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Determining the Effectiveness of a Telehealth Strategy as a Self-Management Education Tool on Adult Patients with Type 2 Diabetes Mellitus to Manage Their Glucose Level: An Integrative Literature Review

Jamal Mohammed Hamzi*
Primary Health Care Nursing Specialist, Directorate General of Health Affairs ،Jazan 82723, Saudi Arabia, KSA

Original Research Article

***Corresponding author**
Jamal Mohammed Hamzi

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Abstract: Telehealth is increasingly used to manage many long-term conditions including ones which affect physical and mental health. The range of methods of delivering telehealth is increasing as technology, and the internet, develop and become increasingly ubiquitous. The various means of delivering telehealth includes the use of computers, smart phones, mobile phones and landlines. As the means of communicating remotely increase, so do the range of ways in which telehealth can be used to both monitor long-term conditions and aid in the delivery of self-care. This paper reviews various applications of telehealth as they are applied to the management of type II diabetes. It examines the role of the different forms of technology in monitoring the disease remotely, in prompting episodes of self-care and in the delivery of proactive education. The review identifies sixteen randomised controlled trials which all use telehealth, in at least one of its forms, to deliver monitoring, disease management prompts and proactive education (or any combination of the three) remotely. The quality of the evidence uncovered is variable, with the long-term utility of many of the approaches remaining largely unproven because of the time limited nature of the research available. The least equivocal findings are from the studies which take a three pronged approach to the delivery of telehealth – monitoring, prompting and educating – which all showed measurable benefit in terms of the management of blood glucose levels. This improvement also held true for the studies which employed both monitoring and real time disease management prompts alone. The evidence suggests therefore, that attempts to use telehealth to improve the management of type II need to include, at the very least, an element of remote monitoring and real-time disease management prompts. Whether the benefits which accrue from these approaches have any long-term value needs to be further researched.
Keywords: Telehealth, diabetes, remote monitoring, education, self-care, blood glucose, HbA1c.

INTRODUCTION

Diabetes mellitus (DM) is a condition that is slowly becoming a worldwide issue within the public health sector, particularly in developed countries. Statistically, it is estimated that more than 425 million adults globally have diabetes, and one in two adults with diabetes remains undiagnosed (212 million), representing almost 9.1% of the world's adult population. This number is projected to rise by more than 50% to 642 million people by the end of 2040 [1]. The disease, which is a distinct cluster of several other metabolic syndromes, attack the proper functioning of bodily organs that regulate blood sugar levels (BSL). Diabetes represents an implausible number of precipitated deaths among those who have the disease [2]. Roughly, 90% to 95% of people with DM suffers from type II diabetes mellitus (DMII), which is recognised worldwide as a major cause of premature death and a high risk of complications such as nephropathy, cardiovascular disease, and retinopathy [3].

Healthy coping, healthy eating, problem-solving, being active, reducing risks, and monitoring are necessary self- management skills that require being established and supported [4]. To maintain and achieve blood glucose level (BGL) in the normal range, diabetic people need to be engaged in a multifaceted system that requires monitoring, checking and decision-making to support well-being [5]. Luckily, with properly informed methods, education, and equipment, together with time-to-time supervision by an approved medical practitioner, the chronic nature of DM can be controlled to levels that will negate the likelihood of early death [6]. In this way, common complications that arise as a result of this disease, e.g., heart disease, nephropathy and partial blindness may be reduced [3]. Many researchers and analysts have concluded that DM is an enduring condition that requires thorough self-

monitoring. Therefore, the key technique suitable for realising a world where there is a systematic decrease in the number of deaths caused by DM is by educating those with DMII on self-management, so that additional self-care can minimise the risk of death due to diabetes complications [7, 8]. Moreover, such interventions can promote health outcomes and decrease healthcare costs [9]. It is not clear how best to encourage patients in developing such skills, and uptake of diabetes self-management education (DSME) remains low. However, Diabetic Self-management (DSM) is therefore considered as one of the most vital skills that DMII patients need to gain.

The introduction of self-monitoring, self-management, telemonitoring, and telehealth has stimulated a need for incorporating information and communication technology to ensure delivery of positive-impact healthcare. It has also devised better interventions that will ensure application of self-care skills for DMII patients [10]. It is also led to the improvement and implementation of several telemedicine strategies and programmes that help to improve self-care. A lack of studies investigating regarding the DSM has caused uncertainty in determining the best ways to provide adequate training for developing these skills among DMII patients. For example, a self-monitoring training seminar was conducted in England in 2014, and approximately 80% of diabetic patients were encouraged to attend. Surprisingly, among 80% of these patients, only roughly 5.1% attended the self-monitoring training [11]. These absences could be associated with many reasons such as the dominant model of structured education, which is group-based sessions, lasting a half or a whole day or spread over regular sessions over several weeks. Patients, such as those who are uncomfortable in groups, those who work or those with caring commitments, may find it challenging to attend [11, 12].

Telehealth (or its specific types) support for DSM could address some of these difficulties, especially in high-income countries, where levels of technology access are high. It has been rapidly developing and expanding due to the ability to reduce costs, enhance access to care, and improve participant satisfaction with care [13]. Telehealth is a group of methods designed to enhance health care, support long-distance clinical health care, professional health-related education, public health, and health administration through use of information and communication technology (ICT) [14]. Web-based interventions carry with it several benefits including privacy, as it maintains personal privacy. Telehealth also provides regular updates on additional information regarding the process of self-management which is necessary for the improvement of the health outcomes [15]. Though studies have shown that telehealth intervention strategies present a major likelihood of improving the well-being of a patient with DMII, there are valid concerns attached to this process, e.g., the difficulty of conducting regular check-ups. This is because most computer-based interventions have trial packages that employ short intervals for checking up on a patient, thereby directly affecting the determination of the patient's ability to self-manage [16]. Thus, patients with DMII need to maintain self-management, even though they often struggle to do so. Management of DMII involves keeping a record of prescribed medication, blood pressure (PB), and BGL. The health sector has embraced the use of innovative technology to communicate and educate patients with the aim of improving diabetes management.

Application of Telehealth in Health care

Telehealth is recommended as a tool for aiding healthcare providers to disseminate education to patients. Healthcare professionals focus on promoting self-care habits and have a better platform for frequently monitoring patients using telehealth. According to Zhai, Zhu, Cai, Sun and Zhao [17], the Veterans Health Administration (VHA) has been focusing on telehealth technology in an attempt to incorporate it as tool in management strategies for ensuring the provisioning of accurate intervention on time. Application devices like monitoring and messaging devices (MMDs) have also been put to use in clinical centres. These devices facilitate communication between the patient and the hospital, and in the provisioning of facilities for education of self-management. The utilization of such intervention to remotely instruct, mentor, and screen has been appeared to diminish subjective decrease, mortality, glucose level and medicinal services costs, and may build information and enhance adherence and self-viability.

Use of telehealth can help manage DM. According to the World Health Organization (WHO), DM is an epidemic. Statistics show that by 2050, one in three individuals will develop DMII. In addition, 12% ($727 billion) of global health expenditure is spent on DM, and two-thirds of people with diabetes are of working age. Roughly, 425 million adults have diabetes and about 90% to 95% of them are specifically complaining of DMII. One in two adults with diabetes remains undiagnosed (212 million), with the current prevalence rate being higher than 8.5% [1]. Therefore, DMII is considered a serious condition and is known to cause morbidity and mortality, and raises the costs of healthcare providers globally. DMII is also associated with a ten-year shorter life expectancy [1]. Such statistics have influenced the adoption of telehealth programmes in an efforts to manage and control diabetes, and to ensure patients are better informed to carry out self-management tasks.

Telehealth as intervention for diabetes

Evidence from literature review demonstrates telehealth interventions are related with positive results when used to treat people with DMII. Evidence can be found in the rates of effectiveness of telehealth technology as a strategy used for patients with DMII [18, 19, 15, 20-23, 10, 24, 11, 25, 26]. Furthermore, Zhou *et al.*, [27] researched factors that are thought to improve patient outcomes and found that embracing telehealth was among these crucial factors. The study by Park *et al.*, using a telemedicine strategy was found to improve glycaemia results by a significant level, particularly when compared to the effectiveness of using pair-wise analyses [28]. The researcher noted that some changes had a clinical positive impact on the patient. However, the research did not record any significant effects on other aspects of the BP, cholesterol, quality of life (QOL), or hypoglycaemic risk.

Interventions that have been conducted using telehealth indicate it as a feasible and acceptable tool. However, there is evidence that show that telehealth programmes have limited potential for improving outcomes specific to some conditions. In reference to this, a study conducted by Brown-deacon *et al.*, [29] indicates that in a comparison of the use of MMDs and other telephone nursing services in a randomised trial, will enhance the patient's confidence regarding disease management. The study did not observe any differences between the two groups in other aspects such as functional status, QOL, or depression. In a study that assessed the outcomes for diabetic patients who participated in care management programmes that used a telehealth strategy (televideo and MDD devices), participants were seen in a timely manner. The opposite was noted to be true for participants who acted as a matched group, and who did not receive telehealth services. The results also indicate a significant decrease in the need for hospital admission and fewer days of care required. The researcher also observed a subgroup, and analysis of glycated hemoglobin (HbA1c) found that telehealth strategies had direct implications on decreasing the number of hospitalised individuals, compared to the comparison group.

Another study by Kim *et al*., [22] used interviews conducted with staff members in hospitals who used MMDs and video equipment. The staff members worked with patients who had DMII, among other conditions, and the analysis revealed that staff members were enthusiastic about the continued and expanded use of telehealth-medicated care programmes such as MMD programmes. The analysis also indicates administrative concerns like the need to ensure that telehealth funding priorities are in accordance with other funding needs and clinical programmes, to ensure its success even with financial constraints. In the interviews, telehealth providers and physicians agreed that more information was needed on the use of MMDs for providing patient care. However, Kim *et al.*, [22] highlights the need for clinics to use well-developed programmes to ensure successful implementation of telehealth services in multiple hospital sites. The study's analysis interpreted no need for acquiring more information about the use of telehealth (MDDs) strategies in practice. The report recommends that the focus should be on identifying factors that can aid the implementation of telehealth programmes, identify potential barriers to implementation, and suggest probable solutions to overcome these barriers. A normalisation definition for telehealth involves incorporating telemedicine in the daily practices of a clinical setting [30]. To achieve this target, more studies are needed to ensure the understanding of processes, facilitating factors, and potential barriers. The diabetes quality enhancement research initiative (DM-QUERI) identifies the use of telehealth as a crucial component for aiding in the provisioning of care to those newly diagnosed with DMII.

Using telehealth to provide diabetes car

The general view according to most research findings is that telehealth (or its specific types) is a significant factor used in managing diabetic patients. Research conducted by Lewandowski, Mazurkiewicz and Kardas [21] found several benefits for diabetic patients as a result of using telehealth programmes. These benefits include having a beneficial system for patients, particularly in terms of providing timely and appropriate monitoring. Care providers argue that using telehealth for monitoring health is effective, since the professional acquires first-hand affirmation of patients' conditions on a real-time basis, and the information provided is more accurate than what is recorded in a patient report when patients visit a clinic for scheduled clinical care. Furthermore, telehealth systems are reported as facilitating medication changes and timely responses to patient needs. In instances where a patient is released from hospital and goes home, the clinician can be confident about relying on a MDD device to follow the patient's BGL and monitor their insulin usage. By acquiring accurate information in time, the healthcare provider can intervene early and eliminate any last-minute urgency.

The focus of telehealth (or its specific types) is to provide care by promoting education about self-management among patients. The technology has been reported as helping patients manage diabetes. Lee, Chan, Chua and Chaiyakunapruk [31] argues that the use of telehealth is helpful, as it promotes care delivery and is a tool for helping clinics manage their patients. Ideally, the patient is required to enter their information using, for example, a MMD device. Clinicians use this information to make clinical judgments, effect follow-ups, and provide personalised education to patients on how to manage their condition better. The effectiveness of telehealth is, however, dependent on many factors

including the patient's motivation to use the device, the level of knowledge related to using it (for both clinicians and patients), and whether or not the technology is used as a tool to provide better care.

Wu, Forbes, Griffiths, Milligan and While [32] note that there is a need to have realistic expectations about the type and number of patients who would be willing to participate in MDD programmes. The willingness of a patient to participate in a telehealth programme has a direct correlation on the extent to which such a patient will benefit from the programme. Patients who are reluctant to participate are not likely to benefit from the programme as well as others. Promoting self-will to participate is therefore important when assessing the effectiveness of a telehealth programme. However, the researchers noted that it is challenging to identify those patients who are most willing to participate, and point out a need to have an explicit and measurable mode of identifying patients.

According to So and Chung [33], the usability of telehealth devices requires improvement. Technical issues are suspected to affect the reliability and usability of devices; additionally, issues that pertain to assessment and monitoring also require additional assessment. Regarding technical and individual issues, some patients fail to use their devices and in turn, this complicates efforts to assess the effectiveness of telehealth devices. Similarly, Lewandowski, Mazurkiewicz and Kardas [21] argue that the implementation of telehealth tools may reflect an increment in clinical workload, which in turn may reduce the effectiveness of the technology, and thus suggests that implementation considerations should address the need for more staff to improve successful implementation.

Despite all the trials in the effectiveness of telehealth in blood glucose level (BGL) control, there still exists complication in managing BGL among self-care patients. These obstacles are caused by computer illiteracy and accessibility. Therefore, there is a need to develop electronic based care service to educate and train patients, on how to access information and operate these devices.

Aim of the Review

This integrative review will evaluate the effectiveness of a telehealth strategy for providing education on self-management to patients living with type 2 diabetes in order to manage their glucose level.

METHODOLOGY

This review aims to conduct a professional study to efficiently assess how effective the application of telehealth is in educating diabetic patients about self-management. The integrative literature review was selected as a best methodology for this research, as it will facilitate the aim of this review, i.e., to assess the research question in an efficient manner. This type of review used because it is the basis for validating the nursing diagnoses process [34]. It also allows reviewers and academics to develop their research by combining a range of both non-experimental primary data and experimental data. As a framework, it provides for summarising and analysing results that other researchers have found in a variety of studies. The researcher then draws conclusions according to the cumulative weight obtained after analysing multiple findings. The results and conclusion examine the researcher's proposed themes, and the researcher uses the findings to confirm/deny or reassess the outcomes established by their research [35]. This will assist the researcher to develop a comprehensive reflection of the performance recorded by a telehealth tool as a choice for dispensing education on self-management to patients with DMII.

Search strategy

To locate the research work that address the effectiveness of telehealth as a tool for educating adult patients with DMII about self-management, a comprehensive computerised search of different databases was conducted. This review focused on using a systematic search approach and employed the databases Medline, Scopus and CINAHL to find a wide-range of relevant articles that address the topic. These databases are renowned for publishing journals addressing issues relating to nursing and healthcare and contain peer-reviewed primary studies with high standard and up-to-date evidence-based practices in nursing. The researcher considered the use of sources by determining whether they included information on the effectiveness of telehealth (or its specific types) in promoting patient education for diabetic patients for Maintaining/controlling BGL. A manual search, which involved locating articles available in the reference lists of identified articles or reviews, was also conducted to enhance the search strategy, and to assist in finding additional studies that were not found via the electronic search. The search was limited to primary studies involving adults (19 years and over), and published in the English language.

Three main search terms and MeSH headings used were 'telehealth', 'self-management education', and 'type 2 diabetes mellitus'. For exploring the topic as broadly as possible, keywords that comprised each search term were then used by adding 'AND' or 'OR' between keywords (Table-1). An asterisk (*) was used, for example, with the word (effect*) to also gain all possible related words.

Exclusion criteria

- Sources that did not have any content on specific components of telehealth, and did not provide reliable results.
- Studies on gestational diabetes.

Inclusion criteria

- Primary studies.
- Studies conducted on ambulatory DMII patients.
- Studies that include content for developing one or more diabetes self-management domains through advice, feedback, goal-setting, reinforcement, or patient decision-making support.
- Studies that examined the use of telehealth (or its specific types), defined as the use of medical exchange between different sites via electronic communications to improve patient health status.
- Articles less than six-years-old to capture the most relevant and latest evidence related to using telehealth as an intervention for adults with DMII.

Table-1: Primary Search Terms and Keywords

Primary Search Term	Keywords
Telehealth/ Telemedicine	mHealth OR eHealth OR Telemonitoring OR telenursing OR mHealth OR telecare, telephone-based, Cloud base, Web based
Self-management education	Patients education OR self-management OR educating patients on self-management OR self- care OR coach* train* OR effect*
Type 2 diabetes mellitus	type 2 diabetes OR diabetes mellitus type 2 OR T2DM, HbA1c,

Search outcomes

PRISMA diagram

The diagram provided below (Figure-1) is a graphic presentation that shows the search process for obtaining relevant sources for this research. The electronic search conducted in the databases using the key terms identified, and after applying limiters, produced 397 articles. Eight extra articles were generated as a result of the manual search. Then, the duplicated articles were eliminated using Endnote software, which led to a reduction in number of articles to 247 papers. The screening process against inclusion and exclusion criteria was then conducted on the new number of sources to determine their usefulness for this research. Many articles were either conference proceedings, secondary research, without full text, or irrelevant to the primary intervention and outcome measure specified in the inclusion criteria, used one or a small size of participants, lacked systematic reviews, and lacked an abstract. From these criteria, 216 articles were excluded as a result.

At this stage, 31 primary studies remained. Further scrutiny was applied to assess the information in these potentially credible sources such as the abstract provided, looking out for the background information, the methodology applied, results acquired, discussions, and recommendations given. An additional fifteen articles were excluded for different reasons (shown in the diagram provided below; (see Figure-1). Therefore, a total of 16 relevant studies were included in this review (Table-2), retained and appraised by using a suitable appraisal tool (A Critical Appraisal Skill Program "CASP" tool), which was also applied to exclude invalid or low quality articles.

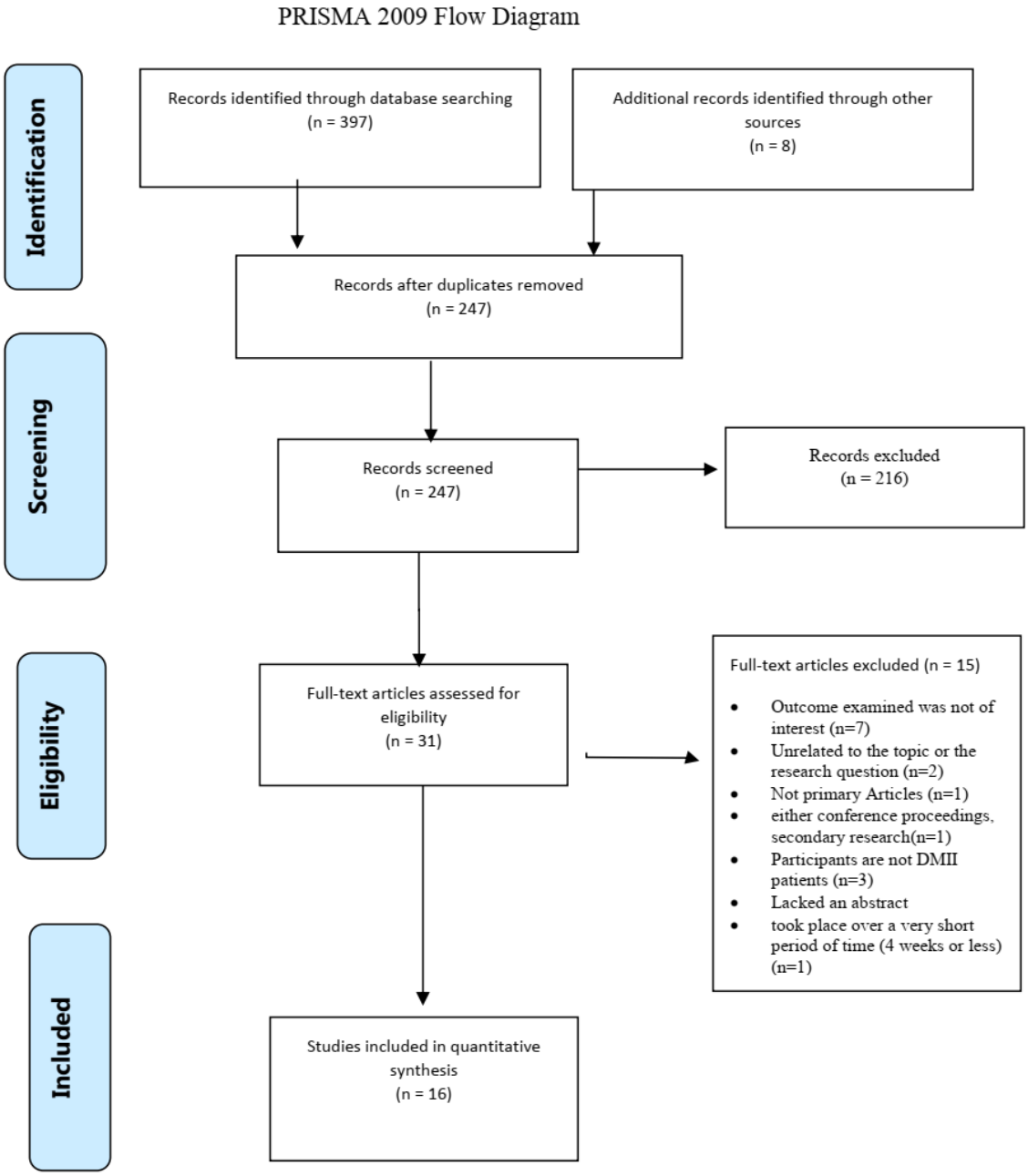

Fig-1: Search outcomes

SEARCH OUTCOMES

QUALITY APRAISAL

Quality appraisal is an efficient method that systematically examines the relevance and reliability of identified research in certain fields. A Critical Appraisal Skill Program (CASP) is a tool that supports evaluate the strength and quality of different methodologies and designs of primary quantitative and qualitative research articles throughout a certain checklist of questions that aims methods and results [36]. The quality appraisal for the final selected researches were conducted using a standardized critical appraisal checklist based on a suitable Critical Appraisal Skills Programme (CASP) procedures prior to confirming them as valid sources for this review. All the confirmed 16 articles conform to RCT requirement for this review. All the CASPS Checklist guidelines were checked and the selected article passed the critical appraisal set which then were described in (Appendix-1).

FINDINGS

Table-2: Description and Analysis of the Studies Grouped by Key Feature

No.	Author / year	Title	Key feature	Setting	Intervention & Control group	Sample	Findings	Theme
Telephone intervention								
1	Brown-Deacon *et al.*, [29]	Can follow-up phone calls improve patients self-monitoring of blood glucose?	**Phone Prompt** No education	Home care	Control group received standard diabetic care. Intervention group received diabetic care plus follow-up phone calls every two weeks after a monthly clinic	N= 41 Control n=20 Intervention n =21	There was a low significant change in the HbA1C in the intervention group at 3 months but not significant between the groups	Less than 1% difference between the two groups.
2	Kaur *et al.*, [16]	Telephonic consultation and follow-up in diabetics: Impact on metabolic profile, quality of life, and patient compliance	**Phone Prompt** No education	Outpatient department	Control groups infrequent and frequent clinic visits; telehealth group received weekly telephonic consultation in addition to the frequently visits.	N=120 2 x Control: n = 40 +40 Intervention n=40	Significantly lower FBS and HbA1C at 12 weeks for intervention versus both sets of controls.	Improved quality of life and decrease in weight in intervention group
3	Mons *et al.*, [37]	Effectiveness of a supportive telephone counseling intervention in type 2 diabetes patients: Randomized controlled study.	**Phone Prompt Education**	Home care	Intervention group received monthly telephone-based counseling intervention, whereas control group had only standardized normal care. 12-month study.	N=204 Control n = 101 Intervention = n=103.	HbA1 decreased significantly for both the groups, intervention (-0.44) and normal care (-0.51), however there was no significant difference between the groups at 6, 12 or 18 months	Significant improvement in quality of life in intervention group.
Text message intervention								
4	Van Olmen *et al.*, [7]	The effect of text message support on diabetes self-management in developing countries – a randomised trial.	**Text message Prompt Education Developing countries**	Countries	Control group allocated to conventional self-management education, and experiment group to self-management education plus. Self-management plus consisted of	N=781 Control: n =380 Experiment: n =401	Change in HbA1c below 7.0% (53mmol/mol) after 2 years. No significant difference between the groups.	Africa and Asia based, some variation in the delivery of the protocol

					mHealthmobile phone integrated with health apps.			
Web monitoring only								
5	Bujnowska-Fedak *et al*., [18]	The impact of telehome care on health status and quality of life among patients with diabetes in a primary care setting in Poland.	**Web based monitoring**. No education No prompt	Primary care	Intervention group were provided with wireless transmitter enabled computers to monitor the glucose levels. While the control received a conventional monitoring system	N= 100 Control n=48 Intervention group = 47	Significance different in Baseline HbA1c and End follow up values. (p=0.02) at 6 months	Less hypoglycaemic episodes and increased QoL in intervention group
6	Kardas *et al.*, [21]	Type 2 diabetes patients benefit from the COMODITY12 mHealth system: Results of a randomised trial.	**Web based monitoring**. No education No prompt	Primary Care setting	Intervention group received COMMODITY12 system: smart phone, and wirelessly connected sensors to manage glucose. Control group receive the standard intervention.	N=60 Control grp n= 30 Intervention grp n=30	mHealth system enhanced FBS at 6 weeks (<0.05) HbA1C =NS	Increased QoL
Web monitoring with prompt and no education								
7	Orsama *et al.*, [38]	Active assistance technology reduces glycosylated hemoglobin and weight in individuals with type 2 diabetes: Results of a theory-based randomized trial. *Diabetes.*	**Web based monitoring Prompt** No education	Home based care	Control group received standard care that included education and counseling about managing diabetes. Whereas the intervention group participated in telephone based remote reporting.	N= 48 Control n = 24, Intervention n=24.	Intervention group recorded a significant change in mean reduction in HbA1c of -0.40% (95% CI -0.67% to -0.14%) vs 0.036% (95% CI-0.23% to 0.30% (P<0.03) 10 month.	Increased weight loss
Web monitoring with e-education and prompt								
8	Iljaz *et al*., [20]	E-healthcare for diabetes mellitus type 2 patients – a randomised controlled trial in Slovenia.	**Web based monitoring**. **Prompt e-Education**	Home-Care setting	Control grp: received the conventional care for DM according to Slovenian guidelines. Intervention grp: received conventional care and eDiabetese app (inc. e-consultations and text reminders)	N=120 Control: n= 62 Intervention: n = 58	eDiabetes resulted in a reduced HbA1c values after 6 months and 1 year (p < 0.05).	Included SMS texts

9	Kim *et al.*, [22]	Randomized, open-label, parallel group study to evaluate the effect of internet-based glucose management system on subjects with diabetes in china.	**Web based monitoring e-Education Prompt**	Hospital	The Intervention IBGMS group received blood sugar monitoring through the internet, while the control group received the conventional treatment on HbA1c treatment and management.	N = 182 Control n = 92 Intervention n =90	Changes in fasting blood sugar in the intervention group at month 3 (P=0.003) and at month 6 (P=0.005) Postprandial sugar level observed in month 6 (P=0.001)	HbAc1 p=0.014 at 3 months but p=0.81 at 6 months
10	Moattari *et al.*, [10]	The impact of electronic education on metabolic control indicators in patients with diabetes who need insulin: A randomised clinical control trial.	**Web based monitoring e-Education Prompt**	Primary health care	Control group participants received a normal conventional diabetes management, while the intervention group allocated specialized designed electronic education program. The education was related to controlling the blood glucose level.	N=48 Control: n =24 Experiment n =24	There were low HbA1c ($p<0.001$) in the intervention group at 12 months	Interactive on line experience
11	Zhou *et al.*, [27]	Web-based telemedicine for management of type 2 diabetes through glucose uploads: A randomized controlled trial.	**Web based monitoring e-Education Prompt**	Hospital	Telemedicine group taught skills on using telemedicine software to feed glucose level info, and the researcher gave advice. The control group receive normal visits.	N=108, Control grp: = 55 Experiment n= 53	Telemedicine group showed lowered HbA1c and FBS ($p<0.05$). Hypoglycemia risk also reduced (p=0.044) at 3 months	Telemedicine group showed healthier HbA1c and FBS controlling ($P < 0.05$). Besides, telemedicine intervention reduced hypoglycemia risk.
Web based monitoring with non-electronic education and prompt								
12	Liou *et al.*, [23]	Shared care combined with telecare improves glycemic control of diabetic patients in a rural underserved community.	**Web based monitoring Education Prompt**	Primary care	Control group received normal care, intervention group were given shared care in addition to telecare.	N=95 Intervention 54 control 41	A significant reduction inHbA1c level compared to control (0.7 ± 1.3% versus 0.1± 1.0%, p=0.03) at 6 months	Shared care equals extended education
13	Lindberg *et al.*, [39]	Telemonitoring and Health Counseling for Self-Management	**Web based monitoring Prompt**	Outpatients	Control group: received usual care, while Intervention group	N=166 Control group n=79,	There was no significant change in the outcome of	The telehealth outcome minimal in this project.

		Support of Patients With Type 2 Diabetes: A Randomized Controlled Trial.			Received both usual care and web-based management.	intervention n=87	HbA1c (p=0.33) from the baseline to the end of follow up, moreover, there was no change between the two groups. 19 months.	MASSIVE DROP OUT 15 controls and 36 intervention
Web monitoring with e-education and prompt and additional features								
14	Hsu *et al*., [15]	Utilization of a cloud-based diabetes management program for insulin initiation and titration enables collaborative decision making between healthcare providers and patients.	**Web based monitoring Prompt e-Education Collaboration**	Home care setting	Control group received standard manual care and phone follow-up, whereas the intervention group care through cloud based diabetes control program and collaborative care regimen.	N=40 Control n = 20 Intervention n= 20	Intervention group greater HbA1c reduction compared with the control group (3.2± 1.5% vs. 2.0%±; p=0.048) at 12 weeks.	Management negotiated: collaborative decision making
15	Crowley *et al.*, [19]	Practical telemedicine for veterans with persistently poor diabetes control: A randomized pilot trial	**Web based monitoring**. **Prompt e-Education Depression management**		Experiment group were educated about managing the HbA1c with comprehensive telemedicine intervention and usual care. Control group received usual care.	N=50 Control: n=25 Experiment n=25	Intervention significant different HbA1c (p <0.05) at 6 months	Decreased depression via intervention
e-education and prompt								
16	Murray *et al.*, [11]	Web-based self-management support for people with type 2 diabetes (HeLP-Diabetes): randomised controlled trial in English primary care.	Usual clinic monitoring only **e-Education Prompt**	21 general practice in England.	Experiment group had a web based training on how to manage diabetes. Control group had normal guidelines in HbA1c management and **non-interactive web education**	N= 374, Cntrl grp: n =189 Exp grp: n= 185	The Experiment group showed a lower HbA1c than the control group. (Mean difference – 0.24/5; 95% CI-0.44 to -0.049; p=0.014) at 1 year	Participants not representative of wider population

ANALAYSIS OF THE ARTICLES

The purpose of this review is to evaluate the effectiveness of a telehealth strategy for providing education on self-management to patients living with type II diabetes in order to manage their glucose level. As telehealth becomes more pervasive, it is important to gain an understanding of how effective the different ways it can be applied actually are. Making the choice to group by patient type, ethnicity, country, or choice of telehealth modality misses the point that technology, and access to it, are developing fast and so understanding how it is best applied, rather than in what populations, or via which modality, it currently works best in, is important.

It is worth noting at this point that no two studies in this review adopted exactly the same approach to researching telehealth, this makes comparison across the studies difficult to undertake. For example, some studies were purely web based, others used phone calls, and some used texts; notably most used a mix of telehealth delivery methods. This makes it difficult to tease out, on the basis of the studies in this review, whether one delivery method is more advantageous than another because there is not enough evidence available regarding any one single approach and, as identified above, this is probably not all that important.

Secondly, and perhaps most importantly for this review, there appears to be a broad definition of what constitutes a telehealth intervention. Again this makes inter-study comparison hard, but it does have the advantage of enabling some of the important themes about what interventions delivered using telehealth, in its broadest sense, are of benefit to emerge. For example, all of the studies, with the exception of that by Murray *et al*., [11], interpreted a telehealth intervention to be, in part, about remote monitoring of blood sugar levels.

Thirdly, the approach to delivering the educative telehealth intervention, differs between the studies reported. There are three broad ways in which the researchers sought to deliver education for example. The first is a prompt for the immediate management of diabetes in response to a blood glucose reading provided as part of remote monitoring (prompting). The second and third element are interrelated in that they refer to a more empowering and enabling approach to education, with a view to increasing the individual's self-management capabilities through either online (e-education), or face to face proactive education provision.

In reality the method of delivering the telehealth intervention(s) is perhaps more driven by the availability of technology in any given place (as is demonstrated in the study by Van Olmen *et al*., [7] and, as stated above, as technology becomes more easily accessible, this will inevitably change. The important question which emerges therefore is not which delivery method(s) work best, but which telehealth intervention(s) have the most impact on the ability of people living with DMII to manage their own disease.

Monitoring

Only one of the studies [11] reviewed did not contain an element of tele-monitoring of the participants' glucose levels in real time. The means by which the monitoring occurred varied between the studies, from phone calls Brown-Deacon, Brown, Creech, McFarland, Nair and Whitlow [29]; Kaur, Kajal, Kaur and Singh [16], and Mons *et al.*, [37]; text messages [7] to some form of web based monitoring system [18]; Kardas, Lewendowski and Bromuri [21]; Orsama *et al*., [38]; Iljaz *et al*., [20]; Kim *et al.*, [22]; Moattari, Hashemi and Dabbaghmanesh [10]; Zhou, Xu, liu, Huang, Xu and Chen [27]; Liou *et al*., [23]; Lindberg *et al.*, [39]; Hsu *et al.*, [15] and Crowley *et al*., [19].

Only two trials included SMART technology monitoring and uploading of glucose levels to the research hub but offered no education, e-education or prompts from the research team. The study by Bujnowska-Fedak, Puchula and Stoica [18] demonstrated a significant difference (p=0.02) in HbA1c levels at the end of their six month study between the intervention and control groups. Kardas, Lewendowski and Bromuri [8] however failed to demonstrate any improvement in HbA1c levels in their small (n=60) Randomised Controlled Trial (RCT), but did for random blood glucose monitoring. The Kardas *et al*., [21] study, which occurred over only 6 weeks, is however a pilot study and may subsequently be used to develop a bigger, longer trial which may show something entirely different.

As well as Kardas *et al.*, [21] study only the studies by Lindberg *et al.*, [39] and Van Olmen *et al.*, [7] failed to show any significant changes in BGLs at study end. Notably, 25% of participants dropped out of Lindberg *et al.*, [39] study and Van Olmen *et al.*, [7] study was based across three countries on two continents, and was the only study to employ text messaging as the means of reporting blood glucose levels.

The emerging evidence from the studies in this review is that where web based and telephone voice monitoring are concerned, monitoring might help improve blood glucose control. This is especially evident in the two studies which deployed only a monitoring telehealth intervention [18, 21].

Prompt

Prompts are in essence immediate, or near immediate, messages advising the recipient on the means of managing their blood glucose in usually response to a blood glucose measure, or a messages about good practice in blood glucose control in a short message format. Like monitoring, prompts do no conceptually feel like a means of empowering patients as they remove the need for decision making from the individual.

In the studies by Brown-Deacon *et al*., [29], Kaur *et al*., [16] and Mons *et al*., [37], prompts were supplied by a care professional over the phone. In each case there was a significant drop in BGL for all participants in the study, but only in the case of Kaur *et al*., [16] was there a significant difference in the BGLs between the intervention and control arms of the study.

Two of the randomised controlled studies employed text messaging to deliver prompts. Van Olmen *et al*., [7] compared outcomes over a two-year period in a large sample from three low and middle income countries - Cambodia (n=84), The Philippines (n=382) and The Democratic Republic of Congo (n=315) – but demonstrated no difference in HbA1c levels between the study arms at the end of the study. The prompting in this study was not in response to reported BGLs, instead it was short educational reminders sent several times a week. In the study by Iljaz *et al*., [20], which demonstrated significant improvements in HbA1c ($p<0.05$) at six months and one year in their study of 120 individuals in Slovenia, by contrast, the text message prompts were provided in response to specific BGLs reported via a web based app.

Orsama *et al*., [38] used a programme loaded onto a smart phone for people in the intervention arm to upload their glucose monitoring data and access automated feedback. This prompt was related to a care plan they had already negotiated with a member of the research team. Participants in the control arm also had the care plan but no access to the smart technology. This study of 48 individuals over a ten-month period demonstrated statistically improved HbAc1 in those in the intervention arm ($p<0.03$). The researchers fail to comment on the content, or nature, of the care plan negotiation. Of itself negotiating the care plan may have an impact on how both groups within this study behaved and perhaps how those in the study arm responded to the prompts, although it is not possible to tell this for certain from the design and reporting of this study.

Kim *et al*., [22] used nurses to provide diabetes management e-prompts to intervention arm participants (n=90), whose blood glucose results had been uploaded via a web based application. This study demonstrated significant falls in 'fasting blood sugars' (FBS) in the intervention arm at three and six months ($p=0.003$ and $p=0.005$ respectively), HbA1c levels at month three and six months ($p=0.014$ and $p<0.01$) and in postprandial blood glucose (PBG) at month six ($p=0.001$) when compared to the controls.

The much shorter study by Zhou *et al*., [27] also used web based technology to upload glucose monitoring data every two weeks in the intervention arm. The participants in the intervention group (n=53) received self-management prompts from the study team in response to these uploads; but not in real time. During the three-month study, the control arm (n=55) received usual, face to face, care. This China based study demonstrated improved management of HbA1c and FBSs (both $p<0.05$) by study end, as well as a reduced risk of episodes of hypoglycaemia ($p<0.044$).

Moattari *et al*., [10], provided diabetes management prompts, in response to remote monitoring uploads, to the 24 intervention arm participants in their twelve-week study. Compared to the control arm (n=24), the participants in the intervention arm demonstrated a highly significant ($p<0.001$) fall in HbA1c at study end. Like Kim *et al*., [22] and Zhou *et al*., [27], Moattari *et al.*, [10] also provided online education.

Lindberg *et al.*, [39], demonstrated no statistically significant difference in HbAc1 between their groups at study end (19 months); despite the use of web-based prompts in the intervention arm. While the study by Liou *et al.*, [23], which was very similar in design to that of Lindberg *et al.*, [39] except that it was set in a very poor rural population, demonstrated a statistically significant impact ($p=0.03$) in reducing HbAc1 levels at six months.

Crowley *et al*., [19], included an intervention to help people in the active arm manage depression in their study while Hsu *et al.*, [15] added collaborative care to their trial protocol. Both studies included real time prompts in relation to e-monitoring of BGLs and both demonstrated a reduction in HbA1c levels for the intervention arm over the control arm of their studies at six months ($p<0.005$; Crowley *et al*., [19] and at 12 weeks ($p=0.048$; Hsu *et al.*, [15].

The one study which differs from all the others is that by Murray *et al*., [11]. This 12-month trial examined the impact of web-based education with occasional text message reminders, prompts, to visit the interactive education website, versus a control group using a non-interactive website with no prompts. There was no monitoring element to the study other than that at the usual clinic visits. Murray *et al*., [11], demonstrated a statistically lower HbA1c result ($p=0.014$) in participants in the interactive arm over those in the control arm.

Like monitoring, the empowering nature of prompts as a means of improving diabetic self-management is questionable. The evidence presented, suggest that prompts, real time or not, may contribute to better self-management in DMII, but the picture is somewhat blurred as every study reported has more than one element to the intervention.

Education

It would be easy to assume that education was the answer to improving self-management in all diseases. Of the studies presented here, those by Brown- Deacon *et al*., [29], Kaur *et al*., [16], Bujnowska- Fedak *et al*., [18], Kardas *et al*., [21] and Orsama *et al*., [38] contained no educative element other than prompts either in relation to reported BDLs or to remind the individual how about how to manage their disease [29], Kaur *et al.*, [16] and Orsama *et al*., [38]. The outcomes of these studies were equivocal with only those by Kaur *et al*., [16], Bujnowska- Fedak *et al*., [18] and Kardas *et al*., [21] showing any objective benefit.

Of the studies which included an overt proactive educative element, that by Mons *et al*., [37] provided the education over the phone; while Van Olmen *et al.*, [7], Liou *et al*., [23] and Lindberg *et al*., [39] provided additional face to face education to the intervention arm over and above that provided in usual care. Of these studies only that by Liou *et al*., [23] demonstrated an improvement in blood glucose readings at the end of the study.

All of the seven studies which included ongoing e-education as part of the protocol to the intervention arms demonstrated benefit in relation to the management of the participants' diabetes Iljaz *et al*., [20], Kim *et al*., [22], Moattari *et al*., [10], Zhou *et al*., [27], Hsu *et al.*, [15], Crowley *et al.*, [19] and Murray *et al*., [11]. It is worth noting here that each of these studies also had a prompting element to it and that each, except that of Murray *et al*., [11] also included real time monitoring of blood glucose readings via some form of upload to an electronic environment. Two of the studies - Hsu *et al.*, [15], Crowley *et al*., [19] – also had additional features included in the study protocol. In the case of Hsu *et al.*, [15] this was a genuine attempt to generate a collaborative treatment decision making model between the researchers and the participant and for Crowley *et al*., [19] an intervention to help reduce depression.

DISCUSSION

It is clear from the diversity of the studies reported here that definitions of what it means to use telehealth technology vary widely, from the use of phone calls and texting through to fully integrated monitoring systems with complex feedback mechanisms and interactive online education packages. The wide variety of approaches to applying telehealth processes (i.e. monitoring, prompting and educating) to the management of diabetes also make it hard to unpack what works and what does not in improving treatment outcomes for patients. There are further complications in unravelling the messages from the studies in that they were set in many different countries around the world and are therefore subject to cultural differences. In terms of creating a meaningful review of the literature, the different approaches to providing telehealth, the wide variation in study length, and differences in the outcome measures make this hard to achieve [40].

What is important to remember at this point is that whatever the care offer is, it is driven by the availability and affordability of the medium in the population being served. The telehealth offer and level of interaction is also subject to local cultural and social norms, such norms set boundaries as to what is usual in the way of interaction between a care provider and a patient.

It is also difficult to come to any meaningful broad understandings from these studies not only because of the issues already identified, but also because many of the studies fail to define exactly what the population of interest is [41]. In essence the control of DMII depends on whether the individual concerned uses diet alone, diet and oral medication or whether they use diet and insulin. For example, Orsama *et al*., [38], refer, in their inclusion criteria, to people with a "known diagnosis of DMII, elevated HbA1c (>6.5%) or currently using oral diabetes medication"; Iljaz *et al*., [20], refer to peoples whose diabetes is diet controlled or who use tablets while Zhou *et al*., [27], have as their inclusion criteria, "all patients diagnosed as DMII according to WHO criteria". Not being clear about inclusion criteria means the external validity of the studies is poor, making generalisability, already difficult enough, very difficult, if not impossible [42].

The studies which demonstrated the best results in terms of improved management of diabetes appear to be those which included web monitoring and at least one other feature, such as education or prompting and advice giving from the research team [20, 22, 10, 27, 23, 15 19]. The use of telephonic technology [29, 37, 7] appears not to be effective in enhancing the management of diabetes; the exception being the study by Kaur *et al*., [16].

Despite over three quarters of the world's population having access to mobile phone technology [43], systematic reviews of the evidence for the effectiveness of their use in the management of chronic disease is equivocal at best [44, 44] with a Cochrane review by de Jongh, Gurol-Urganci, Vodopivec-Jamsek, Car and Atun [46], only being able to find four

long-term evaluations of the health impact of using SMS. In this review too purely monitoring the participants' blood glucose reading remotely using web based technology appears to have produced better health outcomes than the use of SMS. In the study by Bujnowska-Fedak *et al*., [18], participants demonstrated better HbA1c results at six months than controls and in Karda *et al*., [21] study, participants demonstrated improved FBSs at 6 weeks. The key difference between these studies, and those using phone calls and SMS is that the monitoring results are automatically uploaded to the system, so there is no room for error, personal interpretation or missed readings. The use of telehealth as a monitoring tool has been shown in systematic reviews to be beneficial in diseases other than diabetes e.g. heart failure [47] and Chronic Obstructive Pulmonary Disease [48].

One study which demonstrated benefit, Orsama *et al*., [38], provided monitoring and real time prompts to improve self-management, but with no standalone education provision either online or face to face. This adds a further layer of complexity to the use of telehealth in that it provides a feedback loop to the patient prompting them as to how to better manage their diabetes, but does not empower them to take control. Similar studies in hypertension management [49] and a meta-analysis of warfarin dosing studies [50] demonstrate similar outcomes for telehealth monitoring which uses some form of feedback to the patient relating only on the result of the test they have uploaded. The fact that a study with no proactive educative element (other than real-time prompts for disease management) is able to demonstrate a statistically significant improvement in disease control, suggests that the positive outcomes from studies which employ all three features might, in fact, not relate to the use of proactive education at all.

Perhaps the most sophisticated approach to the use of telehealth is to provide monitoring, a feedback/ prompt to the patient as well as some form of online education. The studies featured in this review that used this approach demonstrated outcome benefits to the patient at 3 months [27], 6 months [22] and one year [20, 10], however, the impact of the various elements of telehealth when delivered in this way is hard to gauge. While studies which employ monitoring, feedback and education are commonplace across mental health [51]; ostomy care [52] as well as in supporting informal and family carers in the provision of complex care in the home [53]. However, the studies reported here, provide no clues as to whether one element of the approach is more important than another.

To further complicate efforts to understand the impact of the multifaceted approaches to providing telehealth, one study also employed SMS text message prompts [20], and another [27] used the researcher, rather than a telehealth programme to provide the targeted advice to participants.

Liou *et al*., [23] and Lindberg *et al*., [39], took a different approach to the use of providing monitoring, education and real-time self-management prompts. Participants in the intervention arms of these studies received face to face teaching on the management of their diabetes, plus real-time prompts for the management of their blood glucose levels once these uploaded to the monitoring system. Liou *et al*., [23] classify their intervention as "shared care", but describe an extended period of face to face classroom teaching. Lindberg *et al*., [39] also provided group sessions, their upload of data was manual and the prompts the participants received relating to their own care were not in real-time but were delivered electronically. Like almost all of the studies employing e-monitoring and rapid prompts for diabetes management, Liou *et al*., [23] demonstrated significant reductions in HbA1c at study end (in this case 6 months). The emerging picture being that telehealth provided in the form of tele-monitoring and *real-time* management prompts appear to enhance glucose control regardless of the addition of education; although this might be at the expense of patient empowerment (which is not under review here).

Hsu *et al*., [15] and Crowely *et al*., [19], both employed web based monitoring, prompts and electronic education as well as having a significant further element to their intervention. For Hsu *et al*., [15] this was a concerted effort to develop a collaborative care plan with the participant who was then coached to self-manage their diabetes, and for Crowely *et al*., [19] this was an additional intervention to help participants deal with stress and depressive symptoms. Both of these studies were very small and the study by Hsu *et al*., [15] was only 12 weeks, while that of Crowely *et al*., [19] lasted three months. Both demonstrated impressive management of HbA1c at study end in the intervention arms. As in the previous multifaceted studies, it is difficult to unpick what it is about these studies which makes them work. Certainly if coaching works, it has the potential to roll out to the real world reducing the need for professional input in the long-term; and, if diabetes and depression management can be integrated into one telehealth approach successfully, then real world roll outs of telehealth could become more far-reaching as suggested in many other existing studies. One study which took a different approach to the others was the education and prompting study by Murray *et al*., [11], which singularly among the studies presented here, did not employ tele-monitoring. This yearlong study demonstrated a statistically significant difference in HbA1c between the intervention and the control arms. The intervention arm had access to a highly interactive and comprehensive educational programme and were reminded from time to time to use it. At entry to the

study, participants already had better control of their diabetes and comorbidities than the general population of UK diabetics, and it was not possible to totally blind the research nurses to which arm of the study the participants were in; these observations give rise to concern about the external validity of the study and the potential for observer bias [54, 41]. The contrast with the other studies reported here is clear, although this study does seem to support the emerging picture that prompts supplied via computer based telehealth (and not telephonically) and/or education have a positive effect on glucose control. This effect appears to hold true in every study except at six months in the study by Kardas *et al*., [21] (although it did hold at three months) and the study by Lindberg *et al.*, [39] which was subject to multiple drop outs.

CONCLUSION

Large and important studies into the management of HbA1c and simple blood sugars have demonstrated that even small reductions can have significant health benefits for people with diabetes, including protecting the individual from microvascular complications such as retinopathy and chronic kidney disease [55, 56]. This makes the need to understand which approach(es) to improving self-care in this area work of great importance and underlines the reasons for undertaking this review.

There are a large number of issues with many of the studies reported in this review, not least among which is that many took place over a very short period of time, which makes drawing conclusions about the effectiveness of telehealth for providing education on self-management for patients with type II diabetes over any period of time difficult.

What is meant by education varies between the studies, from prompting (essentially real-time disease management guidance and education) with monitoring [38], web based educative programmes with prompting and no tele-monitoring [11] through to a highly interactive education, support and monitoring model seen in the study by Moattari *et al*., [10] are included in this review. Again this makes understanding the role of tele-health in supporting self-management of type II diabetes difficult to assess. Only two studies which did not use any form of education are included; one demonstrates benefit in glucose management when monitoring is applied [18], and the other [21] does not. This adds a further degree of complexity to the review as it raises questions about whether it is education which leads to improvements in care or merely monitoring.

The wide variations in technology and the interventions which can be delivered via telehealth, as well as the various approaches to promoting self-management, make drilling down to specific very hard to achieve [57]. Subsequent efforts to examine the utility of telehealth in the management of diabetes should therefore focus very tightly on the definition of diabetes and its management in the inclusion criteria, as well as what elements of telehealth are being applied.

Despite the contrary findings of the various study approaches, one approach does appear to work in each study which employed it; that of monitoring, prompting and educating as part of the telehealth package. That said, it is also noteworthy that studies which did not employ proactive education, but which used monitoring and real-time treatment prompts [16, 38] also demonstrated statistically significant benefit. The same holds true of the study by Bujnowska *et al*., [18] which was purely monitoring based.

All these suggest that there is a need for further research which compares variations on the approaches in order to ascertain which approach, or combination of approaches, (monitoring, prompting, proactive education) provides the greatest benefit in terms of outcomes. Notably, none of the studies reported here are longitudinal enough to demonstrate the benefit of these approaches over any period of time. This means the really important outcomes, like avoidance of diabetic complications and decreased mortality are not measured. In this respect fasting blood sugars and HbA1c measures only act as proxy markers of quality of disease management [58] within these studies. For telehealth interventions to work in the real world they need to be acceptable to the patients using them and have a degree of scalability [59]. None of the papers reported here take a long-term or real world view of the use of telehealth in enabling self-care in diabetes. Future research in this area needs to consider identifying the element(s) of telehealth which enhance real outcomes, having identified what important outcomes actually are, and demonstrate that the technology can be used sustainably to enhance the lives of people with type II diabetes.

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