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# Mobile health monitoring based studies for diabetes mellitus: a review

**Omar AlShorman[1], Mahmoud Saleh Masadeh[2], Buthaynah AlShorman[3]**
[1]Faculty of Engineering and AlShrouk Trading Company, Najran University, Najran, Saudi Arabia
[2]Computer Engineering Department, Yarmouk University, Irbid 21163, Jordan
[3]South Alternative Center for Physiotherapy and Rehabilitation, Najran, Saudi Arabia

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**ABSTRACT**

Diabetes as a chronic disease is considered to be a serious problem not only for diabetic patients but also for caregivers, families and countries. Hazardously, as an example, 16% of the Middle East population died every year because of diabetes as it is reported by World Health Organization (WHO). Therefore, it is crucial to utilize the recent advances and technologies to find the best instrument for diabetes monitoring and management. Recently, mobile health (mHealth) technologies have a vital role in the healthcare industrial world. Undoubtedly, mHealth technologies are used to manage, track, monitor, diagnose, and prevent chronic diseases including, diabetes. Certainly, the main advantages of mHealth include a real-time and continuous monitoring with high reliability, accessibility, and availability. In addition to that, mHealth is considered to be a fast, accurate, simple, cheap, comfortable, and safe technology. Hence, the proposed study aims to review existing mHealth studies for managing, diagnosing, tracking, detecting, and predicting diabetic mellitus. Moreover, challenges and future trends of this emerging topic are also discussed



***Corresponding Author:***

Omar AlShorman
Faculty of Engineering and AlShrouk Trading Company
Najran University
Najran, Saudi Arabia
Email: omar2007_ahu@yahoo.com

## 1. INTRODUCTION

Globally, the number of elderly people with chronic diseases are increasing [1]-[3]. Thus, managing chronic diseases, such as diabetes, is crucial to protect the health of patients and to reduce the high cost of healthcare services [4], [5]. However, according to the World Health Organization (WHO), 16% of the population in the Middle East died every year because of diabetes [6]. However, continuous and real-time monitoring for diabetic patients is crucial. Importantly, achieving good healthcare services for diabetic patients is a challenging task for patients and caregivers [7], [8].

Remote health monitoring (RHM) is defined as, using recent advances and modern technology for healthcare monitoring industries. As a part of RHM, mobile health (mHealth) is defined as, using smartphones, tablets and other digital assistant devices with communication technologies to provide medical services between patients and caregivers [9]. In addition, mHealth is also used to manage, track, monitor, diagnose, and prevent chronic diseases [10]. Importantly, the main benefits of mHealth include real-time continuous monitoring with high reliability, accessibility, and availability. Moreover, mHealth is considered to be, fast, accurate, simple, cheap, comfortable, and safe technology [11].

Recently, mHealth technologies have been extensively used for RHM for diabetic patients. Several services have been utilized, including, internet applications, short message service (SMS), and web data processing [12]. Moreover, mHealth is used to manage diabetes by managing and monitoring the dieting system, smoking, glycemic control, obesity, and physical activity [13]. Figure 1 shows the general framework of mHealth monitoring for diabetes [14].

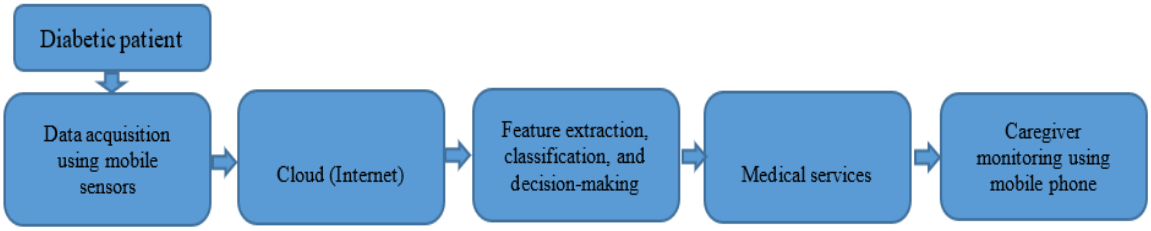


Figure 1. The framework of mhealth monitoring for diabetes

With the help of internet of things (IoT) technologies, mHealth, wirless body sensor network (WBSN), and communication generations and technologies (such as 3G, 4G, GPRS, GPS, and bluetooth) are becoming vital aspects for monitoring patients and elderlies. The proposed review study aims to highlight RHM studies for diabetic patients based on mHealth technologies. Moreover, challenges and future trends of this emerging topic are also discussed and highlighted. The rest of the paper has been organized is being as. Firstly, related works for RHM of diabetic patient's management, monitoring and tracking, as well as detecting and predicting are discussed in section 2. Challenges and possible future works are discussed in section 3.

## 2. RELATED WORK

Recently, several studies have been conducted for RHM for diabetic patients based on mHealth technologies. These studies have focused on several related topics including diabetic management and control [15], [16], diabetes prevention [17], diabetes intervention program [18], diabetes self-efficacy [19], continuous glucose monitoring [20], glycemic control improvement [21], diabetic patients treatment [22], diabetes prediction system [23], diabetes care improvement [24], continuous and remote monitoring system [25], insulin dose management [26], and carbohydrate measurement [27]. However, Tables 1, 2, and 3 show existing mHealth studies for managing, diagnosing, tracking, detecting, and predicting diabetic mellitus, respectively. In more details, Table 1 summarizes the available related studies in the literature for RHM of diabetic patient's management based on mHealth technologies. Table 2 summarizes the available related studies in the literature for RHM of diabetic patients monitoring and tracking based on mHealth technologies. Table 3 summarizes the available related studies in the literature for RHM of diabetic patients detecting and predicting based on mHealth technologies. After reviewing several related studies, it seems that this topic still in its early stages, where more extensive future work is still needed to tackle the existing research problems. Thus, evaluating the efficiency and efficacy of mHealth based diabetes monitoring needs to be investigated more by the researches.

Table 1. mHealth related literature for RHM of diabetic patients management based on mHealth technologies

| Reference | Application | Contribution | Advantages | Drawbacks |
|---|---|---|---|---|
| [28] | Diabetes management | Self-management application for diabetic patients is developed | - Free application<br>- No internet access required | - The usability has to be improved |
| [29] | Type 2 diabetes management and prevention | Short message service (SMS) technology to prevent and manage diabetes is presented | - mHealth intervention | - SMS technology for diabetes management is not efficient |
| [30] | Diabetes management | Self-reported mobile technology system is proposed | - Real time monitoring<br>- Do-it-yourself (DIY) mhealth technology | - The usability has to be improved |
| [31] | Type 1 diabetes management | The efficiency of mHealth applications for managing diabetes is evaluated | - Blood glucose control and management | - Small sample sizes |
| [32] | Cardiovascular disease and Diabetes management | Self-management application for diabetic patients is proposed | - Reducing cardiometabolic risk | - Limited age group<br>- Small sample sizes |

Table 1. mHealth related literature for RHM of diabetic patients management based on mHealth technologies (*continue*)

| Reference | Application | Contribution | Advantages | Drawbacks |
|---|---|---|---|---|
| [33] | Diabetes and obesity management | Evaluation of mHealth interventions for management diabetes and obesity is presented | - mHealth text messaging technology<br>- Glycemic control and weight reduction | - The usability has to be improved |
| [34] | Insulin management application | Evaluation of mHealth tools for diabetes management and prevention is presented | - Blood glucose meters connect remotely with mHealth applications and tools | - Patient engagement has to be assessed |
| [35] | Glycemic control improvement | Self-management application for type 2 diabetes is proposed | - SMS shows a good performance for diabetes self management | - Small sample sizes |
| [36] | Type 2 diabetes management | Blood glucose monitoring for type 2 diabetes based on mHealth and advanced technology is proposed | - Physical activity and dietting are also managed | - The usability has to be improved |
| [37] | Type 2 diabetes management | Multiple mobile health tools technology to manage type 2 diabetic patients is proposed | - Multiple mobile health technologies are proposed | - The proposed study has limited sample size |
| [38] | Type 1 diabetes management | Linkage base monitoring using mHealth technology is presented | - The usability and realibility of the proposed mHealth tool are good | - The proposed study has limited sample size |
| [39] | Mobile application for self-management | Mobile phone application for blood glucose levels monitoring is proposed and evaluated | - No significant improvement is occurred | - Related factores such as physical activity and dietting are not discussed |
| [40] | Type 1 diabetes management | Glycemic control based on mHealth is presented | - The proposed study shows good performance | - The usability has to be improved |
| [41] | Type 1 diabetes management | Mobile phone applications for glucose monitoring are evaluated and reviewed | - The proposed sudy shows an improvement of glycemic control | - The efficacy of the proposed study is not evaluate |
| [42] | Diabetes management | Self-management mobile application for blood glucose monitoring is proposed | - The proposed mHealth application shows good diagnostic accyrcy | - The efficacy of the proposed study is not evaluate |
| [43] | Diabetes self-management | Self-management application for diabetic patients is proposed | - Problem Solving is propsed in this study | - The usability has to be evaluated |
| [44] | Diabetes management system | Android phone application for diabetic patients is proposed | - The proposed study shows good performance | - The usability has to be evaluated |
| [45] | Diabetes self-management | Diabetes management and monitoring platform based on IoT and mHealth is proposed | - Advanced technologies are used to improve the efficacy of the proposed platform | - The usability has to be evaluated |
| [46] | Glycemic control management | Glycemic control management based mHealth technologies (short text messages) are presented | - SMS shows a good performance for diabetes self management | - Small sample sizes |
| [47] | Diabetes management and control program | Nutrition program based on mHealth to manage diabetes is proposed | - Nutrient intake is analyzed | - The efficacy of the proposed study is not evaluate |
| [48] | Diabetes management and control | Diabetes self-management for elderly people based on mHealth technologies are studied and evaluated | - The usability is good | - Limited age group |
| [49] | Diabetes management | The relation between blood glucose, smoking, physical activity, and cardiovascular is studied | - Related factores such as physical activity, smoking and eating are discussed | - The efficacy of the proposed study is not evaluate |
| [50] | Insulin dose management | Blood glucose management based on mHealth technologies along with count the carbohydrates (CHOs) is presented | - Carbohydrates counting mHealth application to manage diabetes | - Eating habits are not considered |
| [51] | Diabetes management | iOS applications for managing diabetes are studied and evaluated | - Advanced technologies are used to improve the efficacy of | - The usability has to be evaluated |
| [52] | Carbohydrate measurement | Glycemic control using smartphone application is presented | - Carbohydrates counting mHealth application to manage diabetes | - The usability has to be evaluated |
| [53] | Type 1 diabetes management | mHealth technology-based interventions for Type 1 diabetes is presented | - The usability is good | - Small sample sizes |

Table 1. mHealth related literature for RHM of diabetic patients management based on mHealth technologies (*continue*)

| Reference | Application | Contribution | Advantages | Drawbacks |
|---|---|---|---|---|
| [54] | Diabetes management | Diabetes self-management for elderly people in china based on mHealth technologies is proposed | - The efficacy of the proposed study is evaluate | - Limited age group |
| [55] | Diabetes management and control | Diabetes management and care improvement based on mHealth technologies are evaluated | - The efficacy of the proposed study is evaluated | - Limited age group |
| [56] | Glycemic control management | Glycemic control based on mHealth for type 1 diabetic patients is presented | - Diabetes management is improved and the efficacy of the proposed study is evaluated | - Reliability has to be improved |
| [57] | Diabetes care improvement and self-management | Mobile phone applications for glucose monitoring are evaluated | - Microvascular outcomes are improved | - Reliability has to be improved |
| [58] | mHealth self-management | Glycemic control based on text messaging program patients is presented | - Two-way SMS framework | - Small sample sizes |
| [59] | Diabetes management and control | Diabetes self-management and monitoring based on IoT and mHealth technologies is reviewed | - Advanced technologies are used to improve the efficacy of the proposed platform | - Reliability has to be improved |
| [60] | Diabetes self-efficacy | Self-management application for diabetic patients based on mHealth technology is proposed | - The efficacy of the proposed study is evaluated | - The usability has to be evaluated |
| [61] | Diabetes self-efficacy | Self-management application for diabetic patients is proposed | - The efficacy of the proposed study is evaluated | - Limited age group |
| [62] | Efficacy of mHealth for managing diabetes | Android phone applications for managing diabetic patients are summarized | - The usability and realibility are evaluated | - Related factores such as physical activity smoking, and dietting are not discussed |
| [63] | Diabetes care improvement and self-management | Diabetes self-management and care improvement based on mHealth technologies are studied and evaluated | - The efficacy of the proposed study is evaluated | - Small sample sizes |

Table 2. mHealth related literature for RHM of diabetic patients monitoring and tracking based on mHealth technologies

| Reference | Application | Contribution | Advantages | Drawbacks |
|---|---|---|---|---|
| [64] | mHealth self-monitoring | mHealth for self-monitoring and self-reported is proposed | - Diabetes prevention program based on mHealth technologies | - The proposed study has limited sample size |
| [65] | Diabetic patients remote monitoring | Utilizing internet of things (IoT) to build a system for monitoring glucose continuously, mHealth, fog and cloud computing, and blockchain is proposed | - Advanced technologies are used to improve the efficacy of the proposed system | - The usability has to be evaluated and improved |
| [66] | Continuous glucose monitoring system | Wearable contact lens and mHealth based continuous glucose monitoring is presented | - Advanced technologies are used to improve the efficacy of the proposed system with cheap price and high performance | - The usability has to be evaluated and improved |
| [67] | Continuous glucose monitoring system | mHealth framework based continuous glucose monitoring is presented | - The proposed framework is fast, cheap and accurate | - The efficacy of the proposed study has to be evaluated |
| [68] | Glucose monitoring and expert decision system | Mobile phone blood glucose monitoring is proposed and evaluated | - Advanced technologies are used to improve the efficacy of the proposed system | - The usability has to be evaluated and improved |
| [69] | Continuous glucose monitoring | Multiple daily injections based real-time continuous glucose monitoring is proposed | - The proposed continuous and remote monitoring system shows high performance with | - The usability has to be evaluated and improved |
| [70] | Foot pathology monitoring | Mobile application called "FootSnap," is developed | - A novel mHealth application for diabetic feet | - The usability has to be evaluated and improved |
| [71] | mHealth self-monitoring | A caloric-monitoring mobile application to manage type 2 diabetes is presented | - Calories counting mHealth application to manage diabetes | - Reliability has to be evaluated |

Table 2. mHealth related literature for RHM of diabetic patients monitoring and tracking based on mHealth technologies (*continue*)

| Reference | Application | Contribution | Advantages | Drawbacks |
|---|---|---|---|---|
| [72] | Remote monitoring system | Health coaching program based on mHealth is proposed | - Advanced technologies are used to improve the efficacy of the proposed system | - Reliability has to be evaluated |
| [73] | mHealth self-monitoring | Mobile phone applications for diabetes are evaluated | - The efficacy of the proposed study is evaluated | - The usability has to be evaluated |
| [74] | Continuous glucose monitoring | Hyperglycemia management based on mHealth is presented | - The realibility of Hyperglycemia management system is evaluated | - The usability has to be evaluated |
| [75] | Remote and continuous monitoring | Blood glucose level monitoring system based on mhealth, GIS, and Arduino microcontroller is proposed | - Advanced technologies are used to improve the efficacy of the proposed system | - The efficacy of the proposed study has to be evaluated |
| [76] | Continuous glucose monitoring | Smart glucose manager base on mobile application is developed | - The efficacy of the proposed study is evaluated | - Small sample sizes |
| [77] | Remote and continuous monitoring | Blood pressure monitoring mHealth application for diabetic patients is presented | - The efficacy of the proposed study is evaluated | - Small sample sizes |
| [78] | mHealth self-monitoring | Mobile phone application based self-management system for diabetes are developed and evaluated | - The efficacy of the proposed study is evaluated | - The usability has to be evaluated |
| [79] | mHealth self-monitoring | Diabetes self- monitoring based on mHealth technologies is proposed | - The realibility is evaluated | - Small sample sizes |
| [80] | Diabetes tracking system | Mobile diabetes tracking and management framework for type 1 and type 2 diabetes is presented | - The efficacy of the proposed study is evaluated | - Reliability and usability have to be evaluated |
| [81] | Diabetes tracking system | Diabetes real-time tracking and monitoring system based on advanced communication, IoT, and mHealth is proposed | - Advanced technologies are used to improve the efficacy of the proposed system | - The usability has to be evaluated |

Table 3. mHealth related literature for RHM of diabetic patients detecting and predicting based on mHealth technologies

| Reference | Application | Highlight | Advantages | Drawbacks |
|---|---|---|---|---|
| [82] | Diabetes intervention program | Diabetes prevention based on mHealth technology is proposed | - The efficacy of the proposed study is evaluated | - The usability has to be evaluated |
| [83] | Diabetic patients' treatment | Blood glucose levels monitoring using mobile applications is presented | - The realibility is evaluated | - Limited age group |
| [84] | Diabetes prediction system | Prediction model for blood glucose monitoring algorithm using mobile application is presented | - The realibility is evaluated | - The usability has to be evaluated |
| [85] | Diabetes care improvement | Mobile phone applications for diabetes are evaluated | - The efficacy of the proposed study is evaluated | - The usability has to be evaluated |
| [86] | Diabetes prevention intervention program | Diabetes prevention platform based on pedometer intervention and mHealth is presented | - Advanced technologies are used to improve the efficacy of the proposed | - Reliability and usability have to be evaluated |
| [87] | Type 1 diabetes detecting system | Diagnosing and early detection of Type 1 diabetic patients based on physical activity and mHealth is proposed | - Related factores such as physical are discussed | - Limited age group |

## 3. CHALLENGES AND FUTURE TRENDS

Achieving good healthcare services for diabetic patients is a challenging task for patients and caregivers [88], [89]. Here, we summarize the main challenges and possible future trends for mHealth based diabetes monitoring:

- The effectiveness and performance of mHealth applications for monitoring diabetes have to be evaluated further [90].
- In the development stage for mHealth application, patients' safety and privacy have to be taken in consideration as a high design priority [91].
- Advanced digital technologies should be applied for diabetes healthcare industry such as insulin delivery systems and insulin pumps [92].
- Continuous glucose monitoring systems should be investigated and evaluated further [93].
- Cost-effectiveness for diabetes healthcare industry should be extensively evaluated [94]

- Related factors with diabetics such as age, gender, pregnancy, physical inactivity, sleep, smoking, dieting system, and obesity should be investigated [95]-[97]
- Diversity of multiple devices and protocols represents a serious challenge to be addressed [98]
- User acceptability and usability, e.g., lack of patient experience on using advanced technologies is one of the main challenges [99].
- Advanced technologies such as IoT, big data analytics, neuro-fuzzy, and advanced signal and image processing should be used to develop mHelath based applications for diabetes [100]-[106].

## 4. CONCLUSION

In this era, elderly and patients with chronic health conditions, such as diabetes, require special and continous healthcare services. However, remote health monitoring (RHM) helps patients, caregivers, and healthcare society to improve healthcare services by benefiting from recent advanced technologies. Importantly, achieving good healthcare services for diabetic patients is still a challenging task. The proposed study aims to review RHM for diabetic patients based on mHealth technologies, including, diabetic management and control, diabetes prevention, diabetes intervention program, diabetes self-efficacy, continuous glucose monitoring, glycemic control improvement, diabetic patients treatment, diabetes prediction system, diabetes care improvement, continuous and remote monitoring system, insulin dose management, and carbohydrate measurement. Some of the main challenges and future trends facing this technology are also discussed. Notably, the proposed study can be considered as a report for researchers in this regard.

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