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Impact of innovative technologies on the lives of adult diabetics: an integrative review

Impacto das tecnologias inovadoras na vida de diabéticos adultos: revisão integrativa

Impacto de las tecnologías innovadoras en la vida de los diabéticos adultos: revisión integrativa

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ABSTRACT

Objective: to review research articles with a view to examining the impact of innovative technologies on the lives of adult diabetics. **Method**: this integrative review of production found in the MEDLINE, CINAHL, LILACS, Web of Science, Springer Link and SciELO and PubMed electronic libraries included randomized clinical trials in Portuguese, English or Spanish published between 2012 and 2016. **Results**: of the 669 publications identified, 12 formed the sample, in which 11 different technologies were identified, ranging from the use of smartphone applications, pharmacotherapies, and monitoring devices to specialized interventions. Most impacted the lives of diabetics beneficially towards effectively controlling metabolic and glycated hemoglobin levels, reducing episodes of hyper- or hypoglycemia, increasing treatment adherence, and so on, while only one displayed adverse effects. **Conclusion**: there is a need for improved technologies, as well as for studies with more accurate research designs and more robust research methods.
Descriptors: Innovation; therapeutics; diabetes mellitus; quality of life.

RESUMO

Objetivo: revisar artigos de pesquisa visando a análise do impacto de tecnologias inovadoras na vida de diabéticos adultos. **Método:** trata-se de uma revisão integrativa de produção levantada nas bases de dados MEDLINE, CINAHL, LILACS, *Web of Science*, *Springer Link* e bibliotecas eletrônicas SciELO e PubMed. Foram incluídos ensaios clínicos randomizados, em Português, Inglês ou Espanhol, entre 2012 e 2016. **Resultados:** Identificaram-se 669 publicações, das quais 12 compuseram a amostra. Identificaram-se 11 tecnologias distintas, que envolveram desde a utilização de aplicativos para *smartphones*, farmacoterapias, dispositivos de monitorização até intervenções especializadas. A maioria impactou positivamente na vida dos diabéticos para o controle metabólico eficaz e dos níveis de Hemoglobina Glicada, redução de episódios de hiper/hipoglicemia, maior adesão ao tratamento, entre outros, enquanto apenas uma apresentou aspectos desfavoráveis. **Conclusão:** há a necessidade de aprimoramento das tecnologias, bem como realização de estudos com desenhos de pesquisa de maior acurácia e com métodos mais robustos de investigação.
Descritores: Inovação; terapêutica; diabetes mellitus; qualidade de vida.

RESUMEN

Objetivo: revisar artículos de investigación con vistas a analizar el impacto de las tecnologías innovadoras en la vida de diabéticos adultos. **Método:** se trata de una revisión integrativa recopilada de las bases de datos MEDLINE, CINAHL, LILACS, *Web of Science, Springer Link* y de las bibliotecas electrónicas *SciELO* y PubMed. Se incluyeron los ensayos clínicos randomizados en portugués, inglés o español, entre 2012 y 2016. **Resultados:** se identificaron 669 publicaciones, de las cuales 12 compusieron la muestra. Se identificaron 11 tecnologías distintas que involucraron desde el uso de aplicaciones para *smartphones*, farmacoterapias, dispositivos de monitorización hasta intervenciones especializadas. La mayoría tuvo impacto positivo en la vida de los diabéticos para el control metabólico eficaz y de los niveles de Hemoglobina Glicolisada, reducción de episodios de hiper / hipoglucemia, mayor adhesión al tratamiento, entre otros; sólo una presentó aspectos desfavorables. **Conclusión:** es necesario el perfeccionamiento de las tecnologías, así como realización de estudios con dibujos de investigación de mayor precisión y con métodos más robustos de investigación.
Descriptores: Innovación; terapéutica; diabetes mellitus; calidad de vida.

INTRODUCTION

Non-Transmissible Chronic Diseases (NTCD) have been presenting epidemic proportions worldwide. In Brazil, they correspond to 66% of the total disease burden. *Diabetes Mellitus* (DM) is one of the most prevalent diseases among NTCDs. It affects individuals of all ages, ethnicities, genders, nationalities and social classes, causing acute and chronic complications, disabilities, high hospitalization and death rates, and significant economic and social problems.[1] The estimated contingent of 11.9 million cases can reach 19.2 million of Brazilians in 2035[2].

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Life habit changes, such as diet and physical activity, regular drug therapy, insulin therapy, and glycemic monitoring, are fundamental for a proper response to treatment, but they are not always easily understood by the population. In addition, the lack of knowledge about this disease added to the public health system's structure deficiency for comprehensive and multidisciplinary patient care contributes to the increase of the epidemiologic rates presented[3].

Aiming at a closer approximation to human physiology, an acceptable glycemic control, and the minimization of hypoglycemic episodes, increasingly sophisticated integrated methods of glucose levels' monitoring and insulin delivery are in a projection and testing phase[4]. There are evidences that the utilization of innovative technologies can improve DM management. Therefore, they focused on applying science and technology to enable the creation of new and profitable tools to help individuals with DM[5]. The exploration of Information and Communication Technologies (ITCs) can help to reformulate the current health care delivery system, shifting the emphasis from the disease to well-being. Also, the utilization of these new approaches offers some advantages: iatrogenic reductions, data generation for disease investigation and increased continuous improvement capacity[6].

However, despite significant advances in therapeutic, pharmacological, and monitoring technologies occurred in the past century and in the beginning of this millennium, there are still big challenges in maintaining acceptable glycemic indexes, DM control, and a healthy lifestyle. Currently, the influence of these therapies on the lives of diabetics is little explored, requiring robust investigation studies. Therefore, the objective of this study was to review research articles aimed at analyzing the impact of innovative technologies on the lives of adult diabetics.

METHODOLOGY

This is an integrative literature review. This type of study consists of an Evidence-Based Practice (EBP) instrument that allows a holistic understanding of the studied phenomena since it admits experimental and non-experimental studies about a particular study area. It enables the association between theoretical and empirical knowledge, as well as the inclusion of a wide range of purposes, such as defining ideas, reviewing theory and evidence, and analyzing problems in the set of rules on how to proceed in order to produce scientific knowledge of a particular theme[7].

For the elaboration of this review, six distinct and sequential stages recommended in the literature were followed[8], namely: 1) identification of the research theme and question; 2) establishment of inclusion and exclusion criteria of studies, with searches in the literature; 3) definition of the information to be extracted from the selected studies; 4) evaluation of the included studies; 5) interpretation of the results and; 6) presentation of the review. As a starting point, the following guiding question was formulated: *What is the impact provided by the innovative technologies on the Quality of Life (QoL) of adult diabetics?*

To answer this question, an electronic research was conducted in the following databases: *Medical Literature Analysis and Retrieval System Online* (MEDLINE), *Cumulative Index to Nursing and Allied Health Literature* (CINAHL), *Web of Science*, *Springer Link, Latin-American and Caribbean Health Sciences Literature* (*Literatura Latino Americana e do Caribe em Ciências da Saúde*, LILACS) and in the *National Center for Biotechnology Information* (NCBI/PubMed) *and Scientific Electronic Library Online* (SciELO) virtual libraries. The search was performed in November 2016, with the crossing of following Descriptors in Health Sciences (*Descritores em Ciências da Saúde*, DeCS) in the basic database form: *Diabetes mellitus* x *Quality of life* x *Innovations*, *Therapy* x *Diabetes mellitus* x *Quality of life*, *Diabetes mellitus* x *Quality of life* x *Technology*. This study selection process of this review is illustrated in Figure 1.

The following were adopted as inclusion criteria: studies whose outlines were well-designed randomized clinical trials (RCTs) (level 2 of evidence) [9], fully published, in the period from 2012 to 2016, in Portuguese, English or Spanish, and which had shown the influence of the new technologies on the lives of adult diabetics. RCTs were chosen due to their best level of evidence and their availability in the literature. The following were excluded: duplicate records in more than one database, when considered only once, performed with children, teenagers or animals, which addressed only DM clinical complications, and investigation with health education as their main intervention, given the intention to analyze only innovative technologies.

In order for data analyses be didactic, a synoptic table was used composed by the following variables: article title, year and country of publication, study outline, population and variables studied, therapy under study and its results.

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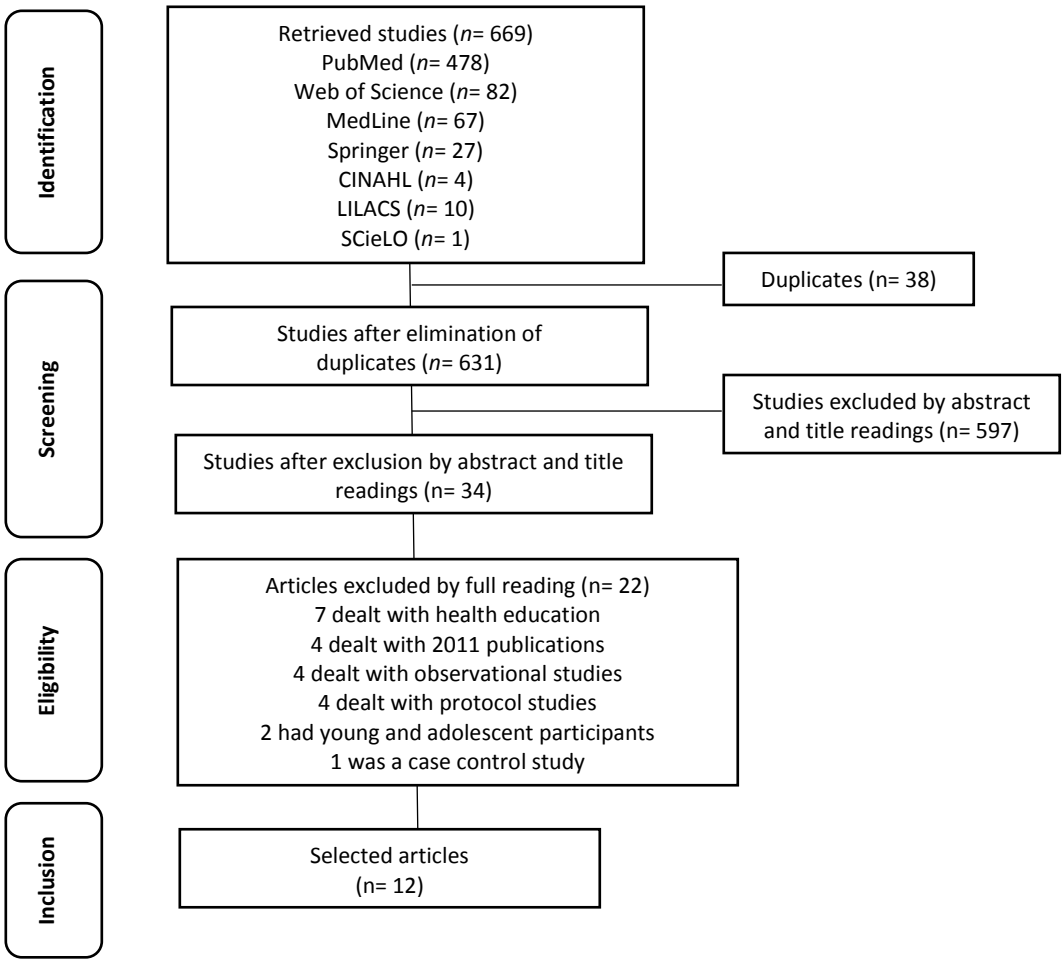

FIGURE 1: Search and selection diagram of the available studies in the databases, elaborated from the recommendations of PRISMA. Campo Grande, MS, 2016.

RESULTS AND DISCUSSION

The characteristics of the reviewed studies[10-21] are shown in Figures 2 and 3. It is noteworthy that these were published between 2013 and 2016, with predominance of United States production (5/12). The analyzed studies explored 11 different innovative technologies for the treatment, surveillance, and control of DM in adults, which included smartphones apps, pharmacotherapies, blood glucose monitoring devices, and interventions. Almost all technologies (10/11) presented beneficial consequences to the lives of diabetics and/or to DM management. Of the technologies that revealed benefits, only the blood glucose continuous monitoring device, with or without alarm function, *Health Coaching, Dapagliflozin,* and *CoolSense* did not present unfavorable aspects to life and management, according to the reviewed studies.

The *Glucose Buddy* smartphone app is a tool that helps the DM patient to take an active role in managing their own care.[10] In a general evaluation, by including 10 smartphone-based blood glucose monitors, *Glucose Buddy* was classified as easy to use, free and noted for its distinctive reminder features.[22] *Glucose Buddy data logs* provide an efficient, individualized and visual way to monitor and control physical exercise, medicine use, serum lipid levels, blood pressure, nutritional intake, and blood glucose.

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Therapy/ Technology	Authors, journal, year, country	Results found
Glucose Buddy	Kirwan et al. Journal of Medical Internet Research, 2013. Australia[10]	- Decreases HbA1c levels - Improves glycemic control - Abandonment of daily glycemic control follow-up
Mobile advice service	Mons et al. Plos one, 2013. Germany	- Decreases HbA1c levels and depression symptoms - Decreases systolic blood pressure - Improves physical QoL - Keeps individual's mental QoL levels - Reduction of the realized benefits when the diabetic individual disconnects from the advice service
Diabetes Integrative Diary: *DID*	Rossi et al. Diabetes Technology & Therapeutics, 2013. USA	- Decreases HbAc1 levels and basal insulin doses - Improves metabolic control - Improves perception of the frequency of hyperglycemic episodes - Improves social relations - Increase in hypoglycemic episodes
CoolSense	Wainstein et al. Diabetes Technology & Therapeutics, 2013. Israel	- Reduces the sensation of pain in the application region (fingers) or in the sites of subcutaneous insulin application - Negative changes were not reported in QoL or management
Dapagliflozin	Grandy et al. Int J Clin Pract, 2014. USA	- Maintains high levels of health condition and QoL - Controls blood glucose - Decreases body weight to the desired level - Self-care difficulties (washing/getting dressed) - Reduction in mobility - Some participants reported pain, discomfort, anxiety and a feeling of depression

REFERENCE: Diabetes Mellitus: DM; Glycated hemoglobin: HbA1c; Quality of Life: QoL; United States of America: USA
FIGURE 2: Distribution of the articles published in the period from 2013 to 2014 on innovative technologies in the lives of adult diabetics. Brazil, 2018.

Besides this, the *logs* can be fully customized according to the user's preference and they include options to allow the individual to view glucose mean values at different hours of the day and to provide an HbA1c estimate. The *logs* also allow the patient to overlap their medication use and exercise over the glucose charts which provide a view to the user on how this affects their life. The app provides reminder notifications in case the user has not completed a selected task[23]. This explains its impact on decreasing HbA1c levels and the improvement of glycemic control, attenuating DM progression and the onset/worsening of comorbidities.

As an unfavorable factor, however, this technology presented glycemic control abandonment after the patient has used it for a while and ceased using it[10]. Non-adherence to treatment can significantly affect patient's health adversely, causing a negative impact on their relationship with the caregiver, apart from increasing the search and use of health resources.[24] Diverse research studies show that to encourage long-term acceptance and adoption, smartphone applications must be precise and *user friendly*[10]. This is especially relevant when the efficiency of smartphone applications is investigated to improve self-care among DM1 patients.

The Mobile Advice Service offered monthly telephonic advising sessions conducted by nurses. All orientations were performed according to the manual specifically elaborated for this end and the sessions were conducted according to the approach proposed by a standard questionnaire developed by the authors. The questionnaire included questions on the patient's physical and mental conditions, adherence to drug therapy, symptoms and on the lives of diabetics[11].

With this approach, the service has improved the physical and mental aspects of the participants, decreasing depression effects, systolic hypertension levels, and HbA1c levels. When there is an efficient educational intervention, in which the addressed content is assimilated by the participants, the knowledge level becomes higher, as seen in this study. This allows, subsequently, for a better disease control by the patients. Many publications in different countries have been reporting the importance of educational programs to promote a wider adherence to the treatment, resulting in a better control of diabetes[25].

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Therapy/ Technology	Authors, journal, year, country	Results found
DRMS	Katalenich et al. Clinical Therapeutics, 2015. USA	- Absence of adverse events - Improves social and professional QoL - Potentiates adherence to therapy - Technical difficulties during calls and operational for insulin types and doses
DBEES	Drion et al. Journal of Diabetes Science and Technology, 2015. Netherlands	- No changes in HbA1c and QoL levels
Health Coaching	Wayne et al. Journal of Medical Internet Research, 2015. Canada	- Reduces body weight and abdominal circumference - Improves life satisfaction and mood - Reduces Hb1Ac and depression symptoms and anxiety - Improves psychological well-being - Increases the usual care measures and the prestige of the importance of physical exercise
Continuous glucose monitoring device	New et al. Diabetic Medicine, 2015 United Kingdom	- Reduces HbA1c levels, hypoglycemic episodes and capillary measurement frequency
Dapagliflozin	Grandy et al. Diabetes, Obesity and Metabolism, 2016. USA	- Eliminates excess body fat - Improves general health condition and QoL - Entails treatment satisfaction
Automates Bolus Calculator	Hommel et al. Diabetic Medicine, 2016. United Kingdom	- Improves metabolic control and HbA1c levels - Offers a low risk of side effects - Provides treatment satisfaction
Empagliflozin	Chirila et al. Qual Life Res, 2016 USA	- Reduces and sustains HbA1c levels - Presence of adverse effects, mainly hyperglycemia, hypertension and urinary infection - Hypoglycemic episodes with the use of the medication

REFERENCE: Diabetes Mellitus: DM; Glycated hemoglobin: HbA1c; Quality of Life: QoL; United States of America: USA
FIGURE 3: Distribution of the articles published in the period from 2015 to 2016 on innovative technologies in the lives of adult diabetics. Brazil, 2018.

However, when the patient stopped using the advice service, the result was a decrease in the beneficial effects previously achieved, this is, the interventions were not capable of promoting definitive behavioral changes[11]. These changes will only be permanent if accompanied by population-wide public health policies and effective primary health care monitoring.

The *Diabetes Interactive Diary (DID)* is a mobile software that works like an insulin *bolus* calculator. It provides support to the patients on managing glycemic levels by a food atlas and on the worsening of the values obtained by blood glucose self-monitoring. Based on the stored data, the application automatically calculates the most proper insulin dose to be injected after each meal. All recorded data are sent to the doctor via SMS. Any therapeutic and behavioral new prescription can be sent from the clinic's computer to the patient's cell phone[12].

As advantages, the *DID* technology presented improvements in metabolic control and in the perception of the hyperglycemic episodes frequency, a significant decrease of HbAc1 and of the daily basal insulin doses, and strengthening of the social relationships[12]. Metabolic control improvement happens simultaneously to QoL in terms of hyperglycemic perception, fear of hypoglycemic and satisfaction on social relationships. The improvement in QoL and in treatment satisfaction represents a key objective in the care for any chronic disease[26,27]. However, the technology presented an unfavorable aspect related to lifestyle and DM control due to the high frequency of hypoglycemic episodes[12].

CoolSense consists of a contact device that, when applied to the skin, anesthetizes the site and reduces pain while performing the glycemic and insulin therapies. Only the expected benefit of a significantly reduced sensation of pain has been reported for this technology[13]. Using the *CoolSense* device significantly decreased the pain caused by needling and the patients also wanted to use the device for daily monitoring. Still, differences on glycemic levels were not observed, since the device does not alter glycaemia in a clinically significant way[13].

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Dapagliflozin is a test drug developed for DM2 treatment. It blocks the sodium-glucose 2 (SGLT2) co-transporter, a protein responsible for kidney glucose re-absorption that leads glucose excess elimination through urine and improves diabetes control. Diverse results have already demonstrated that SGLT2 can reduce body weight in DM2 patients, since glucose elimination through urine leads to a calorie loss (in the order of 200 to 300 calories a day), resulting in a negative energy balance[28].

The technology was associated with important inconveniences classified from mild to moderate, such as self-care difficulties (washing/getting dressed), pain, discomfort, anxiety, a reduction in mobility and feelings of depression. Nevertheless, it had a high-level impact on self-reported general health conditions and lifestyle, on the reduction of blood glucose and of body weight, as well as on treatment satisfaction[14,19]. These data drew attention because, even in front of diverse unfavorable aspects regarding lifestyle, participants were pleased with the Dapagliflozin.

The Diabetes Remote Monitoring and Management System (DRMS) uses technology (cell and/or land-line phones) to minimize the use of human resources. The system uses rule-based technology to automate manual care and monitor the care plans, creating custom actions and interventions based on parameters defined by the physician and on the specific medical protocol. The system was designed to contact the patient daily, via automated text or voice messages. From these messages, the users would be able to report their blood glucose levels or answer later. The system also reminds them to monitor the glucose and to take the medicines, apart from warning the professional when problems come out[15].

The *DRMS* impacted positively on the lifestyle, on treatment efficiency and on DM control, since the absence of secondary adverse events was evidenced, with improvements in the social and professional lifestyles and a wider adherence to the drug treatment. It is understood that the self-care empowerment of diabetes patients improves considerably the adherence to the treatment and, consequently, their clinical condition[29]. Despite customer's satisfaction, the technology presented operational obstacles, such as proper operating setbacks for all types and doses of insulin and technical difficulties during automated calls.

In this sense, a study pointed out that these problems represent a challenge for the users and that they can make them lose interest in using their mobile devices[30]. Another study recorded that the resources added to the application design can compromise the users' capacity to achieve their objectives, since they increase complexity and decrease usability[31]. Therefore, there is a need for improvements in this technology, with a view to simplicity, efficiency and then, wider adherence.

The *Diabetes Under Control* (*DBEES)* system is a smartphone application that provides data related to DM self-care to the patients. With the application, it is possible to store the glycemic values and to calculate the rate of carbohydrate intake. The system has an alarm function which warns the patient about the time to take the medication. Diverse studies have found that diabetes education programs, which included nutritional therapy and individualized health plans, have been associated with reduced HbA1c in individuals with DM[32]. However, *DBEES* did not promote changes in HbA1c levels and, consequently, alterations were not found in the lives of diabetics[16].

Health Coaching is a service defined as *health training*, whose behavior-change specialist offers advice services to diabetics. The coaches have experience in managing chronic diseases and evidence-based theory adapted to the disease state. With the help of the health coach, clients set health-related goals and track daily progress. This technology showed countless benefits related to lifestyle; treatment, complications prevention, surveillance and DM control, and no unfavorable aspects have been observed[17].

These educational interventions designed to facilitate the development of specific skills for diabetes coping can improve the QoL of patients with this disease[33].

The Continuous Glucose Monitoring (CGM) invasive device, with or without alarm function, is an emerging technology that provides a continuous measurement of interstitial glucose levels. Apart from providing a more complete pattern of glucose excursions, CGM uses real-time alarms for hypoglycemic and hyperglycemic values, as well as alarms for rapid glycemic changes. These devices use glucose oxidase-based electrochemical subcutaneous sensors to detect glucose levels in the interstitial fluid. An electric current is generated as the glucose is oxidized by the sensor and the electric current is then transmitted to the receptor or monitor. Data is filtered to remove sensor noise and then the dosage value of blood glucose is provided[18].

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Reduction of hypoglycemic episodes and of capillary measurement frequency, shorter time in hypoglycemic state and a lesser variation in glycemic levels were positive aspects of this device. However, although this technology had a positive result in the reduction of hypoglycemic episodes, there were no significant alterations in HbA1c concentration from the baseline, which indicates that the reduced hypoglycemia was not caused by the worsening of the glycemic control[18].

The *Automates Bolus Calculator* is an insulin therapy counseling technology that accurately calculates fast insulin dose in just three steps: glycemic measurement, introduction of a certain amount of carbohydrates and by acquiring instantaneous insulin *bolus* without manual calculations. The device has a memory function and different possibilities of graphical visualizations for the data stored, significantly improves metabolic control and HbA1c levels, has a low-risk of side effects and diabetics show satisfaction with the therapeutic treatment. Unfavorable aspects related to lifestyle have not been reported[20].

Empagliflozin is also an oral antidiabetic drug that selectively inhibits the SGLT-2 co-transporter and increases urinary excretion of glucose by blocking renal glucose re-absorption[21,34]. The sustained reduction of HbA1c levels was the only immediate positive impact provided to the diabetics who used it. As inconveniences, however, this approach presented a higher frequency of adverse effects like hyperglycemia, hypertension, and urinary infection, with hypoglycemic episodes during the use of the medications[21]. A study reported that the hypoglycemic frequency observed while using Empagliflozin varied according to the background antidiabetic therapy[34]. DM2 patients are more likely to suffer urinary tract infections and genital infections. In addition, a slight increase in the risk of urinary tract infections has been reported in Empagliflozin-treated patients, especially among women. Nevertheless, these are low urinary tract infections that respond well to the recommended therapy[34].

The limitations of this study are the reduced number of RCTs on each of the innovative technologies, indicating a lack of evidence on the use of these approaches, as well as the inclusion of articles only in Portuguese, English, and Spanish, which may have excluded important studies in other languages.

CONCLUSION

Considering the reviewed articles, the main innovative technologies used in DM treatment, surveillance and control play a crucial role in the development of strategies to improve the health outcomes in adult diabetics. A positive influence of these technologies was observed in the management and life of the clients, since practically all of them significantly reduced Hb1Aclevels, as well as promoted a better metabolic and glycemic control. However, diverse open questions and technical challenges are identified as key-factors to fully adopt these systems in the clinical practice.

Despite the great advances achieved in DM therapy, studies with more robust designs are still needed to achieve the most appropriate method of glycemic control and insulin administration for each person and which may favor QoL.

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