ISSN : 2350-0743

www.ijramr.com

International Journal of Recent Advances in Multidisciplinary Research
Vol. 07, Issue 12, pp. 6444-6454, December, 2020

RESEARCH ARTICLE

MOBILE HEALTH TECHNOLOGY TO ENHANCE HEALTHCARE SERVICE DELIVERY IN DEVELOPING NATIONS (SAUDI ARABIA)

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ARTICLE INFO

Article History:
Received 10th September, 2020
Received in revised form
26th October, 2020
Accepted 14th November, 2020
Published online 30th December, 2020

Keywords:
Mobile Health, Developing Nations,
Saudi Arabia, Chronic Diseases,
Diabetes Diseases,
Diseases Hypertension.

ABSTRACT

Saudi Arabia is among the countries that have very high prevalence rates of diabetes and hypertension, with prevalence rates of almost 18% and 25%, respectively. The majority of patients with diabetes and hypertension fail to manage their diseases and to show up for their follow up appointments. Mhealth technology is among the interventions that have been recently adopted to overcome these issues and improve the quality of healthcare services. This study aims to evaluate the effectiveness of a mobile phone application named diabetes and hypertension application (DHA Tracking) to promote adherence for patients with diabetes and hypertension in Mecca, Saudi Arabia. The proposed intervention was designed to promote adherence via two features, namely, refill medication reminder (RMR) and doctor appointment reminder (DAR). The third feature, which is managing the number of unnecessary visits, was covered by the cumulative blood sugar test (Hemoglobin A1c) for patients with their doctors. The study examined the difference in adherence level before the intervention and after the intervention with samples of n = 199 and n = 165 for diabetes and hypertension, respectively. The mhealth intervention was found to have significant effects on both the refill medication reminder and the doctor's appointment reminder. Also, it was found that the intervention was efficient in reducing the number of unnecessary follow-up visits to around 20%. This study supports the evidence in the literature on the effectiveness of mhealth in promoting adherence to medication for patients with chronic diseases in the developing countries and specifically in Saudi Arabia. Positive social change that may result from this study is for better management of chronic disease symptoms and increase the awareness of using mhealth applications. This would improve the quality of life for patients, their families, and the community.

INTRODUCTION

Chronic diseases, such as diabetes and hypertension, have reached epidemic rates worldwide. According to the International Diabetes Federation (IDF) DIABETES ATLAS 2017, around half a billion people worldwide live with diabetes. Also, the majority of those diagnosed with diabetes live in medium to low-income countries. Similarly, hypertension affects more than one billion people globally (World Health Organization, 2013). The diagnosis and treatment of chronic diseases requireprolonged care and management from both patients and the healthcare facilities where patients receive health services. Such diseases increased the burden on the healthcare systems in developing countries where medical, financial, and human resources are limited (Allegranzi et al., 2011). Subsequently, in such a situation, providing high-quality healthcare services to patients with chronic diseases such as diabetes and hypertension became very challenging. In an effort to deal with past challenges, many scholars and healthcare providers have initiated several health interventions to provide high-quality services to patients with a variety of diseases. Among those interventions that have widely been adopted recently is mobile health "mhealth." The mhealth is defined as the use of cell phone and wireless technologies to provide medical care services (Agarwal et al., 2016). Mobile technologies include devices such as "mobile phones; personal digital assistants (PDA) and PDA phones (e.g., BlackBerry, Palm Pilot); Smartphones (e.g., iPhone); enterprise digital assistants (EDA); portable media players (i.e., MP3-players and MP4-players, e.g., iPod); handheld video-game consoles (e.g., PlayStation Portable (PSP), Nintendo DS); and handheld and ultra-portable computers such as tablet PCs (e.g., iPad and Smartbooks)" (Free et al., 2013, p. 2). Mhealth technology has been adopted in several areas of healthcare, including but not limited to adherence to medication (Park, Howie-Esquivel, Chung, & Dracup, 2014), disease prevention (Cole-Lewis & Kershaw, 2010), appointment reminders (Prasad & Anand, 2012), data collection (Tomlinson et al., 2009), and diagnosis of diseases (Breslauer, Maamari, Switz, Lam, & Fletcher, 2009). Figure 1 shows some of the applications of mhealth technology in healthcare. Most of the mhealth implementations were carried out in developed countries. However, in developing countries where healthcare systems lack the resources and efficiency to provide high-quality services, patients, and the community, the adoption of mhealth has not been widely explored. Therefore, this study aimed to enhance the quality of healthcare services for diabetes and hypertension patients with mobile health technology in Saudi Arabia.

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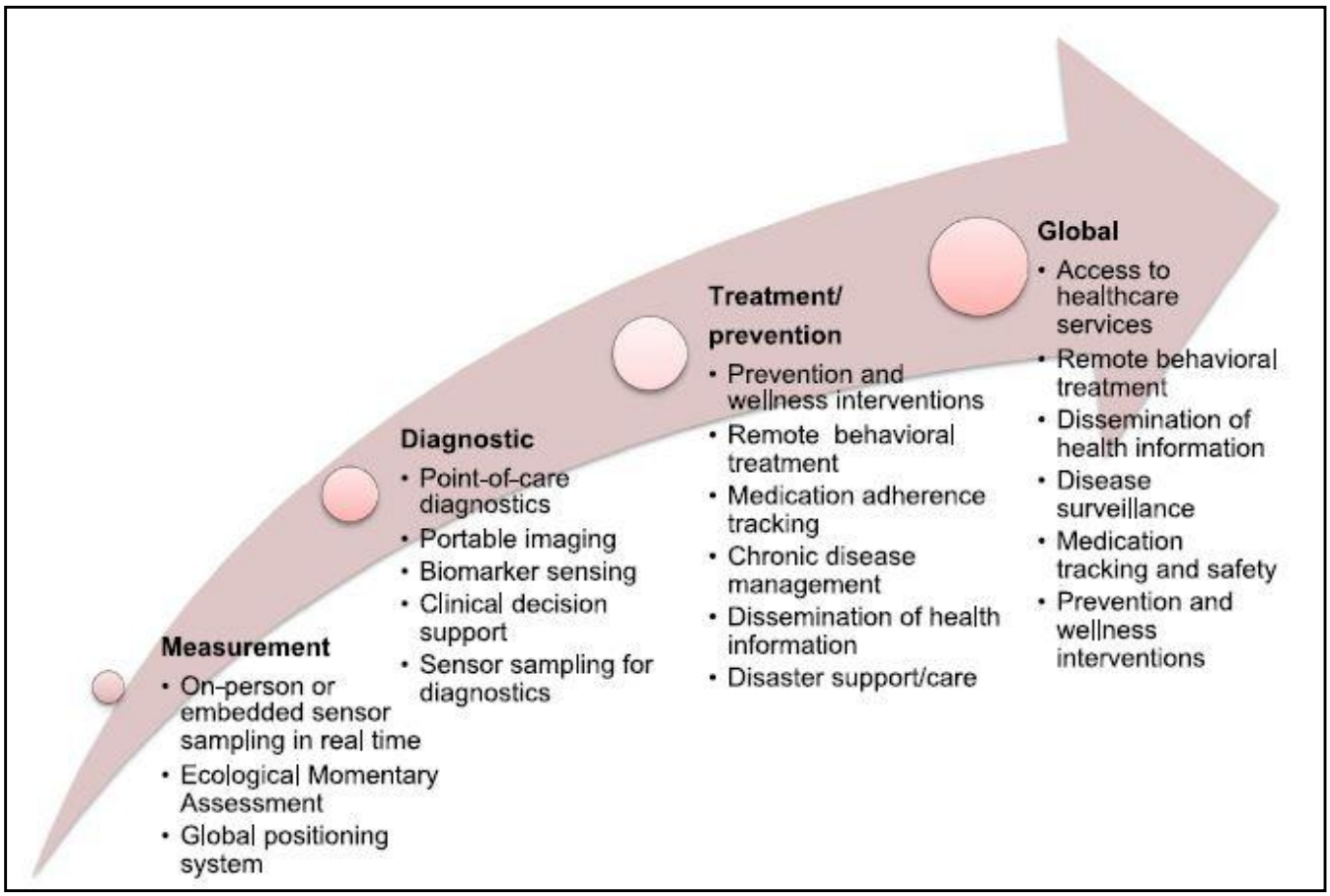

Figure 1. Applications of mhealth technology (Kumar *et al*., 2013)

Theoretical Foundation of Work: Many studies have investigated the factors that may contribute to adherence to medications of patients with chronic diseases such as diabetes and hypertension. In one study, the influence of health beliefs on medication adherence among patients with type 2 diabetes was investigated (Alatawi, Kavookjian, Ekong, & Alrayees, 2016). The Health Belief Model (HBM) was used in this study to explore the medication-taking behavior of diabetic patients in Tabuk, Saudi Arabia. A convenience sample of size 217 diabetic patients of both genders and were over 18 years old were included in the study. A questionnaire containing demographic, medical history, medication adherence, and health beliefs information regarding diabetes was used in this study. The results revealed that almost 43% of the participants did not comply with their medication for at least one day in the past week. In another study, adherence of patients with type 2 diabetes to the standards set by the American Diabetes Association (ADA) was investigated in the city of Riyadh, Saudi Arabia (Al Harbi et al., 2015). In specific, adherence of diabetic patients to 11 ADA standards, including glycemic control, blood pressure control, and lipid management, were studied. A sample of 450 diabetic patients, who were at least 18 years old, and who visited the health center more than once during six months, was selected to participate in the study. The results showed that the majority of the patients were between 50 and 69, with less than half of which being male. Also, about 85% of the patients were either overweight or obese. The results also showed that compliance with the ADA standards ranged from 35.6% for Nephropathy screening to 92.9% for Blood pressure measurement. The effects of some socio-demographic factors on the compliance to the medication of diabetic patients have also been investigated in Abha, Saudi Arabia (Salam & Siddiqui, 2013).

A total of 406 patients with type 2 diabetes were randomly selected to participate in the study. The data were collected from the participants through a questionnaire, which included items on diet, exercise, medication, and follow up. The results showed that patients who were 40 years or younger showed significantly higher levels of adherence to appointment and diet compared to older patients. On the other hand, older patients showed significantly higher levels of compliance with medication. Moreover, the study also reported that most of the patients were compliant with medication and follow up regardless of their personal characteristics. Similarly, a study examined the factors that may have potential effects on the level of non-compliance of diabetic patients in three chronic disease clinics in Al Hasa, Saudi Arabia (Khan et al., 2012). The study used a survey to measure the non-compliance of a total of 353 randomly selected patients with diabetes, 468 of which completed the study. The questionnaire included demographic items such as gender, age, marital status, and level of education. It also included other medical items such as the presence of other chronic diseases, the number of medications taken, the frequency of taking medication, and the frequency of follow up visits. The results revealed that the overall non-compliance rate was found to be 67.9%, with male patients have significantly higher non-compliance rates than female patients. Also, the non-compliance rate of patients taking oral and insulin treatment was found to be more than 79%, while the patients taking only one medication showed a non-compliance rate of 48%. In the same context, medication adherence among patients with chronic diseases visiting an outpatient clinic in Riyadh, Saudi Arabia, was also evaluated (Tourkmani et al., 2012). The study evaluated the potential relationship between motivation and knowledge on the intention to comply with the medication of chronic diseases

such as diabetes and hypertension. A questionnaire was used, and a sample of 347 patients was included in the study. The questionnaire was designed to elicit specific information for the participants including demographic characteristics, medical history, and medication history. The results noted that more than 75% of the participants had at least two chronic diseases and taking on average more than six medications. The results also reported that more than 58% of the participants had a high rate of intention to comply with medication. Furthermore, the study reported that no relationship between motivation and knowledge of medication regarding adherence to medication was found. Moreover, a review was conducted on patients' adherence to medications of chronic diseases, such as hypertension, in the middle eastern countries, including Saudi Arabia (Al Qasem, Smith, & Clifford, 2011). The study reported that patients' self-reporting, pill counts, and blood pressure measurements were used to determine the adherence to the medication of hypertensive patients. The study also reported the reasons for patients' nonadherence to medication and indicated that the nonadherence rate of patients with high blood pressure was higher than those with diabetes. Thus, there is a need to adopt a healthcare intervention such as mhealth to promote self-management for patients with hypertension to reduce the rate of nonadherence to medication that is reported in the literature.

In another study, the factors that may influence the compliance diet, medication, and appointments of patients with diabetes have been explored in Abha, Saudi Arabia (Khattab, 1999). A total of 294 diabetic patients were involved in the study. The compliance was measured based on the number of visits of diabetic patients during a 6-month period. In specific, patients who visited the health center at least one-two occasions during six months were considered to have good compliance. Also, patients who visited the health center on one occasion during the six months were classified to have poor compliance. In addition, poor compliance was defined as the patients who failed to visit the health center during the six-month period. The results revealed that more than 61% of the participants were good compliant with appointments. Regarding compliance with drugs, the majority (84.2%) of the participants showed good compliance, while less than 2% showed poor compliance. The study also reported a significant difference between males and females in terms of good compliance, with male patients being more compliant than female patients. In addition, to identifying the factors influencing patients' adherence to medication, other studies were exploring the reasons that led patients to miss prescheduled appointments. For example, the reasons for missing appointments were investigated in a military hospital in Riyadh, Saudi Arabia (Alhamad, 2013).

The study included two groups of randomly selected patients for each sample of 380. The first group included the patients who missed their appointments, and the second group was set to be the control group, which included the patients who showed up for their appointments. The study defined the missing appointments as either the patients who didn't attend at least one prescheduled with the clinic or the patients who showed up later than their prescheduled appointment time. The results indicated that the difficulty in booking an appointment, long-distance travel, work commitment, lack of transportation, and visiting another hospital were the most frequently reported factors that contributed to missing appointments. Moreover, no significant difference between the experimental group and the control group in regard to the reasons cited for missing appointments. The use of mhealth interventions may promote medication adherence and hence improve healthcare service delivery for patients with chronic diseases. However, the acceptability of such interventions should be evaluated prior to their implementation to ensure feasible results. In fact, Alkhudairi evaluated the acceptability of a mobile phone diabetes management application by diabetes specialists in Saudi Arabia (Alkhudairi, 2016). Specifically, the study examined whether the use of mhealth applications would improve the management of diabetes. The study examined the feasibility and challenges of using a mobile phone application called Glucose Buddy within the context of Saudi Arabia through conducting interviews and questionnaires of selected participants and medical professionals. The study indicated that mobile phone applications such as Glucose Buddy could be successfully implemented within the Saudi context giving appropriate training and incentives.

Electronic health record (EHR) applications have also been used to improve healthcare service delivery in three public hospitals in eastern Saudi Arabia (El Mahalli, 2015). Specifically, the study evaluated the barriers using HER by physicians as well as its utilization. The study used a self-administered survey to gather data from a total of 555 physicians, 357 of which who completed the questionnaire giving an average response rate of nearly 56%. The questionnaire contained items of demographic information, the functionality of HER, and barriers to use HER. The results showed that most of the respondents had access to a computer at work. For chart review, the study showed the highest frequency of utilization was found to 'Obtain and review lab results' (94.4%). However, the study also reported a lack of utilization of communication tools such as email and SMS text messaging. Regarding the barriers to use HER, the study reported that 'system hanging up problem' and 'loss of entree to medical records transiently if the computer crashes or power fails' were the two most cited barriers. Some studies evaluated the effectiveness of mobile health applications in Saudi Arabia. In one study, a randomized control trial was conducted over a six-month period to evaluate the effectiveness of SAED to manage and educate diabetic patients in Tabuk, Saudi Arabia (Alotaibi, Istepanian, & Philip, 2016). A total of 20 patients aged from 20 to 65 years were aimlessly nominated to contribute to the study, and they were separated into two groups, with ten patients allocated to the nonintervention group and ten patients allocated to the intervention group. Patients' information, such as blood glucose levels were recorded two to three times a day on two to three different days a week. Moreover, patients in the control group received weekly SMS text messages to promote their knowledge of diabetes and related risk factors. To measure the effectiveness of SAED, patients' Hemoglobin levels, as well as a test of knowledge about diabetes, were used before and after the intervention. The results revealed a significant reduction in hemoglobin levels of patients in the intervention group compared to the control group. Furthermore, patients' knowledge about diabetes was higher in the intervention group comparing to the control group, although both groups showed a significant improvement in their knowledge before and after the intervention.

In another study, Abbas and his colleagues evaluated the effectiveness of using SMS text messaging to control glycemic of diabetes patients within Riyadh (Abbas, Al Fares, Jabbari,

El Dali, & Al Orifi, 2015). A sum of 100 patients with diabetes type 2 was chosen to participate in the study. Variables such as glycosylated hemoglobin (HbA1c), blood glucose levels, and average fasting blood sugar were assessed before and after the SMS intervention. During the intervention, patients received from five to seven messages every week, including educational information about diabetic care and management in the Arabic language. The text messages were also designed to remind patients of taking their medications and checking their blood glucose levels. The results indicated that a significant decline in patients' blood glucose levels and average HbA1c. The study also reported a significant improvement in patients' knowledge of diabetes. Based on the studies discussed above, there is a lack in the literature regarding the effectiveness of the use of the mobile health platform to provide services such as medication refill reminders, doctor appointment reminders, and managing unnecessary follow-up visits of patients with diabetes and hypertension in developing nations. Although some investigation studies have been conducted about diabetes in Saudi Arabia, no research studies in literature investigated the use of mhealth technology for hypertension disease management in the country. Designing a mobile phone application with such features may help patients better manage their diseases and promote their adherence to medication. This also results in limiting the prevalence of chronic diseases, such as diabetes and hypertension in Saudi Arabia. This study, therefore, aims to fill this gap by developing a mobile phone application that aims to help diabetic and hypertensive patients manage their diseases in Saudi Arabia. Also, the developed application provides other services such as doctor appointment reminders and medication refill reminders.

Research Question and hypothesis

Q1: Does utilizing of refill medication reminder feature of DHA have a positive statistically significant impact on medication adherence levels of diabetic and hypertension patients in developing countries?

Ho1: No, utilizing of refill medication reminder feature of DHA does not have a positive statistically significant impact on medication adherence levels of diabetic and hypertension patients in developing countries

Ha1: Yes, utilizing of refill medication reminder feature of DHA has a positive statistically significant impact on medication adherence levels of diabetic and hypertension patients in developing countries.

Q2: Does utilizing the pre-appointment checkup feature for the Hemoglobin A1c test has a positive statistically significant impact on decreasing the number of visits per patient for diabetic patients in developing countries?

Ho2: No, utilizing the diagnostic feature does not have a positive statistically significant impact on decreasing the number of visits per patient for diabetic patients in developing countries.

Ha2: Yes, utilizing the diagnostic feature has a positive statistically significant impact on decreasing the number of visits per patient for diabetic patients in developing countries.

Q3: Does utilizing doctor appointment reminder feature of DHA have a positive statistically significant impact on adherence to doctor appointments of diabetic and hypertension patients in developing countries?

Ho3: No, utilizing of doctor appointment reminder feature of DHA does not have a positive statistically significant impact on adherence to doctor appointment levels of diabetic and hypertension patients in developing countries.

Ha3: Yes, utilizing of doctor appointment reminder feature of DHA has a positive statistically significant impact on doctor appointment levels of diabetic and hypertension patients in developing countries

METHODOLOGY

Procedures of Sampling/Participants: The sample size of this study comprised of diabetic and hypertensive patients, male and female, who have visited Al-Noor Specialist Hospital during the period from September 01, 2019, to October 30, 2019. A total of n= (364) patients, 199 of which are diabetic patients and 165 patients of which are hypertension patients, were selected to participate in the study. All patients were 18 years old or older and had a smartphone with an applicable system to install the DHA application. The exclusion patients were the prisoners, pregnant, and disabilities patients. There were two different groups in this study, which were the diabetes group and the hypertension group. Both groups received their health care service with mobile health intervention for 60 days, and the author considered these data as post-intervention data. The pre-intervention data was collected from the hospital records for each selected patient for 60 days. The sample of each group was selected based on a stratified random sample approach depend on demographic information such as gender, age, weight, and the history of patients' chronic diseases. "A stratified random sample is a population sample that requires the population to be divided into smaller groups" (Mahardika &Gustomo, p. 627). The comparison will be between the data for each patient before the intervention and after the intervention.

Procedures of the experiment: The DHA consisted of two main features. The first feature is the refill medication reminder (RMR). After the participants completed the registration steps, they were received a refill medication reminder (RMR) messages. Refill a medication reminder (RMR) is a feature to remind the participants to refill their medication through a series of messages. The first message is sent to the participant three days before the refill date. The content of the first message is "Your medication refill date will be ready within three days." A second message is sent to the participant one day before the medication date. The content of the second message is "Your medication refill date will be ready tomorrow." After that, the participant is asked whether or not he or she got the medication. If the answer is yes, then the participant has received a message for the next refill medication date. If the answer is no, then the participant would receive daily messages reminding his or her to refill their medication until they do so. Subsequently, a new message is sent to the participant for the next refill date. This process is illustrated in the left-hand side of Figure 2.

The second feature of DHA is the doctor's appointment reminder (DAR). A doctor appointment reminder (DAR) is a feature that reminds the participants to adhere to the doctor's appointments. After the participants completed the registration steps, they receive doctor appointment reminder (DAR) messages. The first message is sent to the participants three days before the doctor's appointment date. The content of the message is, "Your doctor appointment will be within three days." A second message is sent to the participant one day before the doctor's appointment. The content of the second

message is "Your doctor appointment will be tomorrow." After that, the participant is asked whether or not he or she showed up for the appointment. If the answer is yes, then the participant will receive a message for the next doctor's appointment date. If the answer is no, then the participant will be asked to enter the new doctor's appointment date after rescheduled it with a specialized team. The procedure of this process is illustrated in the right-hand side of Figure 2.

gender, and weight, and patients' medical history. Patients at Al-Noor Specialist Hospital refill their medications based on their health status. In this regard, the study period was divided into two months before the intervention, where patients refill their medication and see their physicians at least two times, and two months after the intervention, where patients refill their medication and see their physicians for at least two times.

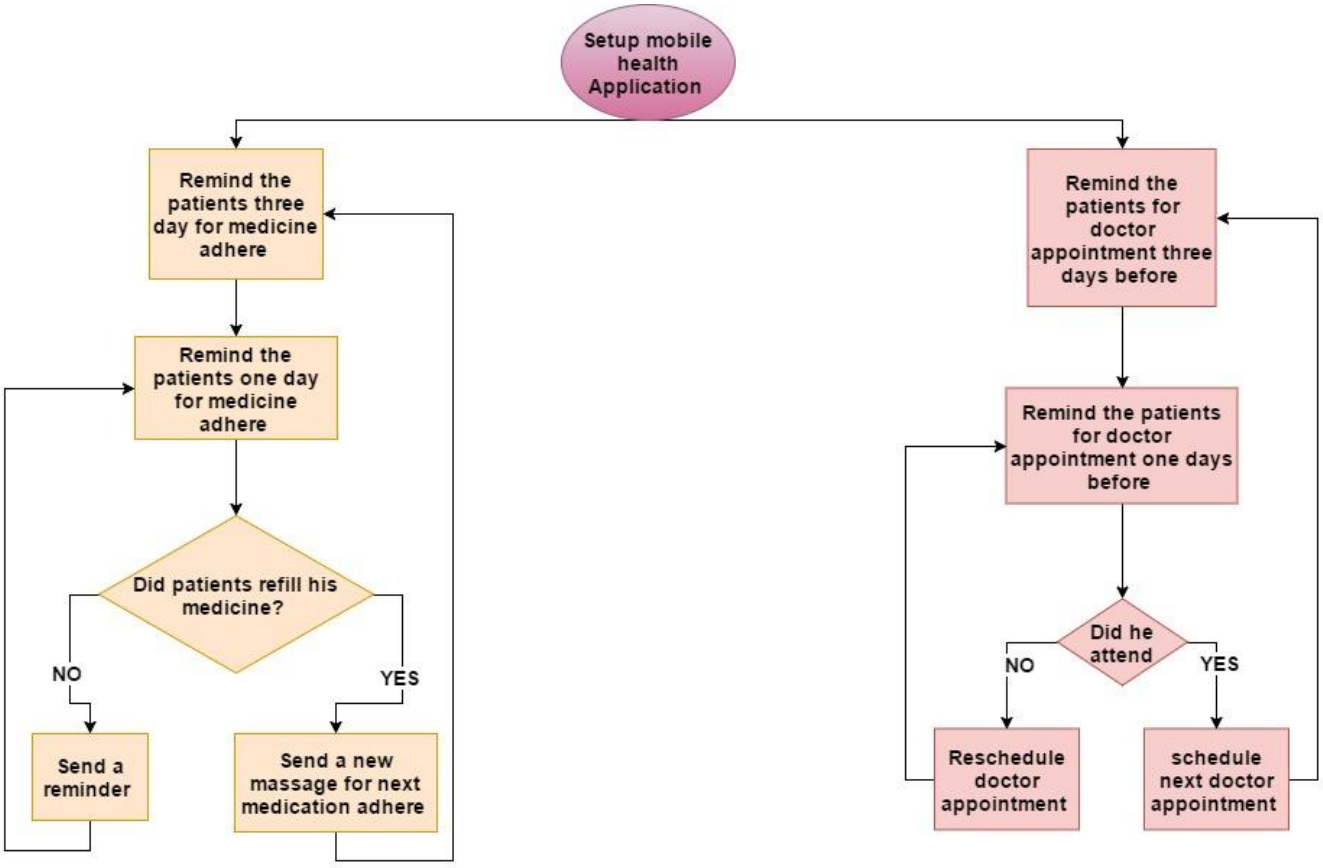

Figure 2. A process flow chart for the first and second features of DHA

In addition to RMR and DAR, the authors investigated the effectiveness of utilizing a pre-appointment checkup feature for Hemoglobin A1c tests for diabetic patients with the aim of reducing the number of unnecessary follow-up visits. To achieve this goal, it is important to know the mechanism of dealing with patients in the hospital, which was as followed: (1) a patient will do the cumulative blood sugar test (Hemoglobin A1c) in the laboratory at the hospital. (2) The results will be entered into the hospital database under the name of each patient. (3) the doctor will see the participant and his or her result, then the doctor will determine the participant's condition and give the necessary treatment and adjust the dose according to the test results. So, to calculate the number of unnecessary follow-up visits, the exact number of patients without their names or any information were getting for five different diabetics clinics and got the Hemoglobin A1c test result for each patient. Then the doctors were met by the principal investigator to see how many patients should not be seen based on their test result.

RESULTS

Data collection: The data for this study was obtained from the hospital's database and the DHA. These data include the demographic information of the participants, such as age,

The pre-intervention period lasted two months starting from August 15, 2019, to October 15, 2019, while the post-intervention period lasted for two months starting from October 15, 2019, to December 15, 2019. The sample sizes for patients with diabetes and hypertension were 199 and 165, respectively. For diabetic patients, 101 of the 199 were male, and the remaining were female. For hypertension patients, 82 were male, and the remaining were female. Participants were selected using a stratified random sampling method where patients stratified based on their gender, age, weight, and history of chronic diseases.

RESULTS AND ANALYSIS

Descriptive Statistics: For diabetes, the study sample size was N = 199 participants of whom n = 98 (49.2%) were female and n = 101 (50.8%) were male. The demographic and descriptive characteristics of the sample population are summarized in Table 1 for diabetes patients with Refill medication reminder and in Table 2 for diabetes patients with doctor appointment reminder.

1. Diabetes Patients -Refill Medication Reminder (RMR):
   - Before mobile health intervention: 111 patients in the Adherence group and 88 in the non- Adherence group

- 111 in the Adherence group: (female= 53 (48%), male=58 (52%)), (have chronic diseases= 75 (68%). No chronic diseases= 36 (32%)), weight (Mean=85, SD=18.6), age (Mean=41, SD=13), Height (Mean=166.6, SD=8.7).
- 88 in the non-Adherence group: (female= 75 (51), male=43 (49%)), (have chronic diseases= 66 (75%). No chronic diseases= 22 (25%)), weight (Mean=84, SD=18.2), Age (Mean=42.4, SD=13.7), height (Mean=165, SD=8.4).
- After mobile health intervention: 155 patients in the Adherence group and 44 patients in the non-Adherence group.
- 155 patients in the Adherence group: (female= 80 (52%), male=75 (48%)), (have chronic diseases= 46 (30%). No chronic diseases= 109 (70%)), weight (Mean=84.3, SD=18.6), age (Mean=40.7, SD=13.3), height (Mean=165.8, SD=8.5).
- 44 patients in the non-Adherence group: (female= 18 (41), male=26 (59%)), (have chronic diseases= 12 (27%). No chronic diseases= 32 (73%)), weight (Mean=86.1, SD=17.7), Age (Mean=45.1, SD=12.8), height (Mean=165.6, SD=8.8).

Table 1. Characteristics of participants stratified by Adherence status and the remainder (Diabetes Patients -Refill Medication Reminder) n=199

Characteristics	Without remainder		With remainder	
	Adherence(n=111)n(%)	Non-adherence (n=88) n(%)	Adherence (n=155) n(%)	non-adherence(n=44) n(%)
Gender				
Female	53 (48)	45 (51)	80 (51.6)	18 (40.9)
Male	58 (52)	43 (49)	75 (48.4)	26 (59.1)
chronic diseases				
Yes	75 (68)	66 (75)	109 (70.3)	32 (72.7)
No	36 (32)	22 (25)	46 (29.7)	12 (27.3)
Weight, Mean (SD)	85 (18.6)	84.32 (18.2)	84.3 (18.6)	86.1 (17.7)
Age, Mean (SD)	41 (13)	42.39 (13.7)	40.7 (13.3)	45.1 (12.8)
height, Mean (SD)	166.6 (8.7)	165 (8.4)	165.8 (8.5)	165.6 (8.8)

Table 2. Characteristics of participants stratified by Adherence status and the remainder (Diabetes Patients - Doctor Appointment Reminder) n=199

Characteristics	Without remainder		With remainder	
	Adherence(n=149) n(%)	Non-adherence (n=50) n(%)	Adherence (n=170) n(%)	non-adherence(n=29) n(%)
Gender				
Female	70 (47)	28 (56)	79 (46.5)	19 (65.5)
Male	79 (53)	22 (44)	91 (53.5)	10 (34.5)
chronic diseases				
Yes	105 (66)	36 (72.5)	123 (72.4)	11 (37.9)
No	44 (34)	14 (27.5)	47 (27.6)	18 (62.1)
Weight, Mean (SD)	85 (18)	83.8 (19.8)	84.9 (18.9)	83.3 (15.5)
Age, Mean (SD)	41.3 (13.3)	42.8 (13.2)	41.5 (13.1)	42.8 (14.5)
height, Mean (SD)	166.1 (8.7)	164.8 (8.4)	165.4 (8.2)	168 (10.6)

2. Diabetes Patients -Doctor Appointment Reminder (DAR):

- Before mobile health intervention: 149 patients in the Adherence group and 50 in the non- Adherence group.
- 149 patients in the Adherence group: (female= 70 (47%), male=79 (53%)), (have chronic diseases= 105 (66%). No chronic diseases= 44 (34%)), weight (Mean=85, SD=18), age (Mean=41.3, SD=13.3), height (Mean=166.1, SD=8.7).
- 50 patients in the non-Adherence group: (female=28 (56%), male=22 (44%)), (have chronic diseases= 36 (72.5%). No chronic diseases= 14 (27.5%)), weight (Mean=83.8, SD=19.8), Age (Mean=42.8, SD=13.2), height (Mean=164.8, SD=8.4).
- After mobile health intervention: 170 patients in the Adherence group and 29 patients in the non- Adherence group.
- 170 patients in the Adherence group: (female= 79 (46.5%), male=91 (53.5%)), (have chronic diseases= 47 (27.6%). No chronic diseases= 123 (72.4%)), weight (Mean=84.9, SD=18.9), age (Mean=41.5, SD=13.1), height (Mean=165.4, SD=8.2).
- 29 patients in the non-Adherence group: (female=19 (65.5%), male=10 (34.5%%)), (have chronic diseases=18 (62.1%). No chronic diseases=11 (37.9%)), weight (Mean=83.3, SD=15.5), Age (Mean=42.8, SD=14.5), height (Mean=168, SD=10.6).

3. Managing the number of unnecessary follow-up visits

- To manage the number of unnecessary follow-up visits for patients with diabetes, each patient should perform the Hemoglobin A1c test. If the Hemoglobin A1c level is high, an appointment with the physician will be scheduled for this patient. If, on the other hand, the Hemoglobin A1c level is normal, then the patient is directed to a primary care unit to receive regular care.
- To calculate the number of unnecessary follow-up visits, patients visiting five diabetic clinics were tested for their Hemoglobin A1c level. Based on this test, the percentages of the unnecessary follow-up visits were calculated for each clinic as shown in the following table.

For hypertension, the study sample size was N=165 patients of whom n=83 (50.3%) were female, and n=82 (49.7%) were male. The demographic and descriptive characteristics of the sample population are summarized in Table 4 for hypertensive

Table 3. Management of the number of follow up visits for diabetic patients

	Number of patients for 30 days	Necessary follow up	Effective clinical appointment rate	Could be eliminated	From	To
Clinic 1	422	342	19.91	80	4/72019	5/5/2019
Clinic 2	399	319	20.55	82	3/8/2019	4/6/2019
Clinic 3	198	138	40.91	81	3/8/2019	4/6/2019
Clinic 4	174	94	21.84	38	3/8/2019	4/6/2019
Clinic 5	525	420	20	105	2/7/2019	3/7/2019

Table 4. Characteristics of participants stratified by Adherence status and remainder (Hypertension Patients -Refill Medication Reminder) n=165

Characteristics	Without remainder		With remainder	
	Adherence(n=109) n(%)	Non-adherence (n=56) n(%)	Adherence (n=158) n(%)	non-adherence(n=7) n(%)
Gender	51 (47)	32 (57)	79 (50)	4 (57)
Female				
Male	58 (53)	24 (43)	79 (50)	3 (43)
chronic diseases				
Yes	67 (61.5)	36 (64)	100 (63.3)	3 (43)
No	42 (38.5)	20 (36)	58 (36.7)	4 (57)
Weight, Mean (SD)	84.76 (17.6)	83 (19)	84 (18.3)	85.3 (12)
Age, Mean (SD)	45.4 (13.5)	43 (12)	44 (12.4)	55.6 (20.9)
height, Mean (SD)	166 (8)	167 (8.1)	166.4 (8.3)	166.3 (6.5)

Table 5. Characteristics of participants stratified by Adherence status and the remainder (Hypertension Patients -Doctor Appointment Reminder) n=165

Characteristics	Without remainder		With remainder	
	Adherence(n=102) n(%)	Non-adherence (n=63) n(%)	Adherence (n=139) n(%)	Non-adherence(n=26) n(%)
Gender				
Female	50 (49)	33 (52.4)	70 (50.4)	13 (50)
Male	52 (51)	30 (47.6)	69 (49.6)	13 (50)
chronic diseases				
Yes	63 (61.8)	40 (63.5)	85 (61.2)	18 (69.2)
No	39 (38.2)	23 (36.5)	54 (38.8)	8 (30.8)
Weight, Mean (SD)	85.6 (18.3)	81.6 (17.4)	84.3 (18.4)	83.1 (16.4)
Age, Mean (SD)	45.9 (13.5)	42.4 (12.1)	44.6 (13)	44 (13.3)
height, Mean (SD)	166.3 (8.1)	166.4 (8.5)	166.2 (8.3)	167 (6.5)

patients with Refill medication reminder features, and Table 5 for hypertensive patients with doctor appointment reminder features.

1. Hypertension Patients -Refill Medication Reminder (RMR):

- Before mobile health intervention: 109 patients in the Adherence group and 56 patients in the non-Adherence group.
- 109 in the Adherence group: (female= 51 (47%), male=58 (53%)), (have chronic diseases= 67 (61.5%). No chronic diseases= 42 (38.5%)), weight (Mean=84.8, SD=17.6), age (Mean=45.4, SD=13.5), height (Mean=166, SD=8).
- 56 in the non-Adherence group: (female=32 (57%), male=24 (43%)), (have chronic diseases= 36 (64%). No chronic diseases= 20 (36%)), weight (Mean=83, SD=19), Age (Mean=43, SD=12), height (Mean=167, SD=8.1)..
- After mobile health intervention: 158 patients in the Adherence group and 7 patients in the non-Adherence group.
- 158 patients in the Adherence group: (female=79 (50%), male=79 (50%)), (have chronic diseases=100 (63.3%). No chronic diseases=58 (36.7%)), weight (Mean=84, SD=18.3), age (Mean=44, SD=12.4), height (Mean=166.4, SD=8.3).
- 7 patients in the non-Adherence group: (female=4 (57%), male=3 (43%)), (have chronic diseases=3 (43%). No chronic diseases=4 (57%)), weight (Mean=83.3, SD=12), Age (Mean=55.6, SD=20.9), height (Mean=166.3, SD=6.5).

2. Hypertension Patients -Doctor Appointment Reminder (DAR):

- Before mobile health intervention: 102 patients in the Adherence group and 63 patients in the non-Adherence group.
- 102 patients in the Adherence group: (female= 50 (49%), male=52 (51%)), (have chronic diseases= 63 (61.8%). No chronic diseases= 39 (38.2%)), weight (Mean=85.6, SD=18.3), age (Mean=45.9, SD=13.5), height (Mean=166.3, SD=8.1).
- 63 patients in the non-Adherence group: (female=33 (52.4%), male=30 (47.6%)), (have chronic diseases= 40 (63.5%). No chronic diseases= 23 (36.5%)), weight (Mean=81.6, SD=17.4), Age (Mean=42.4, SD=12.1), height (Mean=166.4, SD=8.5).
- After mobile health intervention: 139 patients in the Adherence group and 26 patients in the non-Adherence group.
- 139 patients in the Adherence group: (female=70 (50.4%), male=69 (49.6%)), (have chronic diseases=85 (61.2%). No chronic diseases=54 (38.8%)), weight (Mean=84.3, SD=18.43), age (Mean=44.6, SD=13), height (Mean=166.2, SD=8.3).

Table 6. Diabetes Patients-Refill Medication Reminder: Intervention and Predictor Variables for adherence (N = 199) according to logistic regression analysis

	B	S.E.	Wald	p	Exp(B)	95% CI for EXP(B)	
						Lower	Upper
Constant	-2.202	2.193	1.009	.315	.111		
Gender Female Male	 .068 -	 .222 -	 .092 -	 .761 -	 1.070 -	 .692 -	 1.654 -
chronic diseases Yes NO	 -.198 -	 .250 -	 .627 -	 .429 -	 .821 -	 .503 -	 1.339 -
Intervention Yes No	 1.044 -	 .225 -	 21.580 -	 .000*** -	 2.84 -	 1.829 -	 4.413 -
Weight	-.001	.007	.013	.910	.999	.986	1.013
Age	-.016	.009	3.071	.080	.984	.967	1.002
height	.020	.014	1.996	.158	1.020	.992	1.048
χ^2	28.544***						
df	6						
Correct Classified	67.3%						

*Note: ***p < .001.*

Table 7. Diabetes Patients -Doctor Appointment Reminder: Intervention and Predictor Variables for adherence (N = 199) according to logistic regression analysis

	B	S.E.	Wald	p	Exp(B)	95% CI for EXP(B)	
						Lower	Upper
Constant	.349	2.509	.019	.889	1.417		
Gender Female Male	 .558 -	 .261 -	 4.584 -	 .032* -	 1.747 -	 1.048 -	 2.912 -
chronic diseases Yes NO	 .436 -	 .275 -	 2.511 -	 .113 -	 1.546 -	 .902 -	 2.651 -
Intervention Yes No	 .690 -	 .262 -	 6.955 -	 .008** -	 1.994 -	 1.194 -	 3.329 -
Weight	-.004	.008	.226	.634	.996	.981	1.012
Age	-.009	.011	.738	.390	.991	.971	1.012
Height	.005	.016	.109	.741	1.005	.974	1.037
χ^2	14.7*						
df	6						
Correct Classified	80.2%						

*Note: * p < .05, ** p < .01, ***p < .001.*

- 26 patients in the non-Adherence group: (female=13 (50%), male=13 (50%)), (have chronic diseases=18 (69.2%). No chronic diseases=8 (30.8%)), weight (Mean=83.1, SD=16.4), Age (Mean=44, SD=13.3), height (Mean=167, SD=6.5).

Covariates and Logistic Regression Analyses

1. Diabetes patients - Refill Medication Reminder: The first logistic regression for diabetes patients dialed with the refill Medication Reminder feature was conducted with regards to the dependent variable of adherence. Variables: intervention, gender, chronic diseases, weight, age, height were included in the regression model. The model chi-square was significant, χ^2 (6, N = 199) = 28.544, p=0.000 < .001, indicating that the independent and/or covariate variables significantly predicted adherence at diabetes patients dialed with RMR. The non-significance of the Hosmer and Lemeshow chi-square test indicated that the model adequately fit the data, χ^2 (8) = 10.614, p = 0.225. The results from the logistic regression are presented in Table 6. The classification table output for model 0 (the model without the various predictor variables) correctly classified 66.8% of adherence. In comparison, the classification table for model 1 (which included the various predictor variables) indicated that correctly classified 67.3% of adherence.

There was a minimal difference in the classification tables between model 0 and 1. The Nagelkerke R2 indicated a 7.0% variance in the model. One variable (Intervention) significantly predicted (p < .001) in the dependent variable (adherence), where (B=1.044, odds ratio Exp(B)=2.84 CI 95%(1.829-4.41), p=0.000) indicates if there was Intervention, so the adherence increases 2.84 times more than without Intervention.

2. Analysis for Diabetes Patients - Doctor Appointment Reminder

Logistic Regression. The first logistic regression for diabetes patients dialed with doctor appointment reminder feature was conducted with regards to the dependent variable of adherence. Variables: intervention, gender, chronic diseases, weight, age, height were included in the regression model. The results from the logistic regression are presented in Table 7. The model chi-square was significant, χ^2 (6, N = 199) = 14.7, p=0.023<.05, indicating that the independent and/or covariate variables significantly predicted adherence at diabetes-visiting the patient. The non-significance of the Hosmer and Lemeshow chi-square test indicated that the model adequately fit the data, χ^2 (8) = 6.76, p = .563. The classification table output for model 0 (the model without the various predictor variables) correctly classified 80.2% of adherence. In comparison, the

classification table for model 1 (which included the various predictor variables) indicated that correctly classified 80.3% of adherence. There was a minimal difference in the classification tables between model 0 and 1. The Nagelkerke R2 indicated 6.0% variance in the model Two variables significantly predicted ($p < .05$) in (diabetes-Refill the medicine). Intervention variable was significant (B=.690, odds ratio Exp(B)=1.994, p=0.008) indicates if there is Intervention so the adherence increases 1.99 times more than without Intervention. The gender variable was significant (B=.558, odds ratio Exp(B)=1.747, p=0.032) indicates if the patient was female so the adherence increases 1.75 times more than male.

p = .562. The classification table output for model 0 (the model without the various predictor variables) correctly classified 80.9% of adherence. In comparison, the classification table for model 1 (which included the various predictor variables) indicated that correctly classified 80.9% of adherence. There was a clear difference in the classification tables between model 0 and 1. The Nagelkerke R2 indicated a 24.7% variance in the model. One variable (Intervention) significantly predicted ($p < .05$) independent variable (adherence), where (B=2.469, odds ratio Exp(B)=11.807, p=0.000) indicates if there was Intervention, so the adherence increases 11.8 times more than without Intervention.

Table 8. Hypertensive patients-refill medication reminder feature: Intervention and Predictor Variables for adherence (N = 165) according to logistic regression analysis

	B	S.E.	Wald	p	Exp(B)	95% CI for EXP(B)	
						Lower	Upper
Constant	3.125	3.153	.982	.322	22.756		
Gender							
Female	-.384	.308	1.554	.213	0.681	.372	1.246
Male	-	-	-	-	-	-	-
chronic diseases							
Yes	-.009	.316	.001	.978	0.991	.534	1.841
NO	-	-	-	-	-	-	-
Intervention							
Yes	2.469	.421	34.342	.000***	11.807	5.171	26.959
No	-	-	-	-	-	-	-
Weight	.007	.010	.461	.497	1.007	.988	1.026
Age	-.001	.013	.006	.940	.999	.974	1.024
Height	-.017	.020	.696	.404	.984	.946	1.023
χ^2	55.025***						
df	6						
Correct Classified	80.9%						

Note: * $p < .05$, ** $p < .01$, ***$p < .001$.

Table 9. Hypertensive patients- doctor appointment reminder (DAR): Intervention and Predictor Variables for adherence (N = 165) according to logistic regression analysis

	B	S.E.	Wald	p	Exp(B)	95% CI for EXP(B)	
						Lower	Upper
Constant	1.937	2.696	.516	.472	6.938		
Gender							
Female	.055	.260	.045	.832	1.057	.635	1.760
Male	-	-	-	-	-	-	-
chronic diseases							
Yes	-.194	.271	.511	.475	.824	.485	1.401
NO	-	-	-	-	-	-	-
Intervention							
Yes	1.210	.269	20.223	.000***	3.354	1.979	5.683
No	-	-	-	-	-	-	-
Weight	.008	.008	1.010	.315	1.008	.992	1.025
Age	.012	.011	1.147	.284	1.012	.990	1.034
Height	-.016	.017	.841	.359	.985	.952	1.018
χ^2	25.73***						
df	6						
Correct Classified	73.3%						

3. Analysis for hypertension Patients -Refill Medication Reminder

Logistic Regression. The first logistic regression for hypertension patients dialed with a refill medication reminder feature was conducted with regards to the dependent variable of adherence. Variables: intervention, gender, chronic diseases, weight, age, height were included in the regression model. The results from the logistic regression are presented in Table 8. The model chi-square was significant, χ^2 (6, N = 165) = 55.025, p=0.000<.001, indicating that the independent and/or covariate variables significantly predicted adherence at hypertension patients dialed with RMR feature. The non-significance of the Hosmer and Lemeshow chi-square test indicated that the model adequately fit the data, χ^2 (8) = 6.763,

1. Hypertensive Patients -Doctor Appointment Reminder

Logistic Regression. The first logistic regression for hypertension patients dialed with doctor appointment reminder (DAR) feature was conducted with regards to the dependent variable of adherence. Variables: intervention, gender, chronic diseases, weight, age, height were included in the regression model. The results from the logistic regression are presented in Table 25. The model chi-square was significant, χ^2 (6, N = 165) = 25.73, p=0.000<.05, indicating that the independent and/or covariate variables significantly predicted adherence at hypertension patients dialed with DAR. The non-significance of the Hosmer and Lemeshow chi-square test indicated that the model adequately fit the data, χ^2 (8) = 6.39, p = .604.

The classification table output for model 0 (the model without the various predictor variables) correctly classified 73.0% of adherence. In comparison, the classification table for model 1 (which included the various predictor variables) indicated that correctly classified 73.3% of adherence. There was a minimal difference in the classification tables between model 0 and 1. The Nagelkerke R2 indicated a 10.9% variance in the model.
One variable (Intervention) significantly predicted ($p < .05$) independent variable (adherence), where (B=1.21, odds ratio Exp(B)=3.354, p=0.000) indicates if there was Intervention, so the adherence increases 3.35 times more than without Intervention. In summary, Refill medication reminder feature for diabetic patients was improved by 22% and 10% improvement for doctor appointment reminder feature. Also, the Refill medication reminder feature for hypertension patients was improved by 30% and 22% improvement for doctor appointment reminder feature.

DISCUSSION AND CONCLUSIONS

The purpose of this study was to evaluate the effectiveness of mobile health applications to manage the behavior of diabetic and hypertension patients based on doctor appointment adherence and refill medication adherence by using mobile health applications. In addition, managing unnecessary follow-up visits for them. The three axes of this research were covered by mobile health applications and patient's hospital records. Doctor appointment reminder (DAR) and refill medication reminder (RMR) were covered by mobile health application named (DHA Tracking). The third axis was covered by the patient's hospital record and blood sugar level test (Hemoglobin A1c). The results indicated that RMR and DAR have significantly increased adherence levels for patients with diabetes and hypertension. The results also indicated that the number of unnecessary follow up visits was reduced based on patients' Hemoglobin A1c levels. This study reinforces the evidence in the literature regarding the effectiveness of using mhealth platforms to promote medication adherence for patients with diabetes and hypertension. In specific, this study agrees with the results obtained by (Alotaibi et al., 2016), in which the authors examined the effectiveness of using a mobile health application - SAED to manage and educate diabetic patients in Tabuk, Saudi Arabia. The authors found a significant decrease in the blood sugar of the participants in the intervention group. Research on the adoption of mhealth technology to provide healthcare services in Saudi Arabia is scant.

Most of these studies focused on the use of mhealth to areas such as improving healthcare services in the emergency department, improving dental care services, assisting patients with special needs, and promoting disease prevention for obese children, diabetes, and hypertension. In addition, the majority of these studies have not explored the effectiveness of mhealth in promoting adherence to patients with diabetes and hypertension. Moreover, previous studies have not examined the use of mhealth to provide health services for patients with hypertension. This study is the first study in Saudi Arabia that focused on providing and managing information to hypertensive patients by using a mobile health application. Thus, this study contributes to the body of knowledge on mhealth by in investigating the effectiveness of mhealth in increasing adherence to medication and doctor appointments for diabetic and hypertensive patients in Saudi Arabia. Despite the successful application of DHA, few limitations exist. First, the redness of the patients to use technology. Only 364 out of nearly a thousand patients interacted with DHA. Second, the lack of historical data. For instance, the refill medication process was difficult to track as no records were found in the hospitals or the primary care centers regarding the time and frequency of the refill medication process. Third, the difficulty of tracking the refill medication data for both diabetic and hypertensive patients due to the fact that some patients were taking their medication from the hospital, some were talking their medication from primary health care centers, and the others bought their medications from outside pharmacies. This was giving the team a hard time to check the hospital records and first primary care to find out if the patients adhered to refill their medication or not. Based on the results obtained in the study, a few recommendations could be noted. First, the addition of a survey or questionnaire to measure the readiness and interest of participants in to participate in future mhealth interventions. Second, increasing the scope of the study to include other areas in Saudi Arabia such as the rural areas where a large proportion of the population resides, and there is a lack the resources for efficiently providing care and treatment for patients with chronic diseases. Third, the extension of the study period could be considered in future studies. For instance, the pre-intervention period could be extended to six months or one year, while the post-intervention period could be increased to one or two years. Fourth, the addition of a diagnostic feature to the app. Controlling and managing chronic diseases, such as diabetes and hypertension are very important. However, preventing these diseases and providing awareness to the public about these diseases and their risk factors have the same importance.

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