Database: PsychINFO
Keyword: type 2 diabetes + efficacy
Results: 10

Database: PsychINFO
Keyword: mHealth + efficacy
Results: none

December 20 – 2012

Database: PsychINFO
Keyword: telehealth + efficacy
Results: 90

Database: PsychINFO
Keyword: mobile health + efficacy
Results: 4

December 23 – 2012

Database: PsychINFO
Keyword: mobile health + interventions
Results: 5

Database: PsychINFO
Keyword: mobile health + patient empowerment
Results: none

Database: PsychINFO
Keyword: patient empowerment
Results: 4

Database: PsychINFO
Keyword: diabetes empowerment
Results: 2

Database: PsychINFO
Keyword: type 2 diabetes + empowerment
Results: none

Database: PsychINFO
Keyword: diabetes self-management
Results: 15

Database: PsychINFO
Keyword: mobile + chronic illness management
Results: none

Database: PsychINFO
Keyword: mobile management
Results: 5

Database: PsychINFO
Keyword: mobile + chronic illness + monitoring
Results: none

Database: PsychINFO
Keyword: mobile monitoring
Results: 3

Database: PsychINFO
Keyword: mobile self-management
Results: 1

Database: PsychINFO
Keyword: mobile diabetes management
Results: none

Database: PsychINFO
Keyword: meta-analysis + diabetes
Results: 5

December 28 – 2013

Database: PsychINFO
Keyword: meta-analysis + efficacy
Results: 99

Database: PsychINFO
Keyword: mobile + type 2 diabetes + monitoring
Results: 5

January 4-16 – 2013

Database: Pubmed
Keyword: mobile health
Results: 12,424

January 19-22 – 2013

Database: Pubmed
Keyword: mHealth
Results: 61 items

Database: Pubmed/Medline
Keyword: diabetes + mHealth (Title/Abstract)
Results: 6

Database: Pubmed/Medline
Keyword: mobile health interventions + diabetes (Title/Abstract)
Results: none

Database: Pubmed/Medline
Keyword: diabetes self-management + mobile (Title/Abstract)
Results: 4

Database: Pubmed/Medline
Keyword: mHealth efficacy (Title/Abstract fields)
Results: 4

Database: Pubmed/Medline
Keyword: diabetes + mobile (Title/Abstract)
Results: 106

Database: Pubmed/Medline
Keyword: mobile chronic illness + monitoring (Title/Abstract)
Results: none

January 24-30 – 2013

Database: Pubmed/Medline
Keyword: mobile + chronic illness + monitoring (Title/Abstract)
Results: none

Database: Pubmed/Medline
Keyword: diabetes + mobile health (Title/Abstract)
Results: 2

Database: Pubmed/Medline
Keyword: diabetes + mobile apps (Title/Abstract)
Results: none

Database: Pubmed/Medline
Keyword: diabetes + mobile apps (ALL fields)
Results: 1

Database: Pubmed/Medline
Keyword: diabetes + health apps (Title/Abstract)
Results: none

Database: Pubmed/Medline
Keyword: mobile chronic illness monitoring (Title/Abstract)
Results: none

Database: Pubmed/Medline
Keyword: diabetes + mobile + health intervention (ALL)
Results: 10

Database: Pubmed/Medline
Keyword: diabetes + telemedicine (Title/Abstract)
Results: 239

February 1-10 – 2013

Database: Pubmed/Medline
Keyword: diabetes + telemedicine + self-efficacy (Title/Abstract)
Results: 11
Database: Pubmed/Medline

Keyword: diabetes + telemedicine + self-efficacy (ALL)
Results: 15

Database: Pubmed/Medline
Keyword: diabetes + self-efficacy + mHealth (Title/Abstract)
Results: 1

Database: ScienceDirect
Keyword: mobile phone + diabetes
Results: 756

February 11-14 – 2013

Database: ScienceDirect
Keyword: mHealth (Title search field)
Results: 4

Database: ScienceDirect
Keyword: mHealth + Mobile health (Abstract search field)
Results: 605

February 15 – 2013

Database: ScienceDirect
Keyword: mHealth (Key Word, Abstract search fields)
Results: 8 articles

Database: ScienceDirect
Keyword: mobile app (Title, Abstract, Key Words search fields)
Results: 9 items total

Database: ScienceDirect
Keyword: mobile + healthcare (Title, Abstract, Key Words)
Results: 90

February 16-28 – 2013

Database: ScienceDirect
Keyword: chronic illness (Title, Abstract, Key Word)
Results: 2, 580

March 1 – 2013

Database: ScienceDirect
Keyword: non-communicable disease + mobile health + diabetes
Results: 162

Database: ScienceDirect
Keyword: NCD (Title, Abstract, Key Words)
Results: 8

March 2-5 – 2013

Database: ScienceDirect
Keyword: diabetes self-management (Title, Abstract, Key Words)
Results: 423

March 7 – 2013

Database: ScienceDirect
Keyword: mobile + chronic illness + management (Title, Abstract, Key Words)
Results: none

Database: ScienceDirect
Keyword: electronic + monitoring + chronic care (Title, Abstract, Key Words)
Results: 2

Database: ScienceDirect
Keyword: mobile + self-management (Title, Abstract, Key Words)
Results: 72

Database: ScienceDirect
Keyword: mobile + diabetes management (Title, Abstract, Key Words)
Results: 8

Database: ScienceDirect
Keyword: mobile phone + interventions (Title, Abstract, Key Words)
Results: 66

Database: ScienceDirect
Keyword: web + interventions + diabetes (Title, Abstract, Key Words)
Results: 78

March 10 – 2013

Database: ScienceDirect
Keyword: diabetes + patient self-efficacy (Title, Abstract, Key Words)
Results: 121

Database: ScienceDirect
Keyword: mHealth + efficacy (Title, Abstract, Key Words)
Results: none

Database: ScienceDirect
Keyword: mobile health + efficacy (Title, Abstract, Key Words)
Results: 21

Database: ScienceDirect
Keyword: Mobile health + patient empowerment (Title, Abstract, Key Words)
Results: none

Database: ScienceDirect
Keyword: diabetes + telehealth (Title, Abstract, Key Words)
Results: 6

Database: ScienceDirect
Keyword: diabetes empowerment (Title, Abstract, Key Words)
Results: 48