Assessment of remote patient monitoring (RPM) systems for patients with type 2 diabetes: a systematic review and meta-analysis

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Abstract

Introduction The objective of this study is to conduct an assessment of Remote Patient Monitoring (RPM) systems compared to usual care for controlling glycosylated hemoglobin in type 2 diabetes.

Methods The study was a systematic review with meta-analysis and meta-regression. A systematic search was performed via the most important electronic databases of medical resources, such as PubMed, Scopus and Cochrane library. The main outcome was HbA1C. The heterogeneity sources were examined using Chi-square (Q) and I² tests. Meta-analyses were done using Stata version 11 software. Statistical significance was defined as $P < 0.05$. Random effects model was used in meta-analysis, and the heterogeneity more than 50% was considered as significant.

Results The results of the systematic review and meta-analysis indicated that the effect size index (Difference of Pre-test/Post-test Control Design-2nd method “using pooled pretest SD” (DPPC2)) among users of RPM for type 2 diabetic patients was -0.32 with a confidence interval of 95% (from -0.45 to -0.19) as compared to the control group. The current study declared a vital role of RPM technology in reduction of hemoglobin glycogen levels. The results of the subgroup analysis showed that RPM is more effective for patients who are residents of cities, having intervention lengths less than 6 months, getting the orders from the physician and using the websites as their intervention type.

Conclusion The current study indicted the efficacy of RPM in reducing HbA1c among type 2 diabetic patients, which could be a base for policymakers to decide on the introduction of this technology in Iran.

Keywords Remote monitoring · Glycosylated hemoglobin · Type 2 diabetes · Systematic review · Meta-analysis

Introduction

Diabetes is a common chronic disease, causing unprecedented loss of health care systems around the world [1]. Currently, diabetes is the seventh leading cause of death in America and the fourth cause of visiting a physician in Western communities [2, 3]. The diabetes outbreak has increased dramatically over

the past two decades and it is estimated to increase to over 438 million by 2030 [4]. The number of diabetic people in Iran shows an outbreak of 9.3%, and is expected to reach 13.1% in 2030 [5]. Diabetes is associated with different other diseases such as retinopathy, neuropathy, cardiovascular and cerebrovascular diseases. The treatment of diabetes needs long time, moreover, the probability for treatment success is low, and it is

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expensive compared to other diseases. Considering the age and gender, the costs of diabetic patients is, on average, 20.3 times higher than the cost of other patients [3, 6].

Residents of villages, rural and remote areas are deprived of access to specialists and appropriate services in the service units. Factors such as geographical conditions, time, physical disabilities, and financial problems prevent their timely admission to specialized units in the city, which leads to injustice and imposition of costs on the health system [7]. Through digital technologies of RPM, the distances are eliminated. Health data is collected in places like the patient's home, and sent to health care providers in different places for evaluation and getting recommendations through telecommunication lines, bringing about the analyses of physiological parameters such as blood pressure, weight, blood glucose, counseling, training, and early diagnosis [8, 9].

Patient information is constantly monitored by healthcare provider and in case of emergency, the patients are quickly supported, and instant warnings are sent to the service provider and patient companions whenever needed; thus, the patients and their family have no worries about the problem [10].

Evidence indicates that using RPM technology reduces the number of visits to the emergency ward, hospitalization and length of hospital stay. Thus, this technology is a good solution to prevent diseases, reduce health care costs, provide adequate access to services, reduce adverse events, and encourage innovative programs. With RPM technologies the allocated resources are used with high productivity [10–13], which significantly increases people's quality of life [13].

Like other medical services, these services have acceptable precision and the confidentiality of patient information is taken into account [9]. Therefore, RPM can bring about more satisfaction along with being more cost-effective compared to other approaches [14].

In chronic diseases, the patient's condition heavily relies on his collaboration and ability to follow long-term recommendations of the physician. Patient education is critical for disease management [15]. The time saved because of RPM technology enhances efficiency and allows health care providers to devote more time to distance education and communication with the patient [16].

Given the interaction between the care system and the patient, RPM technology enhances diabetes treatment and increases the physicians' ability to monitor and control patients in the health system. Thus, with 1% reduction in HbA1c levels, type 2 diabetic patients suffer cataracts 19% less than others, the risk of heart failure reduces by 16%, the likelihood of amputation or death from peripheral artery diseases reduces up to 43%, and overallly the risk of diabetic retinopathy, neuropathy, and nephropathy decreases by up to 25% [17, 18].

RPM technology has created sustainable growth in the North American (USA, Canada and Mexico),

European (Germany, France, England, Italy, Spain, and Russia), Asia-Pacific (Japan, China, India, Australia, South Korea and Taiwan) and LAMEA markets (Brazil, Turkey, Venezuela, Saudi Arabia and South Africa) [19].

Researchers estimate that the number of patients controlled through telemedicine will reach 50.2 million over the next four years, of whom 25.2 million will be using RPM technology, and its use will increase by 38% from 2016 to 2022 [20–23].

Hence, this research was conducted to assess the remote monitoring of type 2 diabetic patients in the primary care system, in terms of safety and effectiveness via gathering relevant evidence. The subgroups analysis which was held in this research can guide health care policy makers to make proper decisions on the implementation of RPM in the health systems.

Methods

This was a systematic review with meta-analysis and meta-regression which was performed by robust stages as follows; *) determining the PICO (population, intervention, comparison and outcomes); *) designing the relevant search strategies; *) defining the inclusion and exclusion criteria; *) performing the quality assessment of included studies; *) performing data extraction; and *) Data analysis and determining the effect size.

- Determining the PICO (population, intervention, comparison and outcomes)

– Participants

The population of type 2 diabetic patients.

– Intervention (s)

A smartphone or a personal digital assistant (PDA) device (software, applications, or related text message) used to transmit patient information to a physician; Any wearable device placed on one part of the body to record specific physiological changes; Any biosensor device that uses biological or chemical reactions to record data; Websites and computer software where the data is transmitted to the physician by the patient; Or a combination of these interventions provided that communication platform or communication network is used to send the data to the physician.

– Comparison (s)

Comparison with other routine programs (standards outpatient care).

– Outcomes (s)

HbA1c.

• Search strategy

The search was performed systematically until July 25, 2018 in the most important electronic databases of medical resources, such as PubMed, Scopus and Cochrane, as well as IEEE. Moreover, to increase the coverage and search sensitivity and to reach the highest number of studies. In addition to the cognitive databases mentioned above, Google and

Google Scholar were used through search engine sensitivity maneuvers, such as reference tracking of the related studies. Moreover, in some cases, tracking the exact phrase was used to access the full text from Medline and Science Direct. Separate and appropriate search strategies were used and examined independently by two authors for each database and the disputes were resolved through discussion and in the event of disagreement by the third party. Preferred reporting items for systematic reviews and meta-analysis (PRISMA) principles have been used [24].

• Inclusion and exclusion criteria

The study had no limitations on the timeline and type of study language. Various studies such as randomized

Fig. 1 Screening flowchart of the studies according to PRISMA standard

Table 1 The characteristics of the included studies

Characteristics Studies	Country	Participants	Age range (years)	Follow-up time (months)	Type of intervention	Provider	Study location	Duration of diabetes (years)	Lost to follow- up	Study quality score
Hyuk-Sang Kwon, 2004	South Korea	101	≥30	3	Website / internet	Physician	City	6.8	9	3
Jae-Hyoung Cho, 2006	South Korea	80	≥30	30	Website / internet	Physician	City	6.8	9	5
Steven Shea, 2006	America	1665	≥55	12	Website / internet	Nurse	Remote areas / village	11.1	306	3
H. J. Yoo, 2009	South Korea	123	30–70	3	Glucometer and automatic transmission via the Internet	Physician	Unknown	6.6		3
Hugh D. Tildesley, 2010	Canada	47	Not mentioned	6	Website / internet	Physician	City	18.8	12	3
Maria Magdalena Bujnowska-Fedak, 2010	Poland	95	18–75	6	Glucometer and automatic transmission via the Internet	Physician	Unknown	7.9	3	2
Ernest L Carter, 2011	America	47	≥40	9	Website / internet	Physician	City	Unknown	5	3
Jae-Hyoung Cho, 2011	South Korea	71	≥40	3	Mobile / PDA	Physician	Remote areas / village	8.9	27	3
Charlene C. Quinn, 2011	America	140	18–64	12	Mobile / PDA	Physician	Unknown	8.6	7	6
Paul C Tang, 2013	America	415	≥18	12	Glucometer and automatic transmission via the Internet	Nurse	Unknown	Unknown	24	6
Robert S.H. Istepanian, 2014	Iraq	12	Not mentioned	6	Glucometer and automatic transmission via the Internet	Nurse/ Physician	City	10.2	28	3
Adam Steventon, 2014	England	513	≥18	12	Glucometer and automatic transmission via the Internet	Nurse	Unknown	Unknown	0	5
Bonnie J. Wakefield, 2014	Canada	94	≥18	3	Glucometer and automatic transmission via the Internet	Nurse	Unknown	Unknown	0	3
Stelios Fountoulakis, 2015	Australia	80	18–86	6	Glucometer and automatic transmission via the Internet	Physician	Remote areas / village	Unknown	24	5
Deborah A Greenwood, 2015	Canada	81	30–70	6	Glucometer and automatic transmission via the Internet	Nurse	Unknown	8.2	10	3
Antonio Nicolucci, 2015	Italy	302	> 45	12	Glucometer and automatic transmission via the Internet	Physician	Unknown	8.5		3
Mohammed M. Alotaibi, 2016	Saudi Arabia	20	20–65	6	Glucometer and automatic transmission via the Internet	Physician	City	5.9	0	3
Maria Cecilia Anzaldo-Cam, 2016	Mexico	202	18–75	10	Glucometer and automatic transmission via the Internet	Nurse	City	8.3	0	4
Heidi Holmen, 2016	Norway	81	≥18	12	Glucometer and automatic transmission via the Internet	Nurse	Unknown	9.5	21	4
Hun-Sung Kim, 2016	China	182	≥18	6	Glucometer and automatic transmission via the Internet	Nurse	City	Unknown	19	5
Jae Hyoung Cho, 2017	South Korea	484	Average age 74	6	Glucometer and automatic transmission via the Internet	Nurse	City	Unknown	0	4
Claudio Dario, 2017	Italy	299	Average age 73	12	Glucometer and automatic transmission via the Internet	Physician	Unknown	Unknown	0	3
Nora J. Kleinman, 2017	India	90	18–65	6	Mobile / PDA	Physician	City	9.25	28	6
Robin Warre, 2017	Australia	126	≥18	6	Mobile / PDA	Nurse	City	Unknown	22	5

controlled trials, cohort, and case-control studies were examined and the studies such as technical reports, case reports, or letters were excluded.

The studies which had follow up duration less than 3 months were excluded. Non-digital technologies, such as landline phones, and devices that record only clinical outcomes and do not transfer them to the physician, and the studies not examining our defined comparison and outcome, or health plans targeting only specialists or those healthy people who want to prevent diabetes were excluded. Studies that examined other unrelated diseases and diabetes in pregnant women were excluded as well.

The studies examining a multitude of types 1 and 2 patients, but whose outcomes are not stated separately were excluded from this study. Studies not receiving feedback from the service provider or having feedback as a predefined algorithm were also excluded from our study. Interventions with one-way communication, such as the SMS service used to send text messages containing reminders, training or motivations for the patient participation in self-care without scrolling through the patient information, were excluded from the study. Studies monitoring real-time intervention and provided feedback, as well as non-real time were included. Studies with only title or abstract available, where the full text was not available, were excluded.

- The quality assessment of included studies

The quality assessment of the studies was done independently by two researchers, and the disagreements were resolved by negotiation or consulting the third person. The quality of the studies was examined by using the criteria described by the Cochrane tool. For the quality of selected studies, various features were considered for risk assessment in each study: including selection bias, performance bias, diagnosis bias, sample loss bias, and reporting bias.

- Data extraction

Data extraction form was designed based on the information contained in the included studies and the information needed according to the previous studies related to the topic. Firstly, the information of several studies was extracted in the pilot form. Then the defects of the form were eliminated and a final form was designed. The extracted data were the characteristics of the study (design, length and duration of the follow up study), the attributes of the participants (age, gender, and number of patients), the definition of the intervention and the outcomes measured. Thus, the two researchers individually did this on a specific format and discussed the differences, and a third party was consulted in case of disagreement. For the studies not providing enough information about design or results in the text of the paper, the author was contacted to obtain the necessary information.

- Data analysis and determining the effect size

The mean and standard deviation of the studies were extracted according to the principle of maximum subscription. If the mean or standard deviation was not reported, the authors were contacted and, if not available, the data available, such as the median, intermediate quartile domain, *P* value, and confidence interval were used for calculating these values according to the method recommended in Cochrane Handbook 5.1.021. As the data obtained in both the intervention and control groups are pre and post type, DPPC2 effect size index was used to calculate them. If its value is from 0 and 0.2, it shows a negligible relation, from 0.2 to 0.49, a small relation, from 0.5 to 0.79 a moderate relation and more than 0.8 a strong correlation [25].

$$d_{ppc2} = C_p \left[\frac{(M_{post,T} - M_{pre,T}) - (M_{post,C} - M_{pre,C})}{SD_{pre}} \right]$$

$$SD_{pre} = \sqrt{\frac{(n_T - 1)SD_{pre,T}^2 + (n_C - 1)SD_{pre,C}^2}{n_T + n_C - 2}}$$

$$C_p = 1 - \frac{3}{4(n_T + n_C - 2) - 1}$$

Fig. 2 The risk of bias using Cochrane criteria

Meta-analyses were done using Stata 11 software. Statistical significance was defined as $P < 0.05$. Random effects model was used in meta-analysis, and the heterogeneity more than 50% was considered as significant (according to the Cochrane handbook assigns values greater than 50% to “substantial” heterogeneity).

Forest Plot was used to graphically show the effect size of each study with 95% confidence interval and total effect estimation. The data were analyzed using a random effect model for DPPC2 index for conservative estimation of the care effect through RPM to reduce glycated hemoglobin in type 2 diabetic patients compared to routine treatment, considering any heterogeneity between studies.

– Heterogeneity and analysis of subgroups

The heterogeneity sources were examined using Chi-square (Q) and I^2 tests. Moreover, I^2 can slightly determine the heterogeneity. When this parameter is more than 50%, it shows a significant disparity between the results of the studies. Also, a subgroup analysis was conducted to answer the following two questions:

How much do the variable/variables used in the model justify heterogeneity?

How much do the variable/variables used in the model justify the difference effect size?

Some potentially heterogeneous factors were analyzed using meta-regression. This was done by placing the variables related to the details of the study (e.g., drop-outs during the study, the treatment status of the participants before the study, the type of intervention, the duration of the internment, and so on).

– Sensitivity analysis and publication bias

Sensitivity analysis was done using Jackknife method to identify the factor or factors affecting the result of meta-analysis that potentially could show the most significant effects on DPPC2 index. A funnel plot along Begg’s correlation ranking tests were used to show the evidence of publication bias. When Begg’s test is significant ($P < 0.05$), the publication bias is significant and cannot be ignored; otherwise, publication bias is negligible.

Results

Identification of relevant studies

Overall, 8683 studies were identified. After removing duplicates, 6724 studies were remained, which were reviewed according to title, abstract, and full text. A total of 180 studies were eligible for a full text review, after checking these studies

with inclusion/exclusion criteria, 24 studies were eligible to be included in the final stage. Two more studies were excluded from entering the meta-analysis phase because of failing to convert their outcome index to the standard deviation. The PRISMA Flow Diagram was used to show the process of selecting eligible studies (Fig. 1).

Fig. 3 Summary of the bias characteristics

Characteristics of the included studies

All the studies are randomized controlled trials. The time scope of these studies was from 2004 to 2018. Both men and women were included in the studies. The age group was 18 years old and older. The number of follow-up months varied from at least 3 months to 30 months. In 4 studies, type 2 diabetic patients used data transfer on website / internet to transfer their data [26–29], in 4 other studies via mobile / PDA [29–32] and in 14 other studies a glucometer is used that automatically sends information to the service provider via the Internet [33–38]. The mean BMI of the control group was 28.58 (SD: 3.58), and the mean BMI of the intervention group was 28.84 (SD: 3.80). The studies included in the meta-analysis are done in countries such as Australia (2 studies), Canada (2 studies), China (1 study), UK (1 study), India (1 study), Iraq (1 study), Italy (2 studies), Saudi Arabia (1 study), Mexico (1 study), Norway (1 study), Poland (1 study), the United States (3 studies) and South Korea (5 studies). The studies involved 4684 participants, with the most participants in Steven Shea et al. [28] (1355 participants), and the least in Robert S.H. Istepanian et al. [35] (12 participants), of whom 2403 were under remote HbA1c control. In the intervention group, the incidence of HbA1c at baseline was from 7.2 to 11.19% and at the end of the study from 6.7 to 8.19%. In the control group,

HbA1c level was from 7.19 to 10.9% and from 7.17 to 9.56% at the beginning and end of the study, respectively (Table 1).

The quality assessment of included studies

The quality of the included studies was scored by two authors independently, and the disagreements were resolved by negotiation or consulting the third person. The results of the methodology quality were computed using the Cochrane-based tool to evaluate the risk of bias. For the quality of selected studies, various features were considered for risk assessment in each study: including selection bias, performance bias, diagnosis bias, sample loss bias, and reporting bias. Each item has a certain score. 3 studies earned 6 points, 5 studies 5-points, 3 studies 4 points, 10 studies 3 points, and 1 study 2. for this assessment Revman 5.3 was used (Figs. 2 and 3).

Adverse events

The unwanted events with poor performance and the adverse events of using RPM for type 2 diabetic patients were examined. Although no evidence of this was found in the initial study, it seems that the technology safety issue is not relevant to this health intervention.

Fig. 4 Estimation of meta-analysis to determine the overall effectiveness of RPM technology

Table 2 Determining the effect of lost to follow-up on the effectiveness of RPM technology

Meta-regression					Number of obs = 22	
REML estimate of between-study variance					tau2 = .03086	
% residual variation due to heterogeneity					I-squared_res = 27.34%	
Proportion of between-study variance explained with Knapp-Hartung modification					Adj R-squared = 7.64%	
DPPC2	Coef.	Std. Err	t	P > t	[95% Conf. Interval]	
lost_follo p	.0009432	.0006974	1.35	0.191	-.0005116	.002398
_cons	-.3702228	.0743974	-4.8	0.000	-.525413	-.2150325

RPM overall effectiveness

For meta-analysis of the effectiveness of RPM for type 2 diabetic patients, twenty-two studies were reviewed. Since the studies used were from different communities and the variance between the studies was high, random effect model was used. Chi-square test was used to examine the existence of heterogeneity between the studies, and I^2 index for their heterogeneity. Chi-square index became significant with a value of 0.048, showing heterogeneity and I^2 index was 36.0%.

Meta-analysis results of the effectiveness of RPM for type 2 diabetic patients showed that, compared to routine therapy, its DPPC2 index was -0.32 with a confidence interval of 95% (from -0.19 to -0.45). This outcome revealed that RPM technology showed a small relationship with reducing glycosylated hemoglobin compared with routine treatment, and this relationship is significant ($P = 0.048$). The forest plot is presented in Fig. 4 to demonstrate the size of the effect and the intervals of confidence for all studies.

Then the subgroup analysis was performed to answer the following two questions.

How much do the variable/variables used in the model justify heterogeneity?

How much do the variable/variables used in the model justify the difference in the effect size (ES)?

The type of interventions (RPM types)

According to DPPC2 index calculated, the intervention performed on the website or the Internet has a moderate relation

with the decrease of glycosylated hemoglobin levels (95% CI = -1.16 - -0.04, DPPC2 = -0.60). Two other interventions showed a weak correlation in the decrease of glycosylated hemoglobin levels. In other words, the studies where the patient does not interfere with sending (95% CI = -0.41 -0.13, DPPC2 = -0.27), compared to the one where the patient enters input information manually (95% CI = -0.75 -0.13, DPPC2 = -0.45), reported a weaker correlation with glycosylated hemoglobin in terms of available evidence.

The geographical type (rural and urban)

The results indicated that the people in the city using RPM technology had a moderate effect on the decrease of glycosylated hemoglobin (95% CI = -0.67 -0.33, DPPC2 = -0.50), whereas this ratio was not significant for the villagers (95% CI = -0.28 -0.03, DPPC2 = -0.12).

The duration of the intervention

The results indicated that the studies whose duration of intervention was less than six months (95% CI = -0.59 -0.26, DPPC2 = -0.42), compared to studies with a duration of intervention more than six months (95% CI = -0.38 -0.06, DPPC2 = -0.22), had a greater effect on reducing their glycosylated hemoglobin levels. This means that the longer the use of RPM technology, according to DPPC2 index, the less effect it will have on reducing glycosylated hemoglobin.

Fig. 5 Determining the effect of lost to follow-up on the effectiveness of RPM technology

Fig. 6 Funnel diagram for the study of publication bias

The type of providers

The results showed that in the patients under the supervision of remote nurses, PRM has a weak effect on their glycosylated hemoglobin (95% CI = -0.35 -0.07 , DPPC2 = -0.21). However, in diabetic patients monitored remotely who were getting orders from physicians, this technology has a moderate effect on reducing their glycosylated hemoglobin (95% CI = -0.67 -0.27 , DPPC2 = -0.47).

The treatment status of patients before receiving the intervention

The results showed that patients who had a poor treatment before the intervention justify a higher heterogeneity (21.2%) compared to those with a good treatment status (49.3%) before intervention. The patient's treatment status before the intervention could not ultimately justify the difference in our DPPC2 index.

Because some of our studies were large in sample size and took a long time to investigate, the lost to follow up variable was used to investigate the source of heterogeneity. As lost to follow-up of individuals was a quantitative variable, by conducting a meta-regression to measure the effect of lost to follow-up on DPPC2 index value, it can be concluded that the more the number of people dropped during the study remote patient monitoring technology shows a lower and poorer outcome on HbA1c reduction for type 2 diabetic patients (Table 2, Fig. 5).

The difference between ES index and heterogeneity (heterogeneity of low quality studies = 43.9%, heterogeneity of high quality studies = 27.1%) is not justified Fig. 5.

Risk of bias

To avoid publication bias, initially a preventive approach was used and the search was performed in several databases. Language restrictions weren't applied. The studies were not

based on the number of citations, and gray literatures were also explored. Then, the funnel plot and Begg method were used to demonstrate that the publication bias was insignificant and negligible (Fig. 6 and Table 3).

Sensitivity analysis

Sensitivity analysis of jackknife method was used to examine the effect of bias. According to the results, after jackknife method, our overall composition varied from -0.28 to -0.35 , and our overall effect index was -0.32 . Therefore, our studies are very similar and they don't have any particular effect (Fig. 7 and Table 4).

Discussion

This study provides evidence on the efficacy and safety of a variety of screening strategies for patients with type 2 diabetes to improve glycemic control in these patients. In spite of the homogeneity of the studies, based on the available evidence, our overall monitoring interventions showed little effect on HbA1c reduction compared to usual care, with a mean difference of -0.41 with 95% CI (-0.28 to -0.54). An investigation

Table 3 Estimation of the Begg's order to examine the publication bias

Begg's Test						
adj. Kendall's Score (P-Q) = -53						
Std. Dev. of Score = 35.46						
Number of Studies = 22						
z = -1.49						
Pr> z = 0.135						
z = 1.47 (continuity corrected)						
Pr> z = 0.143 (continuity corrected)						
Egger's test						
Std_Eff	coef.	Std. Err.	t	P> t	[95% conf. Interval]	
slope	.0040702	.0906445	0.04	0.965	-.185011	.1931514
bias	-1.398875	.4339647	-3.22	0.004	-2.30411	-.4936407

Fig. 7 Sensitivity analysis

on other systematic review studies showed that long-term patient monitoring is consistent with improved care. A systematic review of Yun-kai Zhai showed that HbA1c decreased after intervention compared to routine treatment (pooled difference

in means = -0.37 , 95% CI = -0.49 to -0.25 , $Z = .086.08$, $P < 0.001$) [39]. Another study showed a moderate but significant decrease in HbA1c levels ($\sim 0.5\%$ decrease) in favor of monitoring diabetes mellitus compared to routine care for

Table 4 Sensitivity analysis

Egger's test						
Std_Eff	coef.	Std. Err.	t	P> t	[95% conf. Interval]	
slope	.0040702	.0906445	0.04	0.965	-.185011	.1931514
bias	-1.398875	.4339647	-3.22	0.004	-2.30411	-.4936407
metaninf DPPC2 SE_DPPC2, random label (namevar = Author, yearvar = year).						
Study omitted	Estimate	[95% conf. Interval]				
Kwon [24]	-.28161585	-.39887568	-.16435601			
Cho [25]	-.31027916	-.43823326	-.182325507			
Steven Shea [26]	-.35090238	-.48391131	-.21789345			
Tildesley [27]	-.30773848	-.43343836	-.18203862			
Bujnowska-Fedak [31]	-.33396533	-.46554622	-.20238446			
Cho et al. [25]	-.3248333	-.45637357	-.19329304			
Quinn et al. [28]	-.30408099	-.4309808	-.17718118			
Tang et al. [32]	-.34287879	-.47846216	-.20729543			
Istepanian et al. [33]	-.32351565	-.45317101	-.19386028			
Steventon et al. [34]	-.34698534	-.48480478	-.20916589			
Wakefield et al. [35]	-.33541405	-.46640348	-.2044246			
Fountoulakis et al. [36]	-.31505617	-.44412446	-.18598789			
Antonio Nicolucci [40]	-.32754862	-.46379787	-.19129935			
Mohammed M. Alotaibi [41]	-.31916279	-.44795024	-.19037533			
Maria Cecelia Anzaldo-Cam [42]	-.29098266	-.4144209	-.16754442			
Heidi Holmen [43]	-.33522826	-.46504945	-.20540707			
Hun-Sung Kim [44]	-.30117613	-.42817339	-.17417887			
Jae Hyoung Cho [45]	-.33543101	-.47490808	-.19595392			
Claudio Dario [46]	-.34264359	-.47392115	-.21136603			
Nora J. Kleinman [29]	-.31995007	-.45036253	-.18953758			
Warren et al. [30]	-.32610896	-.45934513	-.19287284			
Yoo et al. [11]	-.29612824	-.42030358	-.1719529			
Combined	-.32122782	-.44833221	-.19412343			

adults with type 2 diabetes. Subgroup analysis revealed some interesting findings. Interventions via the Web or the Internet (mean difference (MD) 0.53- with 95% CI between -0.18 to -0.89) compared to the other two interventions (mobile or PDA and biosensor device) have a greater effect on reducing HbA1c. In their study, Spyros Kitsiou et al. concluded that m-health interventions improved HbA1c on average compared to standard care or other non-m-health approaches. In short term (≤ 12 months), The decrease in HbA1c was 0.8% in patients with type 2 diabetes and 0.3% in patients with type 1 diabetes [47]. Subgroup analysis according to the prescriber indicated that patients who are remotely supervised by physicians were more likely to have lower glycosylated hemoglobin (MD = -0.47 with 95% CI (-0.68 to -0.27)). It is more likely for patients to trust doctors' recommendations and pay better attention to advice from health professionals. The greatest potential and capability of remote patient monitoring is to assist people who cannot move to existing treatment clinics due to geographical constraints or resources, however, a subgroup analysis with geographic location showed that people in the city use monitoring technology. Patients using telehealth had a greater decrease in glycated hemoglobin than those living in the village (MD = -0.63 with 95% CI (-0.35 to -0.90)). It may be assumed that people living in the city have more access to and desire for new technologies and they are more familiar with them.

According to the results, the impact of hyperglycemia control programs may decrease over time, thus the duration of intervention may be another factor in the success of long-term patient monitoring programs. Patients with type 2 diabetes lose their flexibility and readiness to change behavior over time, which has been confirmed by many behavior change models and theories such as the belief model or the health belief model [48, 49].

Sample size is an important variable in empirical studies which enhances the internal validity of the studies; however, there may be a greater decrease in these studies compared to studies with fewer but more accessible participants [49].

In addition, studies have been conducted in different areas with different strategies of remote monitoring of type 2 diabetic patients, and the differences in results can be attributed to different reasons. For example, cultural factors may affect the implementation process and therefore affect the results.

Conclusion

Current evidence suggests that telehealth is effective in controlling HbA1c levels in people living with type 2 diabetes. Among all the strategies implemented for RPM; RPM by website was more effective. Future studies should prepare more evidence for long-term RPM experiences. Meta-analysis in the study showed that RPM for type 2 diabetic patients is effective in reducing HbA1c, which can be the base

for policymakers for decision-making on the introduction and implementation of this technology in Iran.

Limitations

The study had some important limitations that should be stated. Firstly, as in various studies, routine treatment is done by different individuals such as internal medicine specialist, endocrine specialist, primary care physician, or usual provider. All of these studies were included in the current meta-analysis. Secondly, lack of long-term follow-up may result in not examining long-term outcomes such as mortality. Another limitation was that raw data for two studies were not available.

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