

## Artikel Ulasan/Review Articles

# Usage of Mobile Applications in Diabetes Management: A Review (Penggunaan Aplikasi Telefon Mudah Alih dalam Pengurusan Diabetes: Suatu Ulasan)

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### ABSTRACT

*Peer-reviewed articles on the usage of mobile applications in the management of diabetes were reviewed. Studies using mobile device applications for diabetes interventions published between January 2007 and March 2013 were included in this review. Studies related to the developmental processes of the mobile applications were excluded. The characteristics of these studies and the outcomes of the methods used in the management of diabetes were gathered. We retrieved a total of 372 articles from ACM Digital library, PubMed and Proquest Medical Library. After applying the inclusion and exclusion criteria, 8 articles were eligible for further review. Most of the studies included in this review showed the effectiveness of mobile applications in diabetes management. Their major contribution comes from feedback functions of the systems that assist participants in the self-monitoring of their blood glucose and dietary intake. However, the majority of the studies showed the limited use of the mobile phone as a tool to input information into systems which would in turn convey a reminder message to the patient. In conclusion, with its features of portability and convenience, mobile application used in the management of diabetes has the potential to improve glycaemic control, resulting in significant clinical and financial benefits.*

*Keywords: Health information technology; mobile phone; diabetes; blood glucose self-monitoring*

### ABSTRAK

*Artikel dari penilai sekepakaran tentang penggunaan aplikasi mudah alih dalam pengurusan diabetes telah dinilai. Kajian menggunakan aplikasi peranti mudah alih bagi intervensi diabetes yang diterbitkan antara Januari 2007 dan Mac 2013 telah disertakan ke dalam ulasan ini. Kajian yang berkaitan dengan proses pembangunan aplikasi mudah alih telah dikesualikan. Ciri kajian dan hasil daripada kaedah yang digunakan dalam pengurusan diabetes telah dikumpulkan. Sejumlah 372 artikel telah diambil daripada pangkalan data ACM Digital Library, PubMed dan ProQuest Medical Library. Setelah melaksanakan kriteria kemasukan dan penyingkiran, 8 artikel telah terpilih untuk penilaian seterusnya. Sebahagian besar daripada kajian yang disertakan menunjukkan keberkesanan aplikasi mudah alih dalam pengurusan diabetes. Sumbangan besar datang dari fungsi sistem maklum balas yang membantu peserta dalam pemantauan sendiri glukosa darah dan pengambilan makanan. Walau bagaimanapun, majoriti kajian menunjukkan penggunaan yang terhad bagi telefon mudah alih sebagai alat untuk memasukkan maklumat ke dalam sistem yang seterusnya akan menyampaikan mesej peringatan kepada pesakit. Kesimpulannya, dengan ciri mudah-alih dan kemudahan, aplikasi mudah alih yang digunakan dalam pengurusan diabetes mempunyai potensi untuk meningkatkan kawalan glisemik, menghasilkan manfaat klinikal dan kewangan yang signifikan.*

*Kata kunci: Teknologi maklumat kesihatan; telefon mudah alih; diabetes; pemantauan sendiri glukosa darah*

### INTRODUCTION

Diabetes mellitus is a group of metabolic diseases characterized by hyperglycaemia. This condition is a result from defects in insulin secretion, insulin action or both. Being one of the most common diseases, type 2 diabetes is mainly due to insulin resistance on glucose and inadequate secretion of insulin (World Health Organization 1999). It is estimated that by 2030, 366 million people worldwide will have diabetes compared to 177 million in 2000 (American Diabetes Association 2013). The American

Diabetes Association recommends individualized medical nutrition therapy (MNT) for individuals who have diabetes to achieve their treatment goals (American Diabetes Association 2012). Diabetes self-management involves the patients to sustain their blood sugar control in the normal ranges by ensuring blood sugar levels are regularly checked, consuming the recommended diet for diabetes combined with physical activity (American Diabetes Association 2012). In line with the rise of information and communication technology use in nutrition education (Bourdeaudhuij et al. 2007; Woodall et al. 2007), mobile

applications have been shown to be advantageous in the improvement of nutritional behaviour (Burke et al. 2009) and weight management (Lee et al. 2010), and more recently, in diabetes management (Forjuoh et al. 2008).

Smartphones are mobile phones with computer-like functionalities, including internet/email access and are able to run applications (or apps) which are programs that carry out various tasks (PC Magazine 2011). In contrast, Personal Digital Assistants (PDAs) are "highly portable, easy-to-use computing and communications devices aimed at the mass market" (Halfhill 1993). The use of mobile devices (i.e., PDA and smartphones such as the Android, BlackBerry or iPhone) in healthcare is increasing rapidly and its capability and popularity have been reported in various studies (Tsai et al. 2007; Wolfenden et al. 2010). Most previous studies using mobile phones involve the use of text messaging in a weight loss program in which motivational and information text messages were received as one of their intervention components (Haapala et al. 2009; Schembre & Yuen 2011). Moreover, recent mobile/PDA application studies have examined their use in weight management and behavior modification, in particular (Burke et al. 2012; Hebden et al. 2014; Lee et al. 2010).

In mobile phone intervention for diabetes, patients can receive information from the mobile phones at the time for blood glucose measurement or other events (like medication), which can lead to improved glycosylated haemoglobin (HbA1c) levels and improved self-care with regard to diet, medication and exercise (Liang et al. 2011). Mobile device interventions are usually well accepted by users attributable to its mobile features and in standby mode and also the current versions of mobile devices with higher processing capacity than previous models, results in a rather refined assessment and intervention applications. (Tsai et al. 2007).

The objective of this narrative review is to describe the usage of various mobile health (mHealth) tools as interventions in diabetes treatment and self-management and to review the effectiveness of their use in various aspects such as blood glucose control and behaviour change. This article will also describe the feasibility and usability of these tools in facilitating the end users to achieve their goals. Implications for future research and development are also addressed.

## MATERIALS AND METHODS

### SEARCHING STRATEGIES AND STUDY SELECTION

The author who was the sole researcher performed an electronic database search in ACM Digital library, Pubmed and Proquest Medical Library. The search was to identify articles published on diabetes management using mobile phone methods, including mobile phone application and text messaging methods. Articles published in the English language between January 2007 and February 2013 were selected. This time period was selected as during these

recent years the usage of mobile applications in diabetes management started being researched either to evaluate its feasibility or its effectiveness in diabetes management. The following keywords were applied in the search: Diabetes Mellitus AND mobile device OR mobile application AND management. We also manually searched reference lists of related articles to identify additional studies. Titles and abstracts were evaluated to select articles evaluating the use of mobile applications in diabetes intervention. The search yielded 372 publications. Articles had to meet the following inclusion criteria: intervention studies using mobile applications, human studies and studies on diabetes type 1, type 2 and gestational diabetes. Only articles with full texts were selected. In addition, the following exclusion criteria were applied: studies on the designing and developmental processes of the mobile phone systems or mobile applications and studies involving the prevention of diabetes. After applying the inclusion and exclusion criteria, 8 articles were shortlisted. The characteristics and results of these studies are summarised in Table 1.

## RESULTS

Eight studies were included in this review. Six studies tested the effects of the intervention on diabetes outcome measures (Faridi et al. 2008; Forjuoh et al. 2008; Hee-Sung 2007; Kim & Kim 2008; Quinn et al. 2008; Yoon & Kim 2008). One study tested the feasibility and acceptability of the application program, including the issues encountered by participants when using the system for self-monitoring (Sevick et al. 2008). Additionally, one study tested the usability of the prototype system on diabetes type 1 patients (Carroll et al. 2007). Four studies used short message service (SMS) in their intervention program (Faridi et al. 2008; Hee-Sung 2007; Kim & Kim 2008; Yoon & Kim 2008). Sample sizes of the studies ranged from 30 to 151 participants. All of the studies conducted involved participants aged 18 years and above and included both men and women, although one study reported a majority of women participants (Faridi et al. 2008). Intervention durations ranged from 3 months to 12 months. Only one study addressed intervention programs conducted specifically on obese type 2 diabetes (Kim & Kim 2008).

### STUDIES USING SHORT MESSAGE SERVICE BY MOBILE PHONES

All studies using short message service (SMS) in their intervention program reported HbA1c as their primary outcome measure (Faridi et al. 2008; Hee-Sung 2007; Kim & Kim 2008; Yoon & Kim 2008). Other outcome measures include fasting plasma glucose (FPG), 2-hour postprandial test (2HPPT), Body Mass Index (BMI), total cholesterol (TC), triglycerides (TG) and high-density lipoprotein-cholesterol (HDL-C).

The main objective of these studies was to maintain blood glucose levels close to or within a normal range.

TABLE 1. Summary of study characteristics

Citation	Population and sample size	Description of intervention and design of Study/Methods	Outcomes and measures	Results
Quinn et al. (2008)	Type 2 diabetes mellitus $n = 30$ (18 – 70 years old)	<p>Intervention group:</p> <p>Well Doc's proprietary Diabetes Manager software</p> <p>Control group:</p> <p>Blood Glucose (BG) logbooks</p>	<p>Primary:</p> <p>To assess the impact on A1c of a cell phone-based diabetes management software system used with web-based data analytics and therapy optimization tools.</p> <p>Secondary:</p> <p>To examine Health Care Provider's (HCP) adherence to prescribing guidelines and assessed HCPs' adoption of the technology.</p>	<p>Reduction of A1c for intervention patients.</p> <p>Intervention patients had medications titrated or changed by their HCP.</p>
Yoon & Kim (2008)	Type 2 diabetes mellitus Intervention: $n = 25$ Control: $n = 26$	<p>Intervention group:</p> <ul style="list-style-type: none"> <li>• Participants send self-monitored blood glucose levels and drug information, including the kinds and dosages of insulin and oral anti-diabetic medication that they used for diabetes control.</li> <li>• Patients were able to see the recommendations from their physicians and nurses, as well as the laboratory data, on the website.</li> <li>• The researcher viewed information on each participant and sent optimal recommendations to each patient via SMS via mobile phone.</li> </ul> <p>Control group:</p> <ul style="list-style-type: none"> <li>• Met the endocrinology specialist several times during the 12 months.</li> <li>• Were provided with recommendations about medication, medication dosage and lifestyle modification by the endocrinology specialist.</li> </ul>	<p>To maintain blood glucose levels within a normal range (HbA1c &lt; 7%).</p>	<p>Participants in the intervention group had lower HbA1c over 12 months when compared with the control group. At 12 months the change from baseline in HbA1c was -1.32 in the intervention group versus +0.81 in the control group. Two hour post-meal glucose (2HPMG) had a significantly greater decline in the intervention group after 12 months when compared with the control group (-100.0 versus +18.1 mg/dl).</p>
Forjuoh et al. (2008)	Subjects aged $\leq 18$ years with type 2 diabetes (T2DM) and last measured	<p>Intervention group only. Participants were provided with the following:</p>	<p>To determine whether enhancing type 2 diabetes (T2DM) self-care with a personal digital assistant (PDA) for patients in the</p>	<p>Reduction of A1c for intervention patients. The mean HbA1c change was higher among reported frequent</p>

Continued

Citation	Population and sample size	Description of intervention and design of Study/Methods	Outcomes and measures	Results
Faridi et al. (2008)	glycosylated haemoglobin (HbA1c) of $\leq 8.0\%$ at their research orientation visit. Participants who completed the intervention: $n = 18$ Participants who did not complete intervention: $n = 25$	<ul style="list-style-type: none"> <li>A loaned password-protected, institutional-registered PDA, pre-installed with "Diabetes Pilot" software for 6 months.</li> <li>One-on-one training on the use of the PDA with the pre-installed software by a trained RA to assist with patient diabetes self-care activity monitoring.</li> <li>A copy of the training manual.</li> <li>1-week follow-up monitoring phone call and ongoing phone support by the research assistant.</li> </ul>	ambulatory setting would improve glycaemic control.	PDA users than among reported infrequent PDA users.
Faridi et al. (2008)	30 type 2 diabetes patients ( $\leq 18$ years)	<p>Intervention group. 3-month intervention:</p> <ul style="list-style-type: none"> <li>Patients tested glucose once daily</li> <li>They wore pedometers during the day</li> <li>Subjects were required to upload their data onto the NICHE server once daily</li> <li>They received tailored messages via mobile phone based on the uploaded data.</li> </ul> <p>Control group:</p> <ul style="list-style-type: none"> <li>They used standard diabetes self-management and tracked step count using a pedometer.</li> </ul>	To assess the feasibility and utility of the NICHE system in enhancing diabetes management	A trend towards improvement in HbA1c in the intervention group was found but without statistical significance. A statistically significant improvement in total self-efficacy scores for the intervention group patients was observed. Additionally, intervention patient's self-treatment efficacy scores significantly improved.
Hee-Sung et al. (2007)	51 subjects with type 2 diabetes mellitus (age not specified) Intervention: $n = 25$ Control: $n = 26$	<p>Patients were briefed on how to input data into the website (30minutes)</p> <p>Intervention group:</p> <ul style="list-style-type: none"> <li>Could contact website and log in whenever it was convenient for them and where Internet access was possible by cellular phone or wire internet.</li> <li>Patients communicate with researcher by sending their glucose and drug information.</li> <li>After integrating the above information, the healthcare staff sent recommendations back to each patient by short message service of cellular phone and wired Internet.</li> </ul>	To keep blood glucose (BG) levels close to normal range. The goal of the intervention was to maintain BG level at a normal range.	Reduction of A1c for intervention patients

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Continue

Citation	Population and sample size	Description of intervention and design of Study/Methods	Outcomes and measures	Results
Sevick et al. (2008)	Adults with type 2 diabetes ( $n = 151$ ; $\leq 18$ years)	<p>Control group:</p> <ul style="list-style-type: none"> <li>Met the endocrinology specialist once or twice during the 12 weeks</li> </ul> <p>Intervention group only. Intervention tested in 3 groups of individuals:</p> <ol style="list-style-type: none"> <li>Those with HbA1c <math>&lt; 8\%</math> and no evidence of chronic kidney disease.</li> <li>Those with HbA1c <math>\leq 8\%</math> and no evidence of CKD.</li> <li>Those with diabetes and evidence of CKD regardless of HbA1c. Also included were those with good glycaemic control as well as those with concurrent kidney disease. Within these strata, participants were allocated to either the treatment group or to an attention control group.</li> </ol>	<p>To investigate</p> <ol style="list-style-type: none"> <li>Feasibility and acceptability of PDA-based dietary self-monitoring.</li> <li>Issues encountered in teaching participants to do self-monitoring using PDAs.</li> </ol>	The PDA-based dietary self-monitoring system was feasible and acceptable
Kim & Kim (2008)	Obese patients with type 2 diabetes ( $n = 34$ ) Intervention: $n = 18$ Control: $n = 16$	<p>Patients were requested to record their blood glucose level in a weekly diary on the website by personal cellular phones or computer internet.</p> <p>The researcher sent optimal recommendations weekly to each patient, by both cellular phone and internet.</p>	<p>To decrease body weight and keep blood glucose concentrations close to the normal range.</p>	<p>Reduction of A1c for intervention patients at 3 months, 6 months, 9 months, and 12 months compared with baseline results in the intervention group.</p> <p>Patients in the intervention group had a decrease in 2-h post-prandial test (2HPPT) at 3 months, 6 months, 9 months, and 12 months compared with baseline data.</p>
Carroll et al. (2007)	Children with type 1 diabetes ( $n = 10$ )	A pilot study was initiated to evaluate user satisfaction with the integrated system, including the potential of the device to transmit self-monitoring data to a website for review and analysis.	To assess the usability of the system	<p>Participants reported that they were very fond of mobile technology. Features of the diabetes phone that the participants liked particularly include</p> <ul style="list-style-type: none"> <li>The number of test results stored.</li> <li>Size of the phone.</li> <li>The cell phone service itself.</li> <li>Fast analysis of test results.</li> <li>Easy-to-follow directions.</li> </ul>



In one of the studies conducted by Kim and Kim (2008), an additional goal was to decrease body weight. The intervention method used in the experimental group was corresponding SMSs through cellular phone and internet. Participants had to send the relevant information for monitoring such as blood glucose levels and insulin dosages to the website via phone or internet. The website will then provide a summary of the data together with the recommendations from researchers. HbA1c showed a decreasing trend throughout the 12 month intervention period in the intervention group, whereas the percentage of change in the control group was not significant. 2-hour post prandial test (2HPPT) also showed a significant decrease compared to the baseline data. The control group showed no significant change in 2HPPT. In the study by Hee-Sung (2007) which involved a total of 51 patients (25 intervention, 26 controls), the intervention group was allowed to contact the website and log in whenever it was convenient for them and where Internet access was possible by cellular phone or internet.

Similar to the study by Kim and Kim (2008), the participants sent self-monitored blood glucose levels, oral anti-diabetic medication and insulin dosages to the website. The researcher can monitor blood glucose levels, medication and other relevant information that has been entered into the system by patients. An additional facilitation by a healthcare provider (nurse) was included of which they will convey recommendations to the participants via short message service and internet after reviewing the medical information entered by the participants into the system. Reminders were also sent to participants who have not key in their glucose readings for more than one week. Furthermore, if an individual had still not recorded glucose levels for more than four consecutive weeks, they were withdrawn from the intervention group. Alternatively, the control group was scheduled to meet the endocrinologist specialist once or twice during the 12-week experimental period. The main goal of the intervention was to keep blood glucose levels close to the normal range.

In a study conducted by Faridi et al. (2008) the technology employed was an interactive informational feedback system that used wireless remote technology to provide tailored feedback and reminders, based on patient specific data, to patients via SMS on cellular phones. A slight difference was that the researchers also recorded physical activity using a pedometer which automatically transmitted the data to an online server. Blood glucose data was also obtained through this method.

#### STUDIES USING MOBILE PHONE APPLICATION/SOFTWARE

The results from this group of studies suggest that mobile phone applications are as effective in self-monitoring compared with conventional methods namely, face-to-face guidance and counselling, in managing diabetes. HbA1c reduction was shown in these intervention studies

among intervention patients using the application system compared to the control subjects (Forjuoh et al. 2008; Quinn et al. 2008). These studies showed diabetes self-care improved more for the treatment group in three domains namely diet, medication and exercise.

A study by Quinn et al. (2008) aimed to assess how HbA1c was impacted by the use of a cell phone-based diabetes management software system with web-based data analytics and therapy optimization tools. The researchers also wanted to examine the Health Care Provider's (HCP) adherence to prescribing guidelines and they assessed HCPs' adoption of the technology. This study used WellDoc's proprietary Diabetes Manager software as the intervention component in the intervention group, whereas the control group recorded their blood glucose in blood glucose logbooks. The results showed a significant reduction of HbA1c in the intervention patients and 84% of intervention patients had medications titrated or changed by their HCP compared to the control group. Additionally, the intervention patients' HCP reported that the system facilitated treatment decisions, provided organized data, and reduced logbook review time.

Another study was conducted among type 2 diabetes patients aged 18 years and above and last measured glycosylated haemoglobin (HbA1c) of more than 8.0% (Forjuoh et al. 2008). The objective of the study was to determine whether improving type 2 diabetes self-care with a personal digital assistant (PDA) by patients in the ambulatory setting would improve glycaemic control. This study only involved an intervention group which was given a PDA pre-installed with the "Diabetes Pilot" software for 6 months. Prior to commencement of the intervention, one-on-one training on the use of the PDA and software application was given. The participants were also followed-up by a monitoring phone call after 1 week and there was ongoing phone support by the research assistant (RA). In addition to the outcome measures evaluated by the studies using SMS as an intervention tool, this study measured the Summary of Diabetes Self-care Activities (SDSCA) and Health Related Quality of Life (HRQOL) measures (Forjuoh et al. 2008). A significant reduction of HbA1c was reported in the participants, moreover significant increases for the foot care and general diet subscales of the Summary of Diabetes Self-Care Activities were also reported.

#### STUDIES EVALUATING FEASIBILITY AND USABILITY

One out of the 8 studies (Sevick et al. 2008) did not report the results of the impact of the intervention program on diabetes monitoring parameters. This study examined the feasibility and acceptability of PDA-based dietary self-monitoring and addressed the issues encountered in its implementation. The investigators used an application software called BalanceLog<sup>®</sup> by Microlife as the tool in their feasibility and acceptability study. This software contained a food database of more than 4300 foods

including over 1700 major brand names. Participants could also record daily exercise from a large database of physical activities. Energy expenditure from the exercise was subtracted from the participants' calorie budget. This study reported that the participants understood the usefulness of PDA monitoring. They found that entering food in the program was easy, feedback graphs were easily interpreted and the participants claimed that they would continue to use the PDA for self-monitoring after the study concluded. The researchers encountered a few challenges in their study. The participants required substantial education or re-education regarding general diabetes self-management before additional Social Cognitive Theory-based principles and goals could be introduced. Some participants had difficulty using the PDA to monitor their food and there were challenges in providing timely goal-directed feedback to participants.

Besides this, a pilot study by Carroll et al. (2007) was conducted using the HealthPiaGlucoPack™ Diabetes Monitoring System which is a prototype system that integrates a glucose monitoring system onto a conventional cell phone. This study was conducted to test the usability of the system. The system had a small blood glucose monitoring device integrated into the battery pack of a cell phone. Blood glucose data was automatically transferred to a server where the records may be viewed by second and third party through the phone display or website provided there is a secure internet connection. Interactions between the patient and healthcare provider was also done using cell phone platform. The results showed that the participants liked the size of the diabetes phone and the ability to use the diabetes phone as a communication tool, with an added function of their glucometer contained within the phone. However, users were unbiased about the usefulness of the diabetes phone website. Despite the assisting function of the diabetes phone allowing users to get along with school activities, users disliked the impact of the diabetes phone towards their relationship with their parents. Participants also reported that utilizing the diabetes phone made them contact their doctors less often. Contact with healthcare providers was also reduced when utilizing the diabetes phone.

## DISCUSSION

Studies in this review suggested that the use of mobile phones are well accepted by participants and contribute to improved blood glucose control in participants compared with conventional methods such as face-to-face counselling. The diabetes interventions using the mobile phone, whether as a mobile phone-based patient terminal or as a tool for SMS, have revealed great efficacy in HbA1c control (Forjuoh et al. 2008; Kim & Kim 2008; Quinn et al. 2008; Yoon & Kim 2008). The service for diabetic patients provided through the internet and mobile phones is on the

rise, whereas the efficacy of this service for glucose control has not been evaluated extensively (Brug et al. 2005; Tate et al. 2003). Many of the reasons for the improved glucose control in intervention study subjects include more frequent communication with the researcher or healthcare provider than those in the control group and the participants in the intervention group received recommendations regarding their diabetes management according to their most recent data that they had put into the mobile application system (Kim & Kim 2008). These factors may have contributed a certain stimulation and motivation to the participants to control their blood glucose, dietary intake and even manage physical activity more carefully.

The advantages of mobile application systems together with online services that provide frequent recommendations through feedback are clear. Patients may contact their researchers or healthcare providers as frequently as possible and whenever they want. The individualized approach in which the care plan was formed according to each patients' blood glucose results and characteristics is also a benefit (Kim & Kim 2008).

A few of the study limitations are that the diet, exercise and adverse effect data were not included into the system by the participants regularly. Additionally, limited internet access may have resulted in some patients not being able to use the cell phone or computer. Also, the participants were not restricted in accessing other websites or resources while participating in the study. There was also no maximum logon frequency limits to the website used in the study which may have created a bias towards the knowledge and information obtained by the participants. Furthermore, the results may have been influenced by the difference of frequency in logons and this was not measured in the study (Hee-Sung et al. 2007; Kim & Kim 2008). Some of the studies reported that the participants encountered technological barriers when attempting to adhere to the intervention protocol (Faridi et al. 2008; Quinn et al. 2008; Sevicik et al. 2008). Another study limitation is the lack of user friendly interfaces and patients' inexperience with pedometers and mobile phone use, resulting in difficulties in proper operation (Faridi et al. 2008). Other limitations include the short duration of the intervention and the small sample size which reduced the power to detect statistically significant changes between groups of participants (Faridi et al. 2008; Forjuoh et al. 2008).

## USABILITY AND ACCEPTABILITY OF THE TOOL IN DIABETES MANAGEMENT

Regarding the overall usability, positive responses were shown by participants in managing their diabetes. Components such as feedback messages, cell phone use and saving of time are among the few factors that contributed to a high percentage of satisfaction (more than 90%) (Quinn et al. 2008). Moreover, the physicians participating in the study reported that the mobile application system facilitated

treatment decisions, made office visits more efficient, organized data better, and was easy to use. The majority of participants also reported being comfortable with the use of their mobile device (Forjuoh et al. 2008). Most studies reported user satisfaction with the mobile application and many users stated their willingness to continue the use of the application in future. Despite the wide acceptance of these mobile application systems, technical barriers in utilizing such technology exists and these include having too many menus to navigate in an application, buttons that are too small and commands that change too frequently (Faridi et al. 2008).

#### KEY FUNCTIONALITIES IN FACILITATING DIABETES MANAGEMENT

Functionalities of a diabetes mobile application play a crucial role in assisting participants in utilizing the technology. Functionalities such as automatic blood glucose data entry are viewed as an advantage to applications developed as these clearly assist users to directly record their BG values while minimizing errors from manual entries (Faridi et al. 2008; Quinn et al. 2008). Additionally, it reduces the time consumed to enter the data. Since self-management of blood glucose needs to be done on a regular basis, it is crucial that an application achieves effectiveness in glycaemic control in relation to the time patients spend using the application. Other features that are shown to be an optimal value includes the food database and the physical activity database (Sevick et al. 2008). However, these functions require proper user training to ensure appropriate data is entered to avoid over/underestimation of calories or macronutrients. One drawback is that extensive user guidance or training on how to utilize the application with this function can be time consuming for users. Another key feature that gives a plus point to mobile diabetes applications is the capability of having a reminder function, especially to remind users to test blood glucose levels or take certain meals at designated times. Communication with the healthcare providers through diabetes management application systems has also been shown to improve outcomes in blood glucose levels (Yoon & Kim 2008).

#### CHALLENGES IN IMPLEMENTING THE USE OF MOBILE DEVICES

The challenges in implementing self-monitoring using mobile devices (Sevick et al. 2008) was highlighted in one of the studies which emphasizes the importance of education or re-education on general diabetes self-management such as the need for glucose monitoring, the functions or actions of their medication and the details of the diabetes diet. Other challenges include the difficulty encountered by participants in using the mobile device to enter the information required (Sevick et al. 2008). This happens particularly in elderly subjects or subjects who rarely use mobile devices. Another challenge is for the

researcher or HCP to provide timely goal-directed feedback to participants. Tailored feedback communicated to the participants play an important role in the outcomes of the self-monitoring process.

#### LIMITATIONS

There are a few limitations in this review. The review was limited to studies done in the past 7 years. In addition, studies which are not referenced in ACM Digital Library, Pubmed and Proquest Medical Library and unpublished studies were not identified, resulting in this study being subject to publication bias. In this review, we report the use of interventions using mobile phone applications where participants are required to have mobile phones or smartphones; this overlooks the needs of populations who do not own mobile phones or smartphones or low-income populations who cannot afford to have this kind of technology. Therefore, the effect of this mode of intervention is not seen in this population group.

#### IMPLICATIONS FOR FUTURE RESEARCH

The review has revealed that personalized structured education and decision-support features are not integrated in most current blood glucose monitoring interventions and were not included in most of the studies in this review. There seems to be a gap between the self-monitoring functions of current diabetes mobile applications and conveying factual and evidence-based information on diabetes and diabetes management to users. Studies on the usage of mobile applications in diabetes management in Malaysia is still in its infancy. Therefore, the usage of mobile application systems with a complete structured education and self-monitoring component in the management of diabetes is an area of active investigation. Future studies should focus on other populations with diabetes. Research in disadvantaged population and pregnant mothers, particularly women with diabetes during pregnancy are lacking. Furthermore, applications using photography as a method to capture information have not been investigated as a dietary self-monitoring tool, and it is still unclear what its effects are on improving self-monitoring, particularly in dietary intake in comparison with conventional methods.

#### CONCLUSION

Positive trends in the utility of mobile applications in diabetes management suggest that with features like portability and convenience, it has the capability to improve glycaemic control resulting in significant clinical and financial benefits. Nonetheless, larger and longer intervention and evaluation studies across multiple populations are necessary, together with a focus on a more structured education feature covering dietary intake



and physical activity. Additionally, applying a detailed interactive feedback system and connections with social media would undoubtedly increase the potential of these mobile application systems in the management of diabetes mellitus.

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