A Model for a Mobile-enabled e-Health System in Saudi Arabia for the Self-management of Diabetes

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Abstract

This paper prescribes the design requirements for a mobile-enabled e-health system for the self-management of diabetes by Saudi diabetes patients. The findings from a survey and a focus group were integrated to achieve this. The requirements, challenges and problems were identified and were supported by published works on the topic. The findings showed that since a variety of stakeholders are involved in such an ecosystem, it is imperative to ensure smooth coordination and an improvement in the outreach of public health campaigns. The findings thus far have highlighted the demographic groups to be targeted for designing and implementing targeted interventions to tackle diabetes in Saudi Arabia. Doing this would require interventions in the healthcare system, hospital and home-based management, and targeted patient interventions. The finer aspects of the system design need to be determined based on similar successful models and expert opinions. Some comments on the boundaries of this research are also provided.

Keywords: e-Health, Mobile Enabled, Diabetes, Saudi Arabia

Introduction

E-health is the use of information and communication technologies for improving quality of care; for example, through the use of electronic patient records (EPR), helping patients with the self-management of chronic diseases or providing accessibility to medical treatment and other fields of healthcare to people in remote communities (telemedicine). The World Health Organisation (WHO) defines e-health as "the use of information and communication technologies (ICT) for health" (WHO, 2019). According to Eysenbach (2001),

E-health is an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies. In a broader sense, the term characterizes not only a technical development but also a state of mind, a way of thinking, an attitude, and a commitment to networked, global thinking, to improve health care locally, regionally, and worldwide by using

information and communication technology.

Therefore, the term "e-health" may also be understood as relating to efficiency, enhancing quality, evidence-based, empowerment, encouragement, education, enabling, extension, ethics and equity (Eysenbach, 2001).

E-health is a crucial intervention in healthcare, especially when considered against the background of healthcare costs for governments across the world. It has been estimated that these costs are increasing and about 75% of this cost is incurred by patients with chronic ailments (Widén & Haseltine, 2015). Diabetes is one of the major chronic illnesses experienced by populations worldwide, with many countries counting diabetes patients (both types 1 and 2) as one of their major chronic illness groups. In Saudi Arabia, the International Diabetes Federation states out of the population of 20.77 million people, 3.852 million adults (18.5%) had diabetes in 2017 (IDF, 2019). News (2019) cited Colliers Report stating that 17.9% of adults had diabetes and 35.4% were obese in Saudi Arabia. As the prevalence of diabetes is rapidly increasing, as shown in the incidence rates among children and adolescents, especially for type 1 diabetes (Robert, Al-Dawish, Mujammami & Al Dawish, 2018), using proper data collection systems at regular frequencies is crucial. The high prevalence rate of diabetes in Saudi Arabia shows that management of diabetic patients and control of the disease is a serious concern for the country's healthcare system.

One of the best ways to reduce the incidence of diabetes is to equip patients with the ability to manage the disease themselves with the support of the hospital and medical staff. Personalised care management is possible through the adoption of e-health practices. In order to manage diabetes, patients need to be educated about diabetes, the factors related to its increased intensity and intervention methods and effectiveness measurement. The personalisation of the tools that can be used for the management of diabetes requires adjustments so each treatment plan suits the individual profile of each patient. Adherence to the treatment therapy and other aspects of care like daily lifestyle changes are possible when e-health is implemented and monitored. Some advantages of e-health are an increase in efficiency and the provision of remote access at any time. It is possible to achieve medical and economic benefits by integrating e-health into the personalised management of diabetes. One such example is smartphones, which are enabled with sensors that can be attached to the patient for continuous monitoring. Since smartphones are used by most people, they are a convenient portable platform for e-health for personalised diabetes management (Coughlin, 2017). The merits of using mobile-enabled personalised diabetes management to address the twin threat of inadequate care and rising costs for both patients and providers was highlighted by Thestrup, Gergely and Beck (2012). In the absence of such an intervention, lost working days and disruptions to labour markets have the potential to cause serious economic development issues for countries.

The prevalence of diabetes in Saudi Arabia and the potential of e-health to assist patients with their self-management of the disease prompted this research development of an e-health model based on smartphone applications (Alanazi & Gay, 2020). Thus, this paper aims to propose a model for a mobile-enabled e-health system for the self-management of diabetes by Saudi diabetes patients. It is through such research that a successful intervention for e-health may be designed, implemented and eventually adopted by medical staff and patients. This paper will highlight the need for and value of e-health in the context of diabetes patients and the scope for e-health interventions to monitor and track how well patients follow doctors' recommendations and prescriptions. In addition to this, a case will also be made to understand the gap and hence the potential for a successful e-health intervention to be implemented. This research is very pertinent as there is scope and a gap for mobile-enabled

health systems for the self-management of diabetes in the context of Saudi Arabia.

Literature Review

The high prevalence rate of diabetes patients in Saudi Arabia and the problem of effective reach were highlighted in the previous section. According to the Saudi Ministry of Health, the average annual cost of diabetes treatment without complications is USD 2,600 per type 1 diabetes (T1D) patient and about $2,000 per type 2 diabetes (T2D) patient. Based on these figures, the country's cost burden for diabetes treatment may reach $6.5 billion by 2020. Alanzi (2018) notes that policy deficits and scarce research on e-health systems for diabetes have resulted in poor implementation at hospital level. The e-health initiatives of the Saudi Ministry of Health have been limited to creating silos of health records and some service facilitations. Thus, any study on the modelling and implementation of e-health systems for personalised diabetes management in Saudi hospitals will contribute knowledge to the field. Some scoping papers like those of Aldahmash, Ahmed, Qadri, Thapa and AlMuammar (2019) and Belcher, Vess and Johnson (2019) are available.

Ruiz et al. (2012) identify the objectives driving healthcare process modelling as ranging from the economic aspects of process optimisation to the increase of transparency and exchangeability of data and knowledge and the assurance and certification of quality. The requirements specification for process modelling should include requirements of the business, the user, the system and other stakeholders (Elgabry, 2016).

As in the case of any other business process modelling, some challenges and barriers in e-health modelling have been identified by some authors. The common problems faced by the e-health industry are listed by van Limburg et al. (2011) as follows:

1. Innovations are slow due to the problems of current financial structures;
2. Inadequate healthcare legislation acting as a barrier to the modernisation of healthcare;
3. Reluctance of involved parties resulting in slow uptake;
4. Too much focus on engineering-driven solutions for e-health technologies;
5. Fragmented implementation of e-health technologies with poor scalability;
6. High levels of complexity due to a large number of stakeholders and dependencies;
7. Inadequate studies on cost-effectiveness of e-health technologies; and
8. Focus only on clinical evidence in terms of health outcomes and a failure to recognise other factors that determine the success of e-health technology.

An archetype of an e-health model based on the standards ISO/IEC TR 24744, ISO-EN 13606, ISO 21090 and ISO/DIS 13940 ContSys was developed and evaluated by García García et al. (2015). The model is presented in Figure 1. A case study was used for the successful validation of this model.

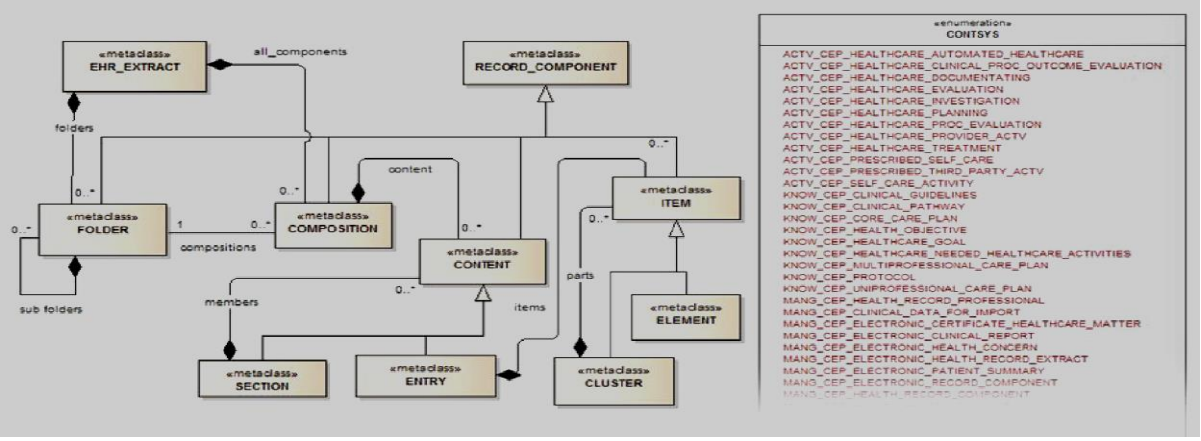

Figure 1 Archetype metamodel of e-health system (García García, Escalona, Martínez-García, Parra, & Wojdyński, 2015).

A method of deriving e-health goals using a gap analysis between systems requirements engineering and e-health goals was done by Alahmadi, Soh and Ullah (2014). Some of the issues and challenges related to e-health modelling have been identified as integration and interoperability (Adenuga, Kekwaletswe & Coleman, 2015); management of change process and collaboration and co-creation among stakeholders (Hyppönen, 2007); incomplete understanding of the end-user needs (Kayser, Kushniruk, Osborne, Norgaard & Turner, 2015); socio-technical problems due to non-clarity on the use of data as a commodity (Ure et al., 2009); long-term fault-free maintenance affecting system resilience (Rejeb, Bastide, Lamine, Marmier & Pingaud, 2012); and privacy and security of data when they are moved to cloud requiring specific methods of protecting them (Rodrigues, La Torre, Fernández & López-Coronado, 2013);

Due to the environment uncertainty, the runtime management of self-adaptive systems is another important issue. In addition to this, new needs for users may arise, even during the use of the system. This could be due to environmental variations. This means that the runtime in a self-adaptive system must evolve depending on the variations required by the user and the context. Inverardi and Mori (2011) and Vasilyeva, Pechenizkiy and Puuronen (2005) and Alanazi, Gay, Alanazi Mohammad and Alturki (2021) offered solutions to this problem. The networkability maturity model for healthcare providers could be used in e-health contexts. The model is useful for assessing the capacity of an organisation for efficient engagement in business relationships. Thus, it becomes an e-health business model (Fitterer & Rohner, 2010).

Mobile e-health or m-health has potential, with the increasing use of smartphones, wearables, mobile virtual reality/augmented reality (AR/VR), smart houses and smart care sensing and interaction facilities all over the world. However, the early promises of this technologies have suffered due to certain challenges. These challenges, as listed by Grundy, Abdelrazek and Curumsing (2018), include the effort required to develop, deploy and maintain them, a low level of end-user acceptance, difficulty in integration with other health systems, difficulty in catering to diverse types of users, inadequate feedback given to developers, a low level of sustainable adoption and even lack of success.

Methodology

This research sought to gain insights that would aid in the development of a model for a mobile enabled e-health system for the self-management of diabetes. In order to do this, a mixed method approach was adopted. For the quantitative aspect, a survey was sent to a total of 2,000 diabetes patients in the Jeddah region. The survey website Qualtrics was used for this research. Hospitals in the Jeddah area were approached and the contact details of their diabetes patients were obtained.

The survey participants were selected from a composite list using a purposive sampling method with the following inclusion and exclusion criteria:

a) Inclusion criteria: Patients aged 18 years or more (adults), Saudi citizens, male and female, more than one year of treatment for diabetes.

b) Exclusion criteria: Patients below 18 years of age, non-Saudi citizens, less than one year of treatment of diabetes.

A total of 210 online responses were received with a response rate of 10.5%. SPSS was used to analyse the data collected.

In addition to the quantitative component, qualitative methods were also used. A focus group was conducted with 30 stakeholders of diabetes management about the personalised diabetic care and management process. These participants were representative samples consisting of five people from each of the following groups: diabetic patients, their close relatives or friends, nurses, doctors, outside IT specialists, and IT staff from the hospital administration. The aim of the focus group was to identify the inputs for modelling the e-health requirements in diabetic care and management and it has the potential to lead to the identification of processes and systems requirements for the study.

Results

Summary of survey results

The survey results showed that e-health could be categorised into four levels of activities and requirements for modelling. The four levels are:

1. Patients: Targeted customised intervention. The variables to consider in modelling are
    a. Demographic profile: Diabetes is more prevalent among women of all ages, especially women from 25 to 50 years of age with a secondary school degree who are unemployed or are government employees with a monthly income lower than 15,000 SAR. The target group for customisation needs to be done on this basis.
    b. Diabetes profile: Requiring special attention in customisation and m-health – T1D of over 5 years. Higher stress to be placed on strictly following diet and physical activity recommendations.
2. Hospitals: Self-care management systems are attached to more hospitals. The problems here are
    a. Healthcare systems: Increase registration of patients for hospital-based e-health self-care management programmes.
    b. Variables of customised e-health self-care programme: Regular blood glucose monitoring, insulin injections, daily food intake and physical activity programme as per the advice and enter into the e-health system on the day itself. Enter any other chronic health problems in the system. Contact local healthcare systems for acute conditions and get treated. Alert healthcare systems about any serious problems for urgent attention.
    c. Desirable: Use local healthcare centres and community health workers for maximum outreach. Patients must be motivated to join the diabetes community group of the area and participate in the discussions and interactions, sharing their own experiences and learning from the experiences of others.

Another key finding was that although medication had been prescribed for about 96% of the participants (n = 199), only 88% (n = 183) followed the prescribed medications (Table 9). Thus, 16 participants were not following the prescribed medications. In addition to this, although a specific diet had been prescribed to about 66% (n = 137) of participants, only about 30% (n = 62)

followed the prescribed diet. This highlights the need for and value of e-health in the context of diabetes patients. There is scope for e-health interventions to monitor and track how well patients follow doctors' recommendations and prescriptions.

The survey also showed that the existence of an e-health self-care management system was reported by only 34.4% of participants (n = 72). This may mean that out of 182 participants who visited a primary care hospital before undertaking self-care at home (Table 14), 110 participants were not part of an e-health based self-care system. This finding highlights the gap and the potential for a successful e-health intervention to be implemented. These findings make this research even more pertinent, as it illustrates the need for mobile-enabled health systems for self-management.

Summary of focus group results

The focus group participants provided an exhaustive list of requirement variables for modelling e-health for self-management of diabetes by Saudi patients. These are discussed below in Table 1.

Table 1: Themes Discussed – Focus Group Discussion

Theme	Discussion
Theme 1: Predisposing factors of diabetes	This theme consisted of identifying the predisposing factors of diabetes. These included hereditary, genomic, other diseases, hormonal imbalance, the quantity and type of food eaten, and lack of physical activity. Eating a lot of sugary food can be the direct cause of an immediate increase in glucose levels. These predisposing factors determine the likelihood of a person getting diabetes and thus become modelling variables.
Theme 2: The need for diabetes management	Modelling must be done to determine the efficient management of diabetes. Since there is no cure, the disease can only be managed so as to contain it and prevent adverse outcomes for the patient. Therefore, this theme provided one justification for modelling, but e-health has not been considered yet. Self-management is necessary to avoid one or more of the physiological factors related to the disease becoming uncontrolled. The most important factors are listed as the variables. The last factor is that of patients requiring instructions to self-administer diabetes control actions, which is the direct reason for the need.
Theme 3: Aim of diabetes control	Having realised the need for diabetes management, the main aims are defined here. Management consists of reducing blood sugar and ongoing diet control and exercise to maintain this control. This aim is one half of the modelling aim. The other half will be e-health, which is considered later.
Theme 4: Primary interventions	For any diabetes management, the primary interventions consist of insulin administration and other medications. Additional interventions include prescribing a planned diet to avoid foods contributing to an increase in glucose levels and some physical activities for active life depending on the patient characteristics like age and occupation, particularly if there are comorbidities. Without these supports, insulin administration will be ineffective. Initially, these interventions are implemented under clinical guidance. When the patient becomes sufficiently capable, these steps are practised at home as a part of a self-management plan. These interventions are the minimum required for effective treatment of diabetes and thus are essential aspects of

	modelling for self-management. The core of modelling is how e-health helps in implementing these practices.
Theme 5: Achievement of control	The variables of a good control system can be viewed as a guideline for modelling. To achieve control of blood glucose levels, close monitoring of glucose and haemoglobin (HbA1c) are essential. Other analyses like measuring body weight and selected enzyme activities may be advised depending on requirements. Psychological problems like stress and anxiety can increase blood glucose levels even if insulin is not required and hence need to be addressed through awareness and counselling. For women, controlling diabetes during menstrual cycles and pregnancy is critically important.
Theme 6: Support	Self-management may require support from many sources, since the facilities of a hospital are not available at home or even, for many people, in close vicinity to home. The patient may be unsure of what steps to take when some problems arise, as was noted in the focus group. Clinical support from the patient's hospital may be available on call. Communities in which the patient lives may have patients already experienced in self-management. There are many organisations which provide free classes, advice and guidance and even extend physical help when required. Administrative support from the government is necessary to ensure an adequate supply of resources that can be easily accessed and are affordable. Insurance firms need to take a compassionate view concerning helping patients who are poor and cannot afford the cost of long-term self-management. All of these supports are built into the population diabetes control in most countries. These supports are particularly relevant in e-health also. This aspect is, therefore, important in modelling.
Theme 7: Going wrong	In the diabetes self-management system, there is scope for a number of errors. These include the failure of interventions, development of psychological problems, support failures and whole system failure itself. These failures need to be factored into the model to save the system from crashing.
Theme 8: Resolving issues going wrong	Instead of trying to prevent failures, it is more prudent to implement steps to resolve them in advance. This should be the way in which the model behaves. Solutions to intervention problems need direct actions when they occur. However, catastrophic risks cannot be predicted in advance. Thus, only psychological and support problems can be foreseen and controlled before they fail.
Theme 9: Advanced methods of intervention	Some advanced methods of intervention may be failure-proof to a great extent and therefore important in modelling. Self-management kits with instructions and interaction opportunities with support on a round-the-clock basis take us almost to e-health systems.
Theme 10: New methods of intervention	Now we are considering e-health to ensure that the diabetes self-management system works to near-perfection. M-health is the application of e-health using mobile (smart) phones and other devices. How mobile phones function is facilitated for this and makes possible elevated standards of care, as described in the theme, are important to be included in the modelling.

Theme 11: Using e-health for in-home self-management	Earlier, we considered the requirements of self-management. Now we examine how e-health facilitates self-management in an e-health enabled system. The concept of e-health is developed around the holistic health of the individual. Physical health, mental health and well-being are the three important components of e-health. M-health is the delivery of e-health via smartphones and other smart gadgets. M-health allows for the customisation of e-health for individual needs, which is especially important when considering the self-management of diabetes. A reduction of hospital visits reduces the workload of physicians, as the entire range of interventions can be practised using mobile devices. Some specific m-health applications are also considered as part of this theme.
Theme 12: Integration of m-health with e-health for self-management	Given that m-health is only a facilitation of e-health based self-management of diabetes using mobile devices, how exactly m-health is integrated with e-health becomes important in modelling for e-health in which m-health is the tool. This theme considers what m-health can currently offer which is compatible with e-health, the possibilities of further technological advancements in mobile devices and what to expect. These factors determine how the integration of m-health with e-health can take place. Some possible negative variables also exist. One of these is when, in spite of all of the facilitations of mHealth, the patient engages in a lifestyle not conducive for diabetes self-management. Other issues of serious concern include affordability and accessibility for patients in rural and remote locations. Internet connectivity, rural income limitations and far away care facilities are the problems in this respect.
Theme 13: Identifying variables of a comprehensive e-health self-care system	This theme provides a list of design requirements for modelling an m-health facilitated e-health system for diabetes self-management. The variables related to this question are described here. It is almost a summary of the variables considered above in terms of personal factors, care factors, customisation, and developments in interventions, mobile applications, support groups and technological facilitations. One considerable drawback in these requirements is that there is nothing specific about the Saudi Arabian context. The focus group questions did not specifically ask about the Saudi context. However, in applying m-health integrated e-health systems for diabetes self-management by Saudi patients, the current status of all these variables in Saudi Arabia will be considered. For example, data on the average profile of a Saudi diabetes patient, gender separation problems in the diabetes care of women, how the social and cultural environment determine community support, the compatibility of current e-health system with diabetes self-management, the availability of mobile availability and the apps related to diabetes self-management, internet penetration and access, costs of diabetes management in urban, rural and remote areas, average family income and the percentage of healthcare expenditure are all relevant factors.
Theme 14: Likely future developments	This theme attempts to foresee future research opportunities. The list includes some possible avenues of future developments in which already some progress has been made and research is being conducted. Some wearable devices and long-acting insulin are already available commercially and improved versions are under development. The destruction of pancreatic beta cells has been identified as the origin of diabetes development. A lot of research on the genomic and

	biochemical aspects of diabetes development has already been done and the search for genomic markers continues. Some of this research may pave the way to prevent diabetes altogether, as further knowledge is developed on diabetes at a genetic level. Together, this research may contribute to healthier and more active national populations.

Integrating the findings of quantitative and qualitative approaches

Eysenbach (2001) listed the requirements of e-health modelling as follows:

a) B2C: The capability of patients for online interaction with their healthcare systems. In this research, the capability of patients indicates their awareness and education about diabetes, its symptoms and the intervention methods to manage the disease. On the side of healthcare systems, the capability is related to the availability of electronic patient records for instant reference, evidence-based interventions, the availability of diabetes specialists, and communication facilities with the patients
b) B2B: Improved possibilities for institution-to-institution transmissions of healthcare data for common benefit as evidence-based medicine. This involves the communication of healthcare data and intervention recommendations with local healthcare systems, community health workers and with new patients through diabetes communities networks.
c) C2C: New possibilities of communication and cooperation among similarly placed patients, especially with respect to the self-management of chronic diseases. Here, communication between diabetes patients within networks of diabetes communities and with new patients enrolled in these networks are included.

Amplifying the above list, a little more, the information and activities at different levels are:

a) Patient: The results of self-monitored blood glucose levels, foods eaten, details of physical activity, any other acute and chronic healthcare problems as and when they occur, any interventions done as per local healthcare recommendations and job details. Also, family details including their health problems with interventions done.
b) Local healthcare systems: Patient healthcare record containing details of visits, tests, diagnosis and interventions recommended.
c) Local community health workers: Ensure that the patient level data listed above are available at the appropriate levels by monitoring, correcting and advising the patient. Educating patients.
d) Centralised healthcare systems covering a large area: Interaction and communication with local healthcare systems, community health workers and community networks, instantly attending to alerts from local systems about any patient, maintenance of a centralised healthcare data of all patients in the area of its jurisdiction, and communication of new evidence-based interventions and revised guidelines to all concerned as and when revisions are done.
e) Community networks of diabetes patients: Interactions with healthcare systems and professionals for expert input, interactions with community health workers for local level actions, interactions among members sharing experiences useful for others.

Theme 13 of focus group results can be related to the above list in the following manner.

Table 2. e-Health activities and their requirements from Theme 13

Level	Required activities	Theme 13 from the focus group discussion
Patient	Results of self-monitored blood glucose levels, foods eaten, details of physical activity, any other acute and chronic healthcare problems as and when they occur and the interventions done as per local healthcare recommendations and job details. Also, family details including their health problems along with the relevant interventions. Enter this information in an electronic data system for use in customised e-health self-management systems.	The extent of commitment, progressively beneficial, having one's own data, expectations, thwart the headway of a steady affliction, own sentiment of hazard. An individual could improve before a potential ailment strikes helped by e-health, careful current partner, identifying elective frameworks, offering scope for control through various medicines or through preventive strategies including diet and physical exercise.
Local healthcare systems	Store electronic patient data and transmit it to the central healthcare system (usually a hospital). Advise interventions to the patients on visits. Visit patients at home frequently to ensure compliance with intervention advice. Provide advice to patients via customised m-health applications.	Receive from a centralised facility customised data for patients in the locality, better assessment of their wellbeing by including a sentiment of commitment, useful social changes, being dynamic legends of their life, not as uninvolved recipients of others' decisions. Include them in the intervention advice to the patient concerned.
Centralised healthcare systems	Interaction and communication with local healthcare systems, community health workers and community networks, instantly attending to alerts from local systems about any patient, maintenance of a centralised healthcare data of all patients in the area of its jurisdiction. Communication of new evidence-based interventions and revised guidelines to all concerned as and when revisions are done and customised m-health applications.	Store the electronic health data of all patients in its jurisdiction. Combine them with evidence-based interventions for customised advice and transmit them to local healthcare systems for their advice to the concerned patient. Work with local systems and community networks to ensure clinical care qualities related to customised medicine, patients' understanding and responsibility concerning the need and continued use. Test and evaluate mobile applications of customised self-care of patients and recommend to local systems and community networks for use.
Community networks of diabetes patients	Interactions with healthcare systems and professionals for expert input, interactions with community health workers for local level actions, interactions among members sharing experiences useful for others.	Collect all useful information from centralised and local healthcare systems and other sources and relate them to actual patient experiences in order to provide useful advice to the network members. Use internet-based interactions with patients to exchange useful methods of customised management and mobile applications.

Based on the above table, the data collected from the survey for modelling e-health can be categorised into the four levels of activities and requirements as follows:

1. Patients: Targeted customised intervention. The variables to consider in modelling are

a) Demographic profile: Diabetes is more among women of all ages, especially 25 to 50 years of age, with a secondary school or degree education who are unemployed or a government employee and have a monthly income of lower than 15,000 SAR. The target group for customisation needs to be done on this basis.

b) Diabetes profile: Requiring special attention in customisation and m-health – T1D of over 5 years. Higher stress to be placed on strictly following diet and physical activities recommendations.

2. Hospitals: Self-care management systems attached to more hospitals. The problems here are:

a) Increase registration of patients for hospital-based e-health self-care management programmes.
b) Variables of customised e-health self-care programme – regular blood glucose monitoring, insulin injections, daily food intake and physical activity programme as per advice and enter into the e-health system on the day the activity is done. Enter any other chronic health problems in the system. Contact local healthcare systems when experiencing acute conditions and receive treatment. Alert the local healthcare systems about any serious problems that require urgent attention.
c) Desirable: Use local healthcare centres and community health workers for maximum benefit. Patients to be motivated to join the diabetes community group in their area and participate in the discussions and interactions, sharing their experiences and learning from the experiences of others.

Discussion

How does the above identification of e-health requirements help to design and implement an efficient and effective e-health based personalised diabetes management?

Community health workers can be adequately trained in e-health management aspects so that they can guide patients effectively in the self-management of diabetes. Greater attention to elders is also a factor to consider (Darkins et al., 2008). This is not part of the e-health system but should be included as an additional requirement.

Patient–physician interaction facilitated by WhatsApp and similar social platforms to patient medical records built into m-health for diabetes. This should be a two-way interaction (Hess, et al., 2007). There is a need to facilitate communication between institutions; for example, in relation to ordering and managing medications and monitoring and detecting early those patients who might abandon care. M-health could be effective in increasing access. There should be interactive communications between patients and local level hospitals and central hospitals for the area, community health workers and the network of diabetes groups (Blaya, Fraser & Holt, 2010). The m-health model to be designed in this study facilitates the incorporation of a suitable interaction platform.

Paschou, Sakkopoulos and Tsakalidis (2013) designed and implemented an e-health mobile application. Unlike the already available applications, this application provided the ability for [who] to create their own smartphone applications, which were data-intensive and independent of the desired healthcare domain. The development part was not visible to users, thus enhancing its utility. Whether one's own smartphone application should be included in the Saudi context at this early state itself is an important question.

Ross, Stevenson, Lau and Murray (2016) considered individual e-health technology, the outer setting, the inner setting and the individual health professionals and the implementation process as important components of the implementation of m-health design. Intervention characteristics and the characteristics of individuals related to the implementation process are important (Keith, Crosson, O'Malley, Cromp & Taylor, 2017). All these components, except for the implementation process, are included in the items listed in Table 1. The implementation process is only relevant after designing a model and for its validation.

Recent developments like cloud computing, the Internet of Things and big data analytics (NandhaKumar & Thanamani, 2017) can be incorporated

into the system depending on the need and availability of resources, facilities and skills in Saudi Arabia. All of these developments offer some potential benefits.

In cases when patients are not sufficiently literate or have difficulty in understanding, the e-health system could be in the form of coaching them like the Digital Coach using Internet of Things (IoT) consisting of tools for patient education, wearable sensors and supporting applications and services to ensure that type 1 or type 2 diabetic patients can do the right thing at the right time in their self-management of health conditions (Winterlich, Stevenson, Waldren & Dawson, 2016). In Saudi Arabia, the population literacy was 95.33% in 2017 (Macrotrends, 2021), with male and female literacy rates at 97.1% and 92.71% respectively in the same year (Country Economy, 2021). So, this is not a major problem in the Saudi context.

One issue is that diabetes patients may not be interested in e-health for self-management, as King et al. (2012) noted from focus groups and interviews. The patients preferred face-to-face contact, only wanting to use e-health to access self-management inputs. In this respect, the choice of technology, personalised instruction in using the programme features and the facilitation of exchanging information with their healthcare team are important. The opinion on the inclusion of other people in virtual social support systems depended on variations in patients' privacy concerns.

Tan's (2014) study found that nurses understood the definition of e-health depending on the kind of e-health system used. They were aware of the effects on patients of different types of e-health technologies and perceived increase an in their workload owing to a higher frequency of nurse–patient interactions in e-health. They therefore had a negative opinion of e-health; however, they did not hold this negative view of m-health as it removes some of their problems. Thus, m-health has better acceptability with nurses than e-health. This finding demonstrates the need to define the role of nurses clearly when designing e-health systems for Saudi Arabia. The implementation of e-health in the self-management of chronic ailments (with a focus on diabetes) needs to be regarded as a national priority to ensure its success and the achievement of healthcare goals, as was seen in the United States (Ricciardi, Mostashari, Murphy, Daniel & Siminerio, 2013).

The main components of most m-health applications are environments, including hospitals, clinics, long-term care facilities, primary care providers and homes to effectively deal with acute, emergency, chronic, primary and outpatient care. These environments must be integrated in an overlapping and interacting manner. The critical variables of e-health implementation for business success include usability, adoption, interoperability, change management, risk mitigation, security and privacy and return on investment (Archer, 2007). The data collected in this research contains all these components for designing and implementing an m-health system in Saudi Arabia.

The use of iOS or Android apps may provide inexpensive ready-to-use m-heath software. In the case of Saudi Arabia, both may be required as patients may be users of either Android or iOS phones. Other logistical requirements for m-health design are administrative aspects, patient healthcare insurance and all payments and medical connectivity. Payments are not an issue for Saudi citizens as healthcare is free for all citizens. Toolkits have been developed to facilitate the design of a system.

A good example for diabetes self-management using e-heath is the proposal of Kafalı et al. (2013) to integrate mobile, cloud and wearable devices in an application platform, which was named COMMODITY12. It is a personal health system (PHS) that facilitates the provision of continuous and personalised health services to diabetic patients. The patients are thus empowered to adopt a healthy lifestyle wherever they are, as the application allows patients to access it from rural and

remote locations. The system components are ambient, wearable and portable devices to acquire, monitor and communicate physiological parameters and other health-related aspects of the patient like their physical activity and vital body signals. Intelligent agents use expert biomedical knowledge to derive important insights about the individual's health status from these data. The findings of the intelligent agents are provided as feedback from the device either to the patient directly or through health professionals. Healthcare professionals use the data for diagnosis, treatment and life management. This European model can be considered for adaptation to Saudi Arabia with necessary changes based on the results of this study and other applicable research. Many other different e-health models for diabetes and other chronic ailments have been designed, tested and validated by many researchers. The difference is in how these models meet the above-discussed requirements and their adaptability to the Saudi Arabian context.

Conclusions

The paper integrates the findings of a survey and a focus group discussion to identify the design requirements for a mobile-enabled e-health system for the self-management of diabetes. The requirements at the patient, home, social, hospital and diabetes community worker levels were identified. The challenges and barriers were also considered with special reference to Saudi Arabia, along with possible solutions. Overall, there is enough evidence to demonstrate that it is possible to design and implement a mobile-enabled e-health system for the self-management of diabetes by Saudi diabetes patients. Triangulation with published literature on the topic provided support for these results.

Comments on the final outcome of this paper

1) Only the design requirements have been identified. Although some challenges and problems have been anticipated, different sets of problems may appear when the e-health system is actually designed.
2) The relative importance of design requirements identified in this paper are not the final list. Their relative importance may change in consultation with experts.
3) Information Technology (IT) engineers have a big role in designing the system, and their perspectives on effective e-health measures may be different to those identified in this paper. Nothing has been anticipated here in this respect.
4) The testing and validation method for the designed system needs to be fixed before it is designed. The methods may be finalised when the design is being done.

The importance of this work cannot be overstated. Given the rise in the number of diabetic patients in Saudi Arabia, the healthcare system faces immense stress and challenges. In addition to this, the recent Covid-19 pandemic has highlighted the need for and value of e-health in assisting patients without physical contact. In this context, therefore, this research is a valuable first step in determining how such interventions may be designed in order to ensure their success.

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