A Comprehensive Review of Modern Methods to Improve Diabetes Self-Care Management Systems

Alhuseen Omar Alsayed[1], Nor Azman Ismail[2], Layla Hasan[3], Farhat Embarak[4]
School of Computing, Faculty of Engineering, University Teknologi Malaysia (UTM), Johor Bahru 81310, Malaysia[1, 2, 3, 4]
Department of Research Affairs Unit, Deanship of Scientific Research (DSR),
King Abdulaziz University, Jeddah 21589, Saudi Arabia[1]

***Abstract*—Diabetes mellitus has become a global epidemic, with an increasing number of individuals affected by this chronic metabolic disorder. Effective management of diabetes requires a comprehensive self-care approach, which encompasses various aspects like monitoring blood glucose levels, adherence to medication, modifications in lifestyle, and regular healthcare monitoring. Innovative techniques for bettering diabetic self-care management have been developed recently as a result of developments in technology and healthcare systems. This comprehensive review examines the modern methods that have emerged to enhance diabetes self-care management systems. The review focuses on the integration of technology, Behavioural Change Techniques (BCTs), behavioural health theories such as Transtheoretical Model (TTM), the Health Belief Model (HBM), Theory of Reasoned Action/Planned Behaviour (TPB), Social Cognitive Theory (SCT) techniques to promote optimal diabetes care outcomes. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 standards were followed in this research's documentation. The Systematic Literature Review (SLR) period, which covered 2009 to 2020, was used to acquire the most recent complete review. Overall, the SLR results show that self-care interventions have a favourable impact on behaviours modification, the encouragement of good lifestyle habits, the lowering of blood glucose scales, and the accomplishment of significant weight loss. According to the review's findings, treatments for diabetic self-management that included behavioural health theories and BCTs in their creation tended to be more successful. In order to assist academics and practitioners with the creation of future applications, the restriction and future direction were finally defined. After recognising the potential for combining BCT methodologies and theories, it creates self-management interventions. Depending on these recognised cutting-edge mechanisms, the current SLR can assist application developers create a model to construct efficient self-care interventions for diabetes.**

Keywords*—*Diabetes self-care; diabetes management; systematic literature review; BCT theories

I. Introduction

Diabetes is a serious condition caused due to high blood sugar levels. High blood pressure, renal disease, and heart failure may all occur as a result of this chronic illness [1]–[4]. Type 1 diabetes and Type 2 diabetes represent two different types of diabetes. While Type 2 diabetes, which accounts for roughly 90% of all cases, is the most common type, Type 1 diabetes, which can't be prevented, is characterised by inadequate insulin in youngsters. A major issue faced by the health system is the rising incidence of diabetes, which has turned into a global crisis. For example, according to the National Diabetes Statistics Report, 13% of Americans have diabetes. Global estimates indicate that 9% of people worldwide have diabetes, and that number is expected to rise to 12% by 2030 [5]. Ageing, obesity, and people's dietary habits are thought to be contributing factors to the rising number of diabetes [3]. These troubling trends highlight the critical requirement for researchers and technologists to develop practical diabetes treatment strategies. Several applications have been created for managing diabetes self-care as a result of the rise of diabetes cases in the world. Applications for managing diabetes are believed to be among the most popular ones from the Google Play store [4]. Numerous studies have demonstrated that diabetes self-care practises can considerably enhance a range of clinical outcomes for diabetics [5], [6]. In earlier studies, the effectiveness of diabetes self-care tools was qualitatively investigated [7], [8]. Additionally, a number of meta-analyses [9]–[11] have examined the usefulness of self-care tools for managing diabetes using quantitative data. The majority of previous investigations, nevertheless, ought to have uncovered the impact of BCTs on self-care management [11], [12]. Besides self-monitoring, the major problem with the existing system models is that the majority of the current mHealth apps make limited usage of BCTs and have few features [13], [14]. Moreover, the absence of customized feedback, poor user interface design, and accessibility concerns with current medical monitoring programmes are further problems (e.g. limited data entry options) [7], [15]–[17]. Additionally, diabetes patients think that e-self-management health applications should be interesting and provide a variety of functions that cover an extensive amount of information encompassing emotional and psychological support [18]. The impact of individual BCTs on diabetes management cannot be discounted because managing diabetes is strongly related to behaviour that requires appropriate modification [19]–[22], Therefore, it seems like there is a lot of uncertainty if these mobile and web-based healthcare applications are an affordable means to give diabetes self-management education and whether they improve health outcomes and provide support in the real world [19], [20], [23].

The study aims to comprehensively review and analyze modern methods designed to enhance diabetes self-care management systems. The formulation of research questions (RQs) is crucial for determining the overarching goals and anticipated results of a study. The study mainly focuses on the research question “How can we use technology and

behaviour-based techniques to make diabetes self-care better and healthier for people with diabetes?" To find a solution for this question, following research questions are framed.

1) How well do diabetes management applications support and facilitate diabetic self-care practices?

2) What are the prevailing methodologies and techniques commonly utilized in the realm of diabetic self-care management to facilitate behavior modification?

3) Which theoretical frameworks and models can be effectively employed to underpin and guide the progress and application of diabetes self-care management applications?

4) What common aspects do diabetic self-care management programmes use today to effectively and completely treat the disease and empower patients?

5) What are the intricate challenges encountered in the current landscape of diabetes self-care applications, and what are the anticipated future directions and potential advancements?

In order to answer this question, the research builds following research objectives: i) to evaluate the extent to which existing diabetes management applications effectively support and facilitate self-care practices among individuals with diabetes. ii) to identify and analyze the methodologies and techniques commonly employed within the domain of diabetic self-care management. This includes an examination of strategies for behaviour modification and lifestyle improvement, iii) to explore and assess the theoretical frameworks and models that can be leveraged to underpin and guide the development and implementation of diabetes self-care management applications. iv) to identify the common elements and best practices employed by successful diabetic self-care management programs to comprehensively address the disease and empower patients in their self-care journey, v) to investigate the intricate challenges and limitations present in the current landscape of diabetes self-care applications. It will also explore anticipated future directions and potential advancements in the field to enhance the efficacy and usability of these applications.

The key significance of this study is that it underscores the importance of addressing various facets of diabetes management beyond medication, including lifestyle modifications and monitoring. It also offers valuable insights into how psychological and behavioral principles can improve diabetes self-management. It serves as a roadmap for future researchers and application developers to develop a more effective tools and interventions for diabetes self-care.

The rest of the sections are given as follows: Section II provides the detailed investigation of literature works on diabetes self-management and healthcare behavioral models, diabetes management interventions. Section III briefs the review methodology that comprises of the selection of articles for the review process. Section IV details the search results and analysis, and Section V briefs the outcomes and findings of the research questions. Section VI provides the overall discussion and Section VII finally concludes the study.

II. Related Works

A. Diabetes Mellitus

A major wellness concern and pandemic disease with a high incidence in both emerging and industrialized nations, diabetes impacts people all over the globe [24], [25]. As per the World Health Organization, diabetes is a chronic disorder with a variety of causes. The characteristic of this illness is prolonged hyperglycemia with abnormalities in carbohydrate, lipid, and protein metabolism induced by impairments in insulin action, insulin synthesis, or both. Additionally, diabetes-related complications and mortality could cause serious economic and social consequences for people, families, enterprises, and society overall [26]. People and medical institutions all across the world are being plagued by this epidemic [27], [28]. Diabetes presents a variety of dangerous side effects, involving dysfunction or long-term damage, and also organ failure [29]. There are numerous causes that might lead to a chronic illness like diabetes, but the following are the most typical ones: the pancreas' insulin is not generated properly or the pancreas has been unable to produce enough insulin. Additionally, if left untreated, increased blood glucose levels, also known as hyperglycemia, raise the risk of long-term harm to a range of organs, including blood vessels and neurons. Some of the diabetes-related symptoms include increased urine and weight loss, weariness, and increased appetite and thirst [30], [31].

Type 1 diabetes affects 10-15% of all diabetics and can appear at any age, with the majority of cases occurring in those under 40. It can be triggered by a range of critical variables such as infections, diet, and toxins in those who are genetically predisposed. An investigation [32] found that people with diabetes who have Type 1 have life expectancies that are around twelve decades lower than those of the entire community. The second type of diabetes, often called non-diabetes, has become the most frequent. It is responsible for 85-90 per cent of all diabetic patients [33]. Diabetes that occurs later in life is referred to as "late-onset diabetes." Dietary changes, a regular fitness routine, and medications could be treated Type-2 diabetes effectively. The third type of diabetes is gestational diabetes. Diabetes develops during pregnancy, unless the pregnant women already have been diagnosed, as a result of enhanced glucose levels or insulin levels. According to the International Diabetes Foundation, around 16% of women giving birth in 2019 have DM during pregnancy, with GD accounting for 85.1% of the total [34].

B. Self-Management of Related Activities

The expression "self-management" denotes the routine tasks or activities that an individual needs to carry out for managing or lessening the effects of disease on their wealth and wellness in order to avoid further illness [35]. Medication adherence, physical exercise, healthy diet, monitoring, good coping, risk reduction, and problem-solving all seem to be examples of diabetes self-management practises that are important for better preventive measures [36]. Patients' adherence to diabetes self-management differed, showing that a number of factors will influence self-management decision-making mechanisms, either as enablers or as obstacles [37]. The care of diabetes mellitus is crucial for reducing long-term

effects and enhancing the T2D patients' quality of life. As per the American Diabetes Association, diabetes self-management-based education has been a pillar for optimum diabetes care. One viewpoint is that the complexity of T2D management necessitates the usage of DSME. Patients are assigned a variety of responsibilities, including a keeping regular doctor's appointments, confirming prescription schedules, and concentrating on self-care measures like online glucose tracking, healthy food modifications, and enhanced physical exercise [38]. However, people frequently struggle to maintain the many behavioral factors necessary for optimum glycemic control. Struggling to meet daily obligations, irritation, various types of mental discomfort, and an absence of self-commitment are all frequent problems [39]. Moreover, patients' levels of commitment to diabetic self-management varied, implying that many factors can affect self-management decision-making processes that could function as facilitators or barriers. DM management is critical for minimising long-term consequences and enhancing T2D patients' quality of life [36]. Therefore, consistent diabetic self-management was already linked to improve fewer complications [40], [41], blood glucose control, better quality of life, and a less peril of diabetes-related mortality [35]. Family members were able to offer both emotional and physical support. Instrument assistance could involve assisting patients with various chores, such as making appointments with healthcare providers or aiding with insulin treatment, and also assisting patients through self-management care. Providing delight and motivation to patients who've been frustrated or unhappy as a consequence of their therapeutic intervention is a common form of emotional support [8], [42]. Additional behavior change treatments are necessary because conventional techniques are ineffective at modifying behaviours [43]. In order to communicate with patients as well as give them the tools they need to manage their individual health; a web-based system is a suitable choice [13]. It has been demonstrated that diabetics' glucose levels could be improved through the implementation of mobile and internet-based diabetes care strategies [44].

C. Concepts and Paradigms of Health Behavior's Impact on Diabetes Management Interventions

Theories of behavioural change aid in understanding human behaviour and change. They provide justification for why particular acts occur. These ideas are crucial for altering behaviour to improve health consequences [45]. Current years have seen the application of these theories to the management of persistent adherence to prescribed drugs and lifestyle changes [46]. Interventions for changing behaviour related to health may be more successful if they are based on the right hypothesis [47]. Through the identification of specific mediators—behaviour-causing variables, change-causing factors, and the mechanisms by which they operate during an intervention—theoretical models shed insight on basic concepts [48]. The following theoretical models are frequently used for strategizing and assessing public health behavioural change interventions: Health Belief Model (HBM), Transtheoretical Model, Social Cognitive Theory, Social Ecological Model, and Theory of Reasoned Action/Planned Behaviour [49], and Information-Motivation-Behavioural Skills models [50].

The Trans theoretical Model, also called as the Phases of Transformation Model [51], is one of the most well-known theories or models for health behaviour change that places a strong emphasis on the person's capacity for decision-making. Prochaska and DiClemente [52] created this model in the late 1970s based on research comparing the experiences of people who modify their conduct on their own to those who get therapy and how capable they are of doing so. This study's framework is based on this model. TTM underlines that people don't alter their behaviours right away but rather gradually, consistently, and through a cyclical process. There are five stages of change that individuals can go via in accordance with TTM: contemplation, planning, action, servicing, and relapsing [53]. When changing their lifestyle, everyone, even those with diabetes and prediabetes, typically goes through these stages. TTM provides comprehensive instructions on how to assist diabetics and prediabetics in making lifestyle and dietary changes that will promote healthy behaviour. The Theory of Reasoned Action (TRA) is expanded upon by the Theory of Planned Behaviour (TPB). Icek Ajzen put out this notion in 1985. According to TPB, an individual's willingness and degree of control over an activity impact how vigorously that behaviour will be carried out. An individual's behavioural intents and behaviour are influenced by their attitude towards a conduct, subjective standards, and perceived behavioural control [48], [54]. According to this principle, the concept of Personality is indirectly affected by beliefs that are influenced by background and demographic information like education, income, personality characteristics, prior behavior's, and aspects of the social and cultural environment [55].

The attitude towards behaviour, the importance others place on the behaviour, and the degree of perceived behavioural control all affect how strong an intention is. This applies to people with diabetes and prediabetes because in order to modify their conduct, they must also alter their mindset. They must also identify the triggers that encourage change [54]. The main significant factor influencing people's behaviour is their want to modify [54]. When patients want to change, they might alter their food and way of life. To forecast human social conduct, this theory is frequently applied and quoted [56]. Self-determination theory (SDT) encourages individuals to act in productive and beneficial ways. SDT emphasises a person's level of self-motivation and self-determination. Objectives and the pursuit of objectives are stressed in SDT. It suggests that what we are working for and why we are working towards it are both crucial for our wellbeing [57], [58]. According to the belief, if someone may pursue their objectives in their own way rather than being forced to adhere to rigorous rules, they would be happier and more successful. When someone pursues their goals for their own reasons and through their own ways, they would be happy and self-actualized [59]. By focusing on health-related advantages, patients will be more likely to accept personal responsibility for their health. The objectives for this must be independent and intrinsic. They should let to choose their own realistic goals. According to studies, SDT therapies for diabetes resulted in successful treatment outcomes [60]. It also encourages individuals by allowing them to identify the driving force behind transformation. Additionally, it is

observed that goal-setting is effective when supported by encouraging and compassionate individuals as opposed to dominating or directive people [61].

The Health Belief Model [62], [63], was created in the 1950s to address why certain individuals do not utilise the available health treatments. According to HBM, perceived vulnerability, severity, advantages, and obstacles all have an impact on conduct. The model describes and forecasts behaviour connected to health, including attitudes about one's health issues, the perceived advantages of taking action, obstacles, and self-efficacy in engaging in health-promoting activity. The health-promoting conduct should be triggered by cues to action. This approach was initially developed by social psychologists at the United States Department of Health and Human Services [64]. The concept of "perceived vulnerability" describes the probability that a person believes to be susceptible to get the illness if they continue with their current behaviors. On the contrary, perceived severity describes how serious the ailment is and how it affects people [65]. The perceived threat changes as a consequence of these behaviors. When people alter their behaviour, there could be apparent benefits or shortcomings of putting the unique activity into practise, among them perceived difficulties which could prevent the successful effectiveness, as well as both. For example, there might be perceived reduction in their chances of getting sick. The four factors mentioned above work together to affect the likelihood of participating in the behaviour. Information on the dangers and consequences of diabetes should be given to patients. Individuals must be made aware of the seriousness of the condition in order for them to change their bad behaviours and adopt healthy ones. Additionally, the advantages and drawbacks of their new outlook and behaviour ought to be explained to them. This should encourage individuals to adopt new habits and maintain their commitment to an improved diet and way of life [66].

Self-Regulation Theory describes the steps and elements involved in making decisions about one's thoughts, feelings, words, and actions. Self-regulation is concerned with the mechanisms that convert beliefs into intentions and intentions into actions, which ultimately results in the accomplishment of the connected objective. This idea focuses on a person's capacity to control their behaviours and their lives [67], [68]. SRT is made up of four components: requirements for desired behaviour, the drive to sustain standards, awareness of the conditions and thoughts that proceed standards-breaching, and willpower. SRT is centred on the idea of people setting the goals and monitoring their development in respect to those goals [69]. When there is a difference between their present situation and their aim during the comparison, individuals adjust their activities and behaviour in order to reach the goal. Diabetics should have the internal fortitude to alter their conduct in order to adjust their food and lifestyle. They should be self-motivated and devoted, with the purpose of transforming coming from inside. Self-control is crucial for developing new habits and viewpoints [70]. It aids patients in committing to their new conduct. In addition, students become more driven to accomplish their goals when they may define their own objectives and assess their progress in relation to those objectives [71]. The Relapse Prevention Model seeks to impart knowledge on how to anticipate and address the issue of recurrence to persons wanting to change their behaviour's. Relapse occurs when a person fails to alter their conduct to match the desired behaviours. This approach proposes two methods for preventing relapses, which may be used either as a targeted maintenance plan or as a more comprehensive programme of lifestyle modification. The major goal of this paradigm is to change compulsive or addictive behavioural patterns.

One of the most well-liked theoretical paradigms for comprehending and altering health-related behavior's targeted at controlling persistent diseases is social cognitive theory (SCT). The SCT has proven significant behavioural changes leading to better health outcomes as the cornerstone of efficient illness self-management strategies [72], [73]. It began as the Social Learning Theory, which was referred to be the convergence of the cognitive and behaviourist approaches. Contrary to many other hypotheses of behavioral modification in health promotion, the concept of the SCT takes into consideration the unique ways that individuals develop and sustain a habit. In the most recent version of social cognitive theory, a complex causal structure is proposed in which beliefs about self-efficacy interact with knowledge of health hazards and advantages, targets, standards for the results, structural and social obstacles to modification, and the perceived facilitators of behavioral growth. In the temporal framework of the Social Comparative Theory self-efficacy plays a crucial regulatory function and is a fundamental belief that significantly impacts behaviour [74]. As per the Social-Cognitive Theory (SCT), interactions between the environment, a person's characteristics, and their behaviour affect behaviour change. The most significant influence on the acceptance of physical activity as a lifestyle change has come from the Social-Cognitive Theory [75]. It uses both cognitive and behavioural elements to encourage behaviour modification, comparable to the TTM [76]. Self-efficacy is the central construct of the social cognitive theory, but it also includes the concepts of social support, outcome expectancies, and self-regulation [77]. According to recent studies, while boosting a person's self-efficacy is vital for enhancing physical activity and exercise adherence, doing so is most successful when combined with using the other SCT elements. For the specialized maintenance approach, attention should be focused on strengthening the maintenance of behavior change, once a person has successfully predicted a behaviour change. The maintenance of behavioral change might take the shape of ongoing meetings, treatments, and other techniques that can make it last longer. Regarding the general one, the emphasis should be on facilitating variations in a person's habits and way of life. This general program's objectives are to instruct the client on how to live a balanced lifestyle and to stop the development of negative habit patterns [78].

The Information-Motivation-Behavioral Skills (IMBS) paradigm promotes the user-centered and evidence-based application of information in health-related situations [79], [79], [80]. It was first created to anticipate HIV preventive behaviour in response to the HIV epidemic. It was effectively used in the design of treatments that enhanced and predicted

adherence to medication among diabetic patients [81]. The IMBS offers a framework for comprehending and supporting disease prevention practises across populations, and it has a wide range of possible applications in health promotion practise [82]. The model focuses on a collection of components (factors) linked with illness management in terms of information, motivation, and behavioural skill. The model claims that behavioural changes are primarily brought about by changes in behaviour that occur as a consequence of informational and motivational interventions [80]. The third part of the model shows how knowledge, motivation, and the behavioural abilities needed to carry out self-management behaviours independently and to a substantial amount indirectly influence actions. When they regularly found a strong correlation among behavioural outcomes and IMBS and in cases of diabetes, academics and educators in diabetes health promotion have used IMBS. Information and motivation affect the behavioural skills of diabetes patients, ensuring that they have the resources necessary to engage in the desired actions. Finally, this boosts a patient's self-efficacy, or belief in their ability to carry out self-management actions [83]–[85].

D. Diabetes Prevention and Management Interventions

Diabetes is a chronic illness with a high incidence in many countries. It is marked by raised blood glucose levels and the possibility of both acute and chronic complications. It is generally recognized that treating diabetes is a difficult procedure that necessitates both a specific pharmacologic treatment plan and a change in lifestyle [86]. Effective behavioural change, thorough education, and self-management are some of the most important ways to prevent complications from diabetes. However, this procedure is time-consuming and costly. Recent research on the use of smartphone technology for managing diabetes has shown to be a useful tool for lowering haemoglobin levels, particularly in Type-2 diabetic (T2D) patients. The effectiveness of this approach among Saudi patients has not, however, been the subject of any recognised studies [87]. Diabetes management is a difficult procedure that needs a wide-ranging strategy. Pharmacologic therapy is crucial, but it must be supplemented with lifestyle changes such a nutritious diet, frequent exercise, and careful blood glucose monitoring. People with diabetes can effectively manage their illness lower their risk of complications, and lead satisfying lives by using these techniques. In order to support diabetic self-management (DSM), mobile phone applications are frequently utilised. Numerous apps have been created to improve diabetic self-management [87]–[120].

Numerous studies have found compelling proof that employing apps motivates individuals to stick to management medical care, enhances glycemic control, and delays or avoids the onset of diabetic complications while also improving their standard of life [10], [121]. Additionally, studies revealed that applications for diabetes self-care can dramatically enhance a number of clinical outcomes related to diabetes [5], [6]. Earlier research examined the effectiveness of self-care applications for diabetes qualitatively [7], [8]. Users' desires and requirements for self-empowerment applications, however, have changed over time. For example, prior to this, the emphasis was primarily on the consumers administering their treatment alone with little help from the healthcare professionals and user preferences [15], [90], a large number of users, however, seem to anticipate that the applications would involve their healthcare providers in their regimens and routines, according to recent research [16], [122], [123]. The absence of customized feedback, poor user interface design, and accessibility concerns with current medical monitoring programmes are further problems (e.g. limited data entry options) [7], [15]–[17]. In addition, very few programmes have been created taking the needs of consumers into account [16], [85], [124]. As an outcome, many currently available programmes lack certain functionality [122]. It has been suggested that not enough thought has been given to end users' preferences as a cause of the low acceptance and utilisation of applications. Investigations are beginning in this area, and it is crucial to incorporate theories of health behaviour modification in the creation of diabetes management. Current research by Block et al. [125] stresses the benefits of the fully automated Alive-PD Diabetes Prevention Programme, which offers six to twelve months of weekly, step-by-step counselling on improving exercise, modifying eating habits, and losing weight . Although it is claimed that several applications have been created employing health behavioural change ideas, these theories have not yet been the subject of any study [126]. Additionally, there is additionally no appropriate outline for preventing diabetes that incorporates behavioral change theories and all other essential components [127].

III. Review Methodology

A PRISMA-based technique is used in the SLR approach. PRISMA provides a reliable and repeatable strategy for identifying literature. It also offers a manual for identifying, evaluating, and choosing research papers. In Fig. 1, the PRISMA procedure used in this SLR is depicted. The following subsections provide details on the SLR procedure:

A. Selection of Resources

The search process was carried out using nine digital online libraries to gather pertinent articles. In this study, Scopus, Google Scholar, ScienceDirect, Web of Science, SAGE, and Taylor & Francis Online were among the online databases that were investigated. These online databases were selected because they were thought to be the most ideal for offering comprehensive information in the area of older persons' social communities. While Scopus is a collection of peer-reviewed literature with approximately 22,000 articles from 5000 publishers worldwide, WoS is a powerful database with around 33,000 journals encompassing more than 250 subjects. In the area of diabetes treatment interventions, other digital libraries including Google Scholar, ScienceDirect, SAGE, and Taylor & Francis Online also have a sizable number of pertinent records available.

The articles from 2010 to 2022 were chosen for the SLR study in order to gain the most recent and complete review: (1) Appropriate resources pertaining to diabetes, mHealth apps (web-based and mobile apps), BCTs, and behavioural change theories make up the search phrase. Terms like "Mobile App" AND "Internet based Application" OR "diabetes" AND

"mHealth" OR ("behaviour change techniques" AND "diabetes" AND "mHealth" AND "Internet based application") are utilized to find more pertinent papers for this review. Moreover, the references of earlier literature were thoroughly examined in accordance with the comparable studies published in [9]–[11], [128], [129].

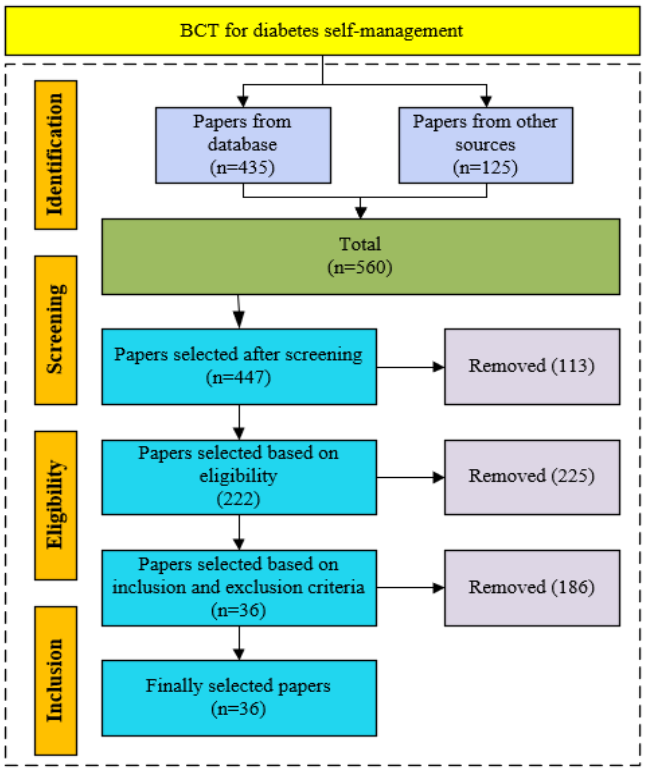


Fig. 1. The flow diagram of the review process based on PRISMA adopted in this study.

B. Selection of Papers

A manual search was taken into account in addition to the search phrases used in the automatic search in order to completely recognize the pertinent research. The 500 research papers were found using keywords during the identification step, comprising 435 records found automatically when searching digital databases and 125 publications found manually by searching citations. After eliminating duplicates, inappropriate, and irrelevant publications, 447 published papers were chosen for the screening stage. 113 papers were ultimately eliminated after the remaining documents underwent additional screening based on titles and abstracts. After that, 222 more entries were subjected to the full-text evaluation. Following the removal of 186 articles based on the inclusion and exclusion criteria as well as the quality rating criteria, 36 articles remained. Regarding literature types, the effectiveness of self-care applications for adults 18 years and older at risk for getting diabetes was only investigated in article journals that concentrate on either research or design. For the current SLR, in particular, experimental, quasi-, and design investigations were taken into consideration. Many eligibility requirements and exclusion criteria are chosen. The studies that were chosen were those that have been peer-reviewed and published in English in journals or conference proceedings. Only conferences and journals are considered as types of literature; review articles, books, book series, and individual book chapters are not included. In order to clear up any ambiguity regarding translated literature, non-English publications were also expelled.

The chosen 36 articles were then imported into Zotero, a reference manager, for synthesis. The retrieved information includes information about the studies' and interventions' characteristics, such as the regions where the research studies took place, the platforms employed for the interventions, the percentage of baseline weight loss, and glycemic level. It should be pointed out that only the publicly accessible materials (such as the primary text, development procedures, supplementary materials, etc.) are taken into account for the extracting the data, identifying the application features, and BCTs coding processes because obtaining detailed information from authors remains challenging in many instances.

C. Coding Scheme

To identify the existence or absence of every method from the evaluated articles, the list of BCTs taxonomy published in reference [130] was given special consideration. To more accurately evaluate the chosen research, the coding process was carried out individually and separately based on the primary publications, protocols, and related investigations. The initial research methods described in reference [131] and the BCT training materials were employed to create an accurate and suitable coding process for the BCT's taxonomy application. It was noted that equivalent research activities could have described the same standardised therapies based on earlier investigations in [132], [133]. But it was also noted that the interventions are described in a different way in the literature for every research, but with some BCTs having been identified in one study yet absent in another and vice versa. The present research uses an imputation approach to tackle these problems and recover the missing BCTs.

Based on the three phases of all intervention data, an analysis was done to find the characteristics in [134]. In order to accomplish this, every application component's description, coding, as well as the platform itself, must initially specified. The imputation process was also used in a scenario where numerous studies evaluated a similar standardised intervention. Furthermore, the characteristics were divided into two categories based on the degree of engagement between the user and the application: interactive (two-way interaction) and passive (one-way interaction). A random sample of all application descriptions was used for these first two steps in order to assess their dependability. Third, each interactive and passive component was collected, examined, and discussed as a whole. These findings led to the identification of common themes between the interactive and passive components. After being divided into interactive and passive elements, the themes or clusters were given individual labels.

D. Quality Evaluation

To avoid the risk of biases in propagating a study, it is also essential to analyse the SLR data and assess its quality. Basically, an inadequately done study's outcomes could be

greatly influenced by a considerable bias from the research process, necessitating careful interpretation. Consequently, in order to produce an objective result in the SLR, these studies must be disregarded or at the very least acknowledged as such. It is also crucial to evaluate the strength of the evidence and any inherent bias in every research investigation using the correct standards. For the quantitative intervention analysis, the National Institute of Health and Care Excellence (NICE) quality evaluation checklist is employed to validate the quality of the chosen studies in [135]. It includes 27 items that allow for the evaluation of external and internal validity when each criterion was met, with "++" denoting the lowest bias risk or greatest level of quality.

IV. Search Results and Analysis

A. Scholarly Publications over Time

Diabetes patients' self-management system seems to be a research study that will be crucial for society development in the future. In this part, the number of publications discovered over a fourteen-year period from 2010-2022 was selected. In Fig. 2, it shows how the quantity of papers has decreased during the last three years. The number of articles published starts from one in 2010, gradually increased to 4 in 2013, 5 in 2016, peaked to 7 in 2019 and afterwards rapidly declined to 1 in 2020 and increased to 3 in 2022.

B. Research Methods and Methodologies

Researchers employed a number of methodologies, including mixed method analysis, non- randomized controlled observational study, randomized controlled observational study, single arm prospective study and quasi-experimental methods to analyse the data connected to online supporting systems for diabetes self-management. The majority of these researches were predicated based on randomized control study. Both qualitative and quantitative methodologies were used in combination to support each other in a certain study. The distribution of included papers across research approaches is shown in Fig. 3.

As shown in Fig. 3, one study employed a quasi-experimental single arm technique. Furthermore, 4 employed both observational study and non- randomized controlled observational study, 3 used single-arm prospective study, 6 employed mixed method design study, 2 employed prospective quasi-experimental study, and majority of the study, 15 articles employed randomized controlled trial-based study.

C. Publication Regions

The articles in this review came from all over the world, namely US, China, Australia, India, Saudi Arabia, Norway, Netherlands, Malaysia, Germany, Finland, Iran, Indonesia, Switzerland, Denmark, Italy and Sweden. In Fig. 4, it shows that the majority of the selected articles, 13 articles (36%) met our criteria from the US followed by China with 4% and Australia with 3%, India, Saudi Arabia and Norway with 2% each, and Netherlands, Malaysia, Germany, Finland, Iran, Indonesia, Switzerland, Denmark, Italy and Sweden with 1% each respectively.

The finding indicated that a large number of publications have been done for countries in the USA. The investigation was carried out in the Middle East, with a focus on Saudi Arabia. Furthermore, according to a WHO report, numerous individuals in Saudi Arabia have DM.

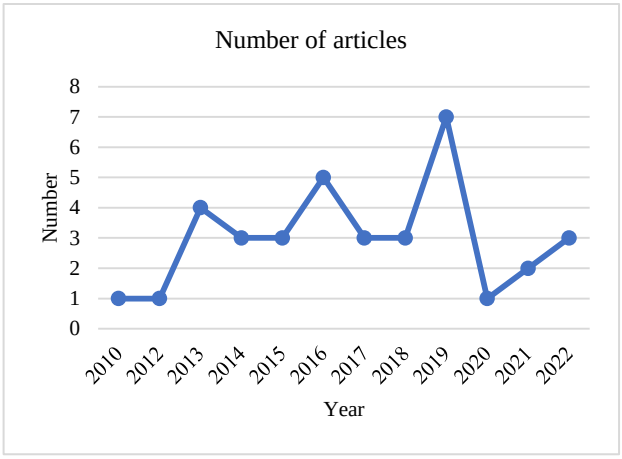


Fig. 2. Total amount of publications based on year.

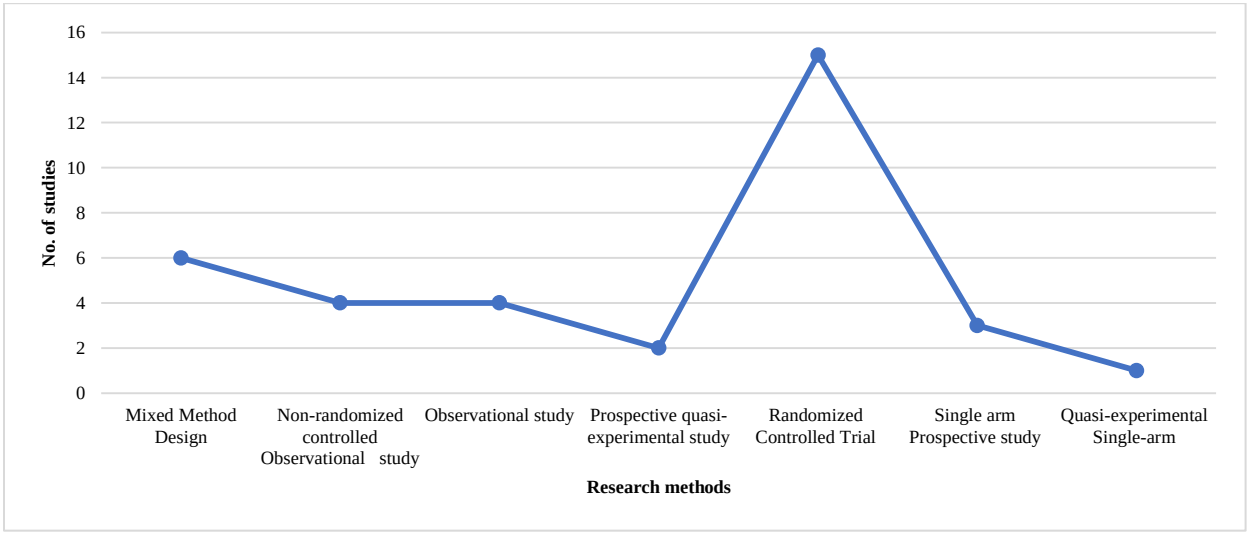


Fig. 3. Studies included over research approaches.

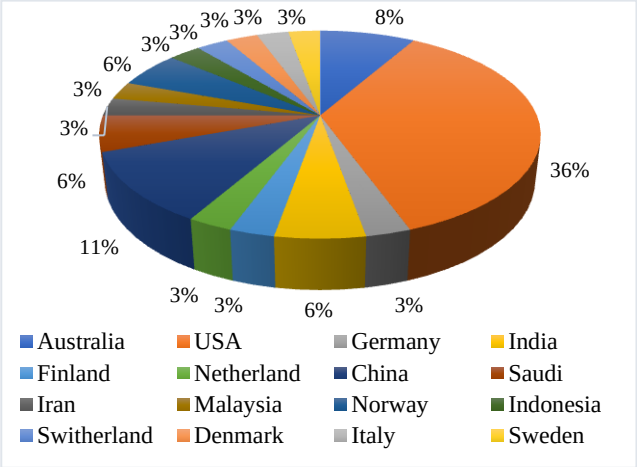


Fig. 4. Publication region/country.

D. Intervention Durations

Intervention duration in the reviewed articles ranged between 3 months and 24 months is showed in Fig. 5. More number of studies, 12 articles took approximately 3 months intervention duration, 10 articles took appropriately 6 months intervention duration, 6 articles took appropriately 12 months intervention duration, while rest of the 7 articles took more than 12 months of intervention duration.

E. Scholarly Articles Based on Theories

Fig. 6 shows the number of studies that have employed theory or model, ranging from Social Cognitive Theory (SCT) and Transtheoretical Model of Behavior (TTM) to Theory of Planned Behavior (TPB) and Health Belief Model (HBM). Other theories and models such as Self-Regulation Theory (SRT), Fogg Behavior Model, Cognitive Behavioral Therapy, COM-B model, IMB (Information-Motivation-Behavioral Skills Model), SDT (Self-Determination Theory), Just-in-time Adaptive intervention design, and Socio-material perspective have also been included.

From the Fig. 6, it is observed that the Social Cognitive Theory (SCT), Transtheoretical Model of Behavior (TTM), and Theory of Planned Behavior (TPB) are the most frequently used theories/models among the studies, whereas some theories/models like Fogg Behavior Model, Cognitive Behavioral Therapy, SDT (Self-Determination Theory), Just-in-time Adaptive intervention design, Socio-material and self-efficacy model have been utilized in a limited number of studies.

F. Scholarly Publications Based on Different Platform

Fig. 7 shows the various platforms used in various studies, showcasing the diverse approaches in delivering interventions or conducting research. Mobile apps emerged as the most frequently utilized platform, accounting for 56% of the studies. The combination of mobile app and web app platforms was employed in 19% of the studies, highlighting the recognition of multiple platforms' advantages. A smaller proportion of studies relied on websites (14%), DVDs (5%), and a combination of Short Message Service (SMS) and Email and a combination of website and mobile app (3%).

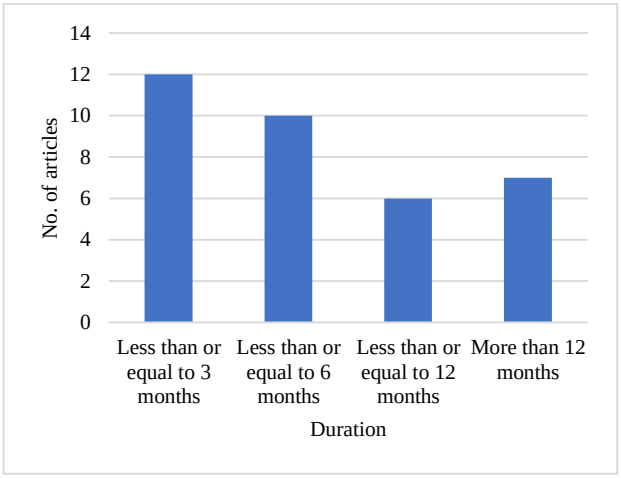


Fig. 5. Intervention durations.

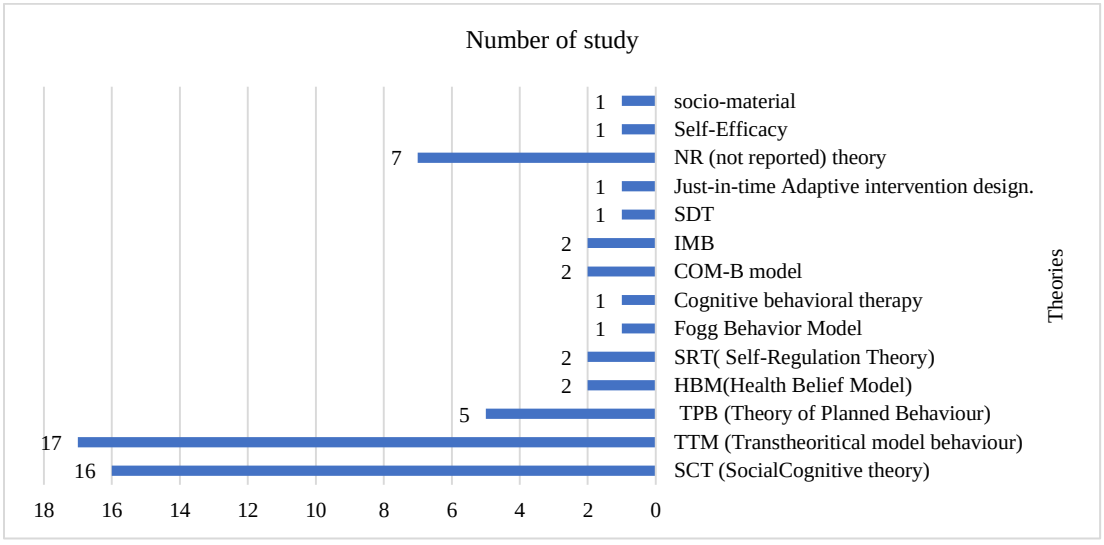


Fig. 6. Number of articles based on different theories.

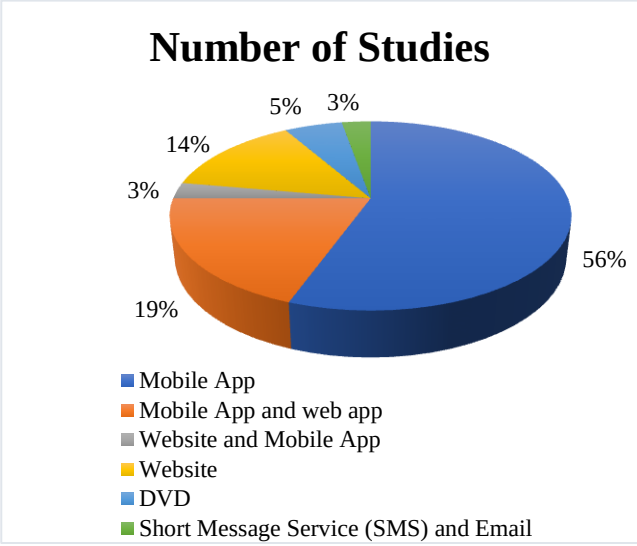


Fig. 7. Number of articles based on different platforms.

V. Research Question Outcome

RQ1- How well does diabetes management applications support and facilitate diabetic self-care practices?

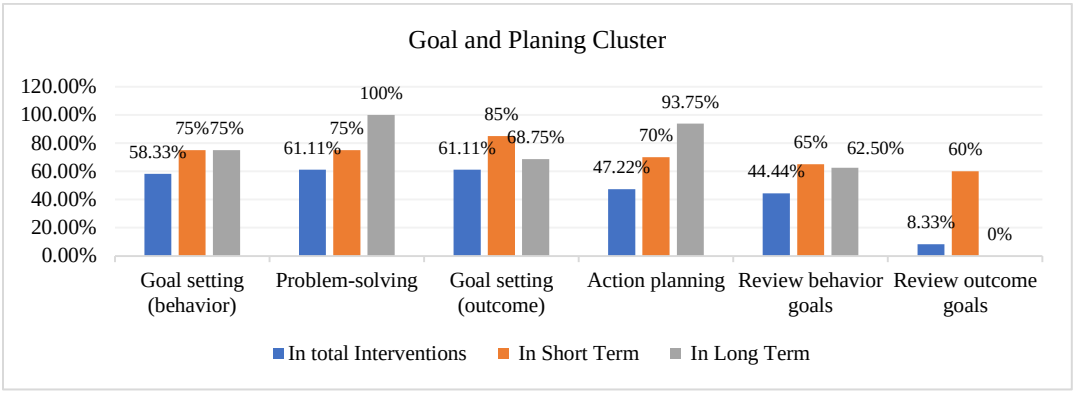
In general, mobile diabetes interventions have shown promise in improving short-term outcomes for individuals with diabetes [87], [88], [90]–[92], [96], [98], [99], [101], [114], [115], [124], [136]–[138]. These interventions typically involve the use of mobile applications (apps) or other digital tools to help individuals manage their condition, track their blood glucose levels, monitor physical activity, and provide educational resources. Several studies have evaluated the effectiveness of mobile diabetes interventions over short-term periods (e.g., a few months to a year), and many have reported positive results that is short-term effectiveness [87], [88], [90]–[92], [96]–[98], [100], [101], [109], [114], [115], [124], [131], [136]–[138]. These interventions have been shown to improve glycemic control, increase self-management behaviors, enhance medication adherence, and promote healthy lifestyle choices, however, twelve interventions were short-term ineffective [91], [94], [98], [104], [105], [111], [113], [117], [139], [140]. Six interventions were long-term effective [92], [98], [110], [111], [136], [137]. Finally, ten interventions were long-term ineffective [101]–[106], [113], [114], [118], [139]. For example, some studies have found that mobile apps with features like glucose monitoring, medication reminders, and dietary guidance can lead to improvements in HbA1c levels (a measure of long-term blood glucose control) in the short term. Additionally, mobile interventions that include real-time feedback, coaching, and personalized recommendations have shown effectiveness in motivating individuals to adopt healthier behaviors. However, it's worth noting that the long-term effectiveness of these mobile interventions may vary. Some studies have reported challenges in maintaining the positive effects over a longer duration. Factors such as user engagement, adherence to the intervention, and sustainability of behavior change can influence the long-term effectiveness of these interventions. As technology advances and more research are conducted, it's possible that newer mobile diabetes interventions may have improved long-term outcomes. It's essential for researchers and developers to continue evaluating the effectiveness and sustainability of these interventions to ensure their long-term benefits for individuals with diabetes.

RQ2- What are the prevailing methodologies and techniques commonly utilized in the realm of diabetic self-care management to facilitate behavior modification?

The term "behavioural change techniques" (BCTs) refers to discrete, observable, and repeatable elements of interventions intended to influence behaviour [131]. BCTs are a part of an intervention meant to change or restructure the causal mechanisms that control behaviour. The BCT Taxonomy, developed by Michie et al. in 2013, is a classification system for 93 hierarchically clustered approaches. Behavior change techniques are specific strategies or methods used to facilitate behavior change in individuals. These techniques are often employed in various fields, including healthcare, psychology, and public health, to promote positive behavior changes and support individuals in achieving their goals. BCTs can be used to modify a wide range of behaviors, including health behaviors like smoking cessation, physical activity, medication adherence, and dietary changes. They can be applied in individual counseling sessions, group interventions, digital health programs, or self-help materials. Behavior change techniques are designed to target specific determinants of behavior, such as motivation, self-efficacy, knowledge, and environmental factors. They are evidence-based and grounded in theories of behavior change, such as the Transtheoretical Model, Social Cognitive Theory, and the Theory of Planned Behavior.

Over the course of all the interventions examined, a total of thirty separate behaviour change methods (BCTs) were discovered, average 11.6 BCTs per intervention. Ten of these behaviour modification strategies were used in at least 55 per cent of both short and long-term interventions. In particular, behavioural goal-setting was used in 58.33% of interventions and was acknowledged in 75% of cases for both the short- and long-term categories. In 61.11% of the therapies that were considered, problem-solving was present, and its success was rated as being 75% short-term and 100% long-term. Defining outcome-related goals was another method that was used in 61.11% of all interventions, with recognition rates of 85% and 68.75% for short-term and long-term efficacy, respectively. Feedback on behaviours was noted in 61.11% of all interventions, with the rate of recognition for short and long-term interventions being 85% and 68.75%, correspondingly. In 80.56% of interventions overall, 100% of short-term treatments and 81.25% of long-term interventions showed evidence of the self-monitoring of behaviour technique. In line with this, the method of self-monitoring behavioural outcomes was recognised in 100% of short-term interventions and 75% of long-term interventions, or 77.7% of all interventions. Additionally, the undefined type of social support was recognised in 61.11% of all interventions, 95% of short-term interventions, and 62% of long-term interventions. Also noted in 50%, 55.56%, and 58.33% of all treatments, respectively, were strategies including informing participants about the potential health effects of their actions, citing reliable sources,

and modifying environmental signals. As mentioned in (see Fig. 8), for short-term and long-term interventions, respectively, the recognition rates for these approaches were 65%, 80%, and 90%.



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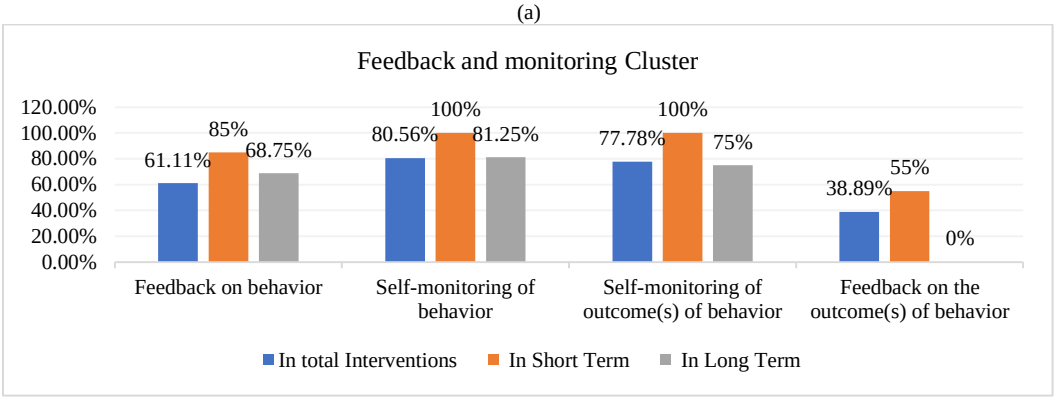

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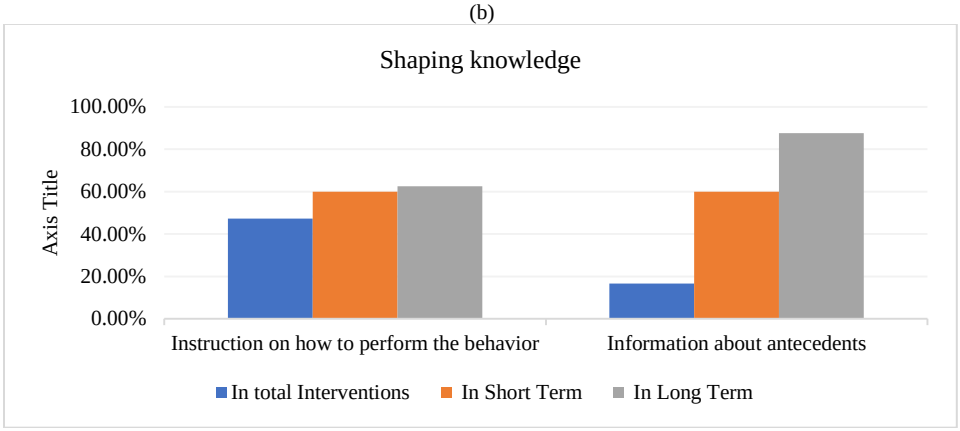

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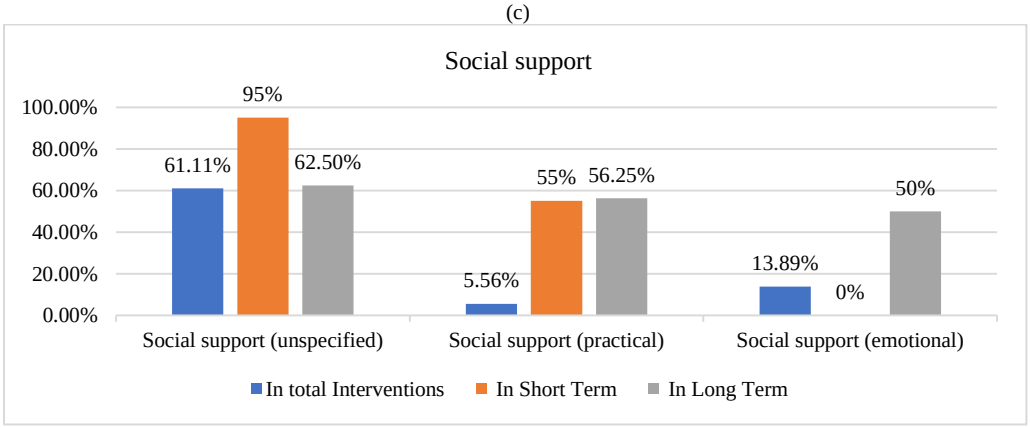


(d)

Fig. 8. BCT interventions (a) Goal and planning cluster, (b) Feedback and monitoring cluster, (c) Shaping knowledge, (d) Social support cluster.

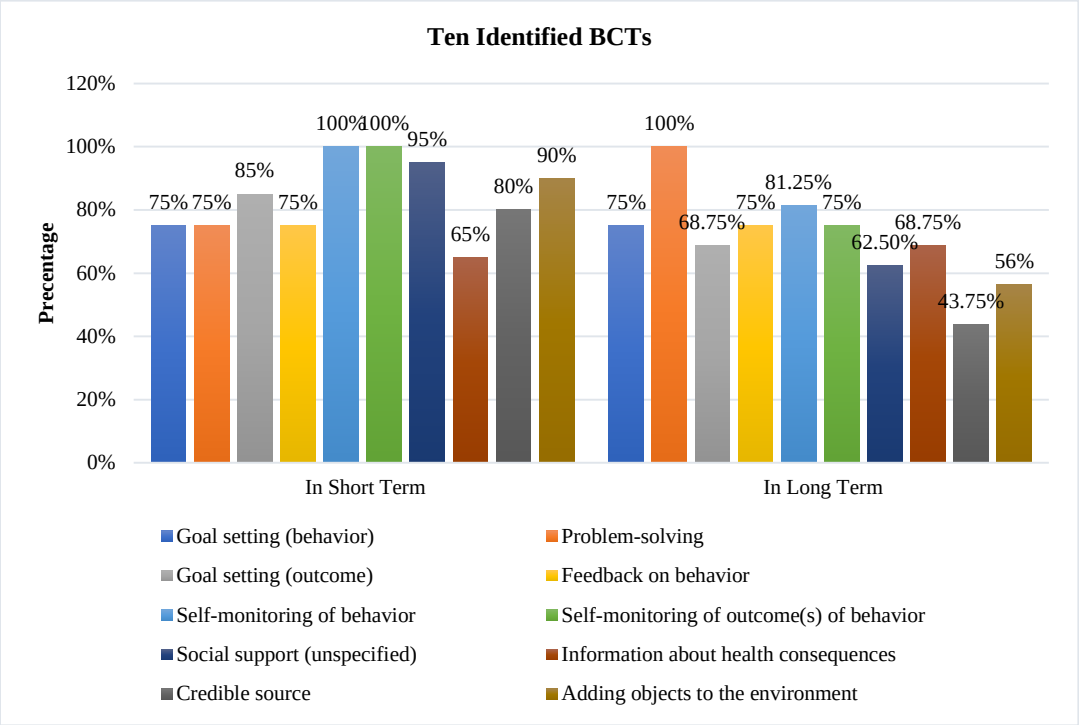


Fig. 9. Ten identified BCTs.

Fig. 9 depicts that the Goal setting (behavior) and problem-solving techniques are consistently employed in both short-term and long-term interventions, with percentages ranging from 75% to 100%. This suggests their recognized effectiveness in promoting behavior change. Goal setting (outcome) is more frequently utilized in the short term (85%), while its usage decreases slightly in the long term (68.75%), indicating a potential shift in focus over time. Feedback on behavior and self-monitoring of behavior are consistently utilized BCTs, highlighting their importance in promoting awareness and accountability. For both short-term and long-term therapies, the percentages range from 75% to 100%. Self-monitoring of behavior's result(s) is heavily used in the short term (100%) but less so in the long term (75%), suggesting a possible change in focus across various stages of behaviour change. Short-term (95%) but long-term (62.50%) use of social support (unspecified) declines, implying a potential shift to more focused types of social support with time. There are differences in percentages between short-term and long-term treatments when it comes to the use of information on health effects, reliable sources, and adding things to the environment. This implies that according to the particular environment and intervention goals, their efficacy and significance may change.

1) Effectiveness in short term: In comparison to long-term therapies, which used an average of 7.8 BCTs per intervention (range from 1 to 16), short-term interventions used an overall of 19 BCTs each intervention (range from 0 to 20). Self-monitoring of behaviours and self-monitoring of the results of behaviours were two behavioural change theories that were identified significantly more frequently in short-term therapies.

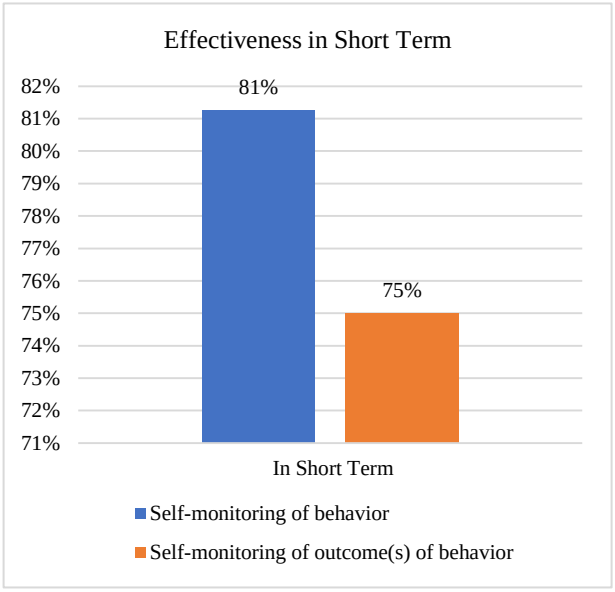


Fig. 10. Effectiveness in short-term.

As depicted in Fig. 10, the effectiveness of this BCT in the short term in self-monitoring of behavior is reported to be 81%. This suggests that when individuals actively monitor and track their behaviors, they are more likely to engage in positive self-care practices. While, the effectiveness of this BCT in the short-term self-monitoring outcome of behaviour is reported to be 75%, which implies that when individuals regularly track and observe the outcomes of their self-care behaviors, they can better understand the impact of their actions and make adjustments as needed.

2) Effectiveness in long term: In contrast to the 19 BCTs per intervention (range from 0 to 20) needed to achieve short-term efficacy, interventions that were long-term effective employed an average of 7.8 BCTs (ranging from 1 to 16). Two BCT found with noticeable higher frequency include action planning with 93.75%, and information about antecedents with 87.5%. As depicted in Fig. 11, the 87.50% effectiveness suggests that providing information about antecedents can be beneficial in promoting sustained behavior change and long-term self-care management. While, the 93.75% effectiveness indicates that when individuals engage in detailed action planning, they are more likely to maintain consistent self-care behaviors over an extended period.

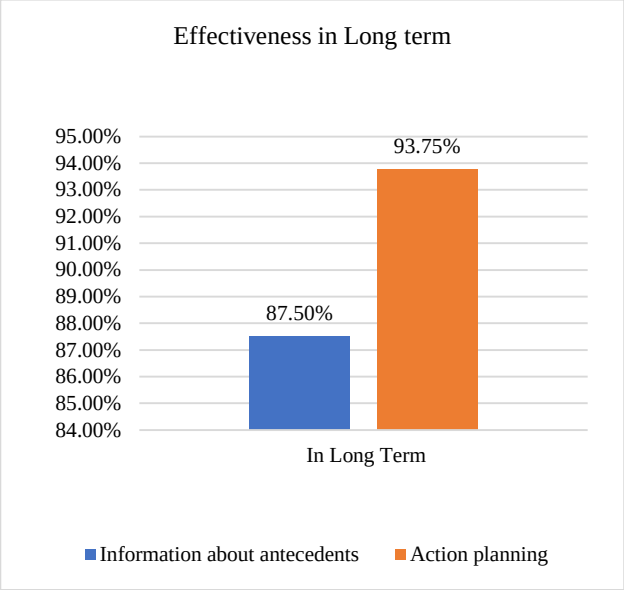


Fig. 11. Effectiveness in long-term.

RQ3: Which theoretical frameworks and models can be effectively employed to underpin and guide the progress and application of diabetes self-care management applications?

Multiple theoretical frameworks are frequently used to develop and assess public health interventions that aim to modify behaviors. The Health Behaviour Model examines a person's impression of a health problem's severity and vulnerability, in addition to the perceived advantages and challenges of implementing preventative behaviors. The TTM suggests that when changing behaviours, people go through phases of transformation. It emphasizes how crucial it is to adjust therapies depending to a person's level of progress. The Theory of Reasoning asserts Action/Planned Behaviors (TPB), a person's attitudes, personal standards, and perceived behavioral control all have an impact on their decision to engage in a behavior. It places a strong emphasis on how societal pressures and a person's beliefs might affect their behaviour. According to the Social Cognitive Theory (SCT), a person's behaviour, personal characteristics, and external factors all interact in a reciprocal manner. It emphasizes the significance of self-regulation and observational learning in behavior change. It also recognises that varieties of variables such as those at the individual, interpersonal, communal, and societal levels, have an impact on behaviors. It highlights how these levels interact and the necessity of therapies that focus on several levels at once.

An overall of 29 interventions made reference to a theoretical underpinning for their design, whereas the other seven interventions made no such mention. Different behavioural change theories were used in the reviewed articles, which include Social Cognitive Theory (SCT) [141], [142], Theory of Planned Behaviour [143], [144], Transtheoretical Model (TTM) [145], [146] [147], Self-determination Theory [148] , Information- Motivation-Behavioral Skills Model [142], Health Belief Model [144], [149]. Furthermore, COM-B model [150], Just-in-time Adaptive intervention design [151], Fogg Behavior Model [146], Self-efficacy [152] have been used in diabetes related interventions design. Twenty-nine interventions were supported (informed) by one theory or more theories. Some studies used several theories [142]–[144], [146], [148], [150], [153]–[166], while other interventions used a single behaviour theory [141], [151], [152], [165], [167]–[171].

Based on the reviewed articles, the most popular theories used in the studies were: Social Cognitive Theory (SCT) [141], [142], [153]–[157], [159]–[162], [164], [166], [172], [173] and the Transtheoretical Model of Behaviour Change (TTM) [144], [146], [154]–[157], [159], [160], [162], [163], [166], [169], [172]–[175]. SCT, which theorises knowledge gaining through social awareness and considers self-efficacy as one of the main channels of goal actualization, was used in 16 articles. TTM, which emphasizes changes as the progressive venture through pre-contemplating of behaviour change to behaviour maintenance [144], was informed in 17 articles. The Fig. 6 illustrate the distribution of the health behavioural theories in the reviewed articles.

According to Webb et al. [176] and Van Rhoon et al. [177], the Social Cognitive Theory and the TTM were among the most frequently utilised conceptual bases. On the other hand, the Theory of Planned Behaviour (TPB) represented one of the more often cited frameworks of theory in Webb et al.'s study [176]. Chao, Lin, and Ma [178] and Kusnanto et al. [179] utilised concept only as an evaluation metric, while those that used concept as a component of the research design provided just a cursory description of how treatments were incorporated into the relevant theory.

Future study should focus on this issue, perhaps highlighting the importance of building a theoretical knowledge of the probable procedure for eliciting behaviour change at the outset of the conceptualization of an approach in [180] and, using Michie and Prestwish's description of the 'standardized' contribution of concept in [181]. Researchers in the future ought to be able to assess the efficiency of the role of concept in these kinds of interventions as well as possibly the relationship among the amount of theory utilised and the changes in behaviour and corresponding health outcomes. This could be possible with an explicit, systematic, and relatively consistent overview of the part of concept in the planning and creation of the intervention.

The management of sicknesses and overall well-being is clearly aided by self-care applications created utilizing health behavioural change techniques. These programmes are effective at encouraging patients to better adhere to their prescription regimens, encourage self-care, enhance their health, and lessen their despair. A number of investigations were undertaken to assess the accessibility of the programmes, and it was determined that these self-care apps were mainly simple to comprehend and utilize since the patients felt comfortable utilizing them and completing the necessary chores. Additionally, self-care behaviours and prevalent concepts employed in their creation have been identified. These concepts encompass the following: the Theory of Planned Behaviour, the model of health beliefs, Cognitive Behaviour Therapy, Self-Care Behaviour, Motivational Interviewing, and behaviour changes. Finding the health behaviour change paradigm that has been employed in previous research more frequently would be fascinating. According to the results of the investigations, every theory has been applied continually, whether solely or in conjunction with other approaches.

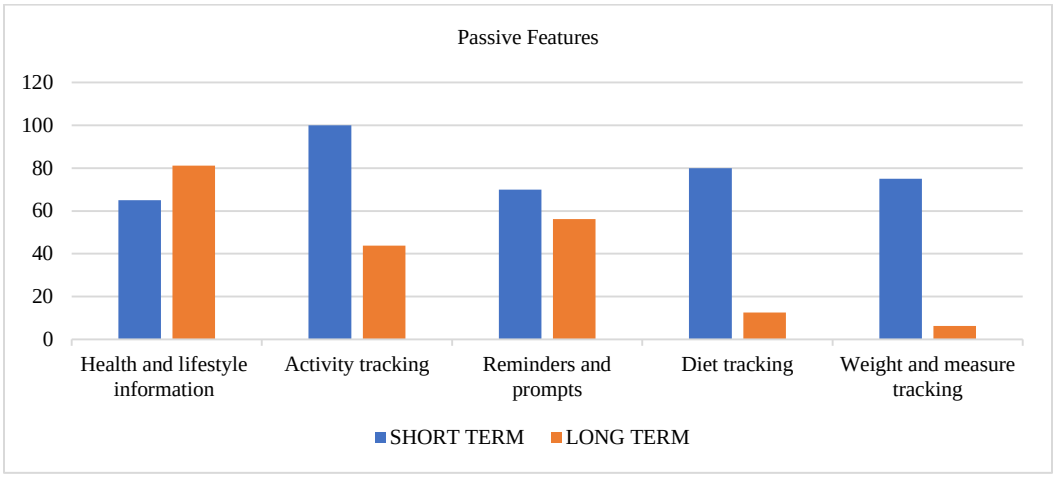
RQ4- What common aspects do diabetic self-care management programmes use today to effectively and completely treat the disease and empower patients?

Thematic analysis [182], was executed across three phases to uncover patterns within all interpolated data points. Initially, comprehensive explanations and codes were provided for every application components and its corresponding platform. Additionally, in cases where multiple studies evaluated identical standardized interventions, the imputation process was carried out. Subsequently, characteristics were classified according to the degree of engagement between the user and the application, categorized as either interactive (involving two-way interaction) or passive (involving one-way interaction). To test for dependability, we finished the initial two phases on an instance of randomly selected app specifications. Furthermore, all both active and passive characteristics were gathered, analyzed, and debated jointly. These findings led to the identification of common themes between the interactive and passive components. The interactive or passive characteristics of the themes or clusters were afterwards classified and labelled in accordance with each theme. In particular, several kinds of mobile and web-based therapies have tools for monitoring blood sugar, diet calories, and body weight, as well as alerts for remembering to take medications or schedule medical appointments. Consider dividing the characteristics into interactive and passive ones.

3) Digital feature descriptions: The different digital passive features are utilized in health interventions. Health and lifestyle information and advice provide educational materials on topics like healthy eating, physical activity, and stress reduction. Activity tracking involves tools like pedometers and accelerometers to record physical activity, while reminders and prompts send notifications to remind participants of specific tasks. Diet tracking allows participants to record their dietary behaviors, including calorie counting and food diaries. Weight and bio-measure tracking involve tools like digital scales and blood glucose monitors to track body weight and biological measures. These features offer one-way interaction without active feedback.

Previous assessments of self-care apps have examined how the effectiveness of these applications is linked to their attributes in managing diabetes. Applications that demonstrated substantial effectiveness incorporated both passive and interactive features, while those with less pronounced effects tended to rely solely on passive attributes [183]. Passive attributes don't require user interaction, whereas interactive attributes involve real-time user engagement. In another investigation [184], diverse attributes in self-care apps were explored. This study revealed that interactive attributes were notably more successful than passive ones in enhancing medication adherence among individuals with type 2 diabetes. Nonetheless, this study exclusively concentrated on type 2 diabetes management, leaving uncertain the most efficacious features across various applications. Interactive elements encourage engagement and active involvement in programmes for a healthy lifestyle. The data shows that gamification, automatic feedback, social media and support, online medical coaching, and educating about healthy living all incorporate interactive components. Passive features include tracking nutrition, weight and measurements, suggestions and alerts, information on wellness and lifestyle, and activity monitoring. These elements are essential for providing people with information and insights so they may choose their lifestyle and health with knowledge. For instance, the majority of interventions incorporate health and lifestyle information, demonstrating the value of this information in educating people about several facets of their well-being [183].

The passive features include activity tracking, weight, biometric measurements, diet tracking, reminders and prompts and health and style information. From Fig. 12(a), it is observed that Health and lifestyle information is a commonly included passive feature in both short-term and long-term interventions. It is present in 58.33% of all interventions, 65% of short-term interventions, and 81.25% of long-term interventions. Activity tracking is another frequently incorporated passive feature, with 52.78% of all interventions including it. In the short term, all short-term interventions (100%) utilize activity tracking, while it decreases to 43.75% in the long term. Reminders and prompts are included in 47.22% of all interventions. They are used in 70% of short-term interventions and 56.25% of long-term interventions. Diet tracking is present in 41.67% of all interventions. It is used in 80% of short-term interventions but decreases significantly to 12.5% in the long term. Weight and measure tracking is utilized in 44.44% of all interventions. In the short term, 75% of interventions include this feature, but it drops to 6.25% in the long term. On average, short-term interventions have a higher number of passive features per intervention (3.81) compared to long-term interventions (2).



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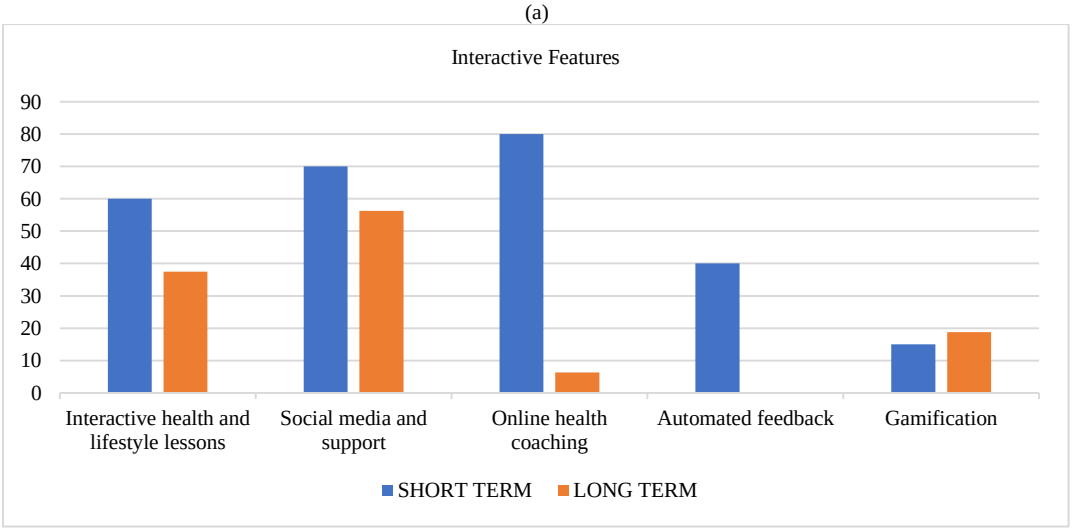

(b)

Fig. 12. (a) Passive features intervention and (b) Interactive features intervention.

The capabilities that are interactive include social media and support, automated feedback, lifestyle lessons, gamification, interactive wellness and online health instruction, and social networking sites. From Fig. 12(b), it is observed that Interactive health and lifestyle lessons are a commonly included interactive feature, present in 55.56% of all interventions. In the short term, 60% of interventions incorporate this feature, while in the long term, it decreases to 37.5%. Social media and support is another frequently included interactive feature, with 52.78% of all interventions including it. In the short term, 70% of interventions utilize social media and support, and in the long term, it remains high at 56.25%. Online health coaching is present in 50% of all interventions. It is used in 80% of short-term interventions but decreases significantly to 6.25% in the long term. Automated feedback is utilized in 36.11% of all interventions. In the short term, 40% of interventions include automated feedback, but it is not present in any of the long-term interventions. Gamification is the least frequently incorporated interactive feature, present in only 5.56% of all interventions. It is used in 15% of short-term interventions and 18.75% of long-term interventions. On average, short-term interventions have a higher number of interactive features per intervention (2.52) compared to long-term interventions (1).

RQ5: What are the intricate challenges encountered in the current landscape of diabetes self-care applications, and what are the anticipated future directions and potential advancements?

While many diabetic self-management software programmes offer features like tracking diet and exercise, it's noteworthy that type 2 diabetes is frequently associated with insufficient dietary intake and insufficient physical activity. The features of machine learning (ML) or AI-powered dietary recommendation and planning, clinical support, fitness tracking, visualizing blood pressure, calorie expenditure estimation, and behavioural intervention (BI) techniques, still clearly have shortcomings. Additionally, most of these apps lacked well-recognized research underpinnings and ideas, including the nudge theory, which would add credibility. As a result, some diabetic self-management software programmes may not successfully help patients manage their condition on their own. It's interesting to note that none of these applications includes a food monitoring system powered by ML or AI, a system for providing individualised nutrition

advice, or a platform for meal recording (micronutrient detection) powered by AI using picture analysis. For diabetics to avoid hypo- or hyperglycemic episodes, improved nutrition management systems can significantly improve glycemic control [128]. These programmes, however, lack thorough feedback systems, such as organised behavioural agreements, consistent self-monitoring tracking, and goal setting. Based on the system's learned insights from recent data and preprogrammed guidelines, this input is customised for patients. Additionally, the majority of applications do not have AI-driven tools like insulin dose calculators that are intended to help patients make informed decisions by offering advice on activities, diets, and medications.

In future, a comprehensive self-care application for diabetes could be envisioned, encompassing both basic and advanced functionalities. This application would encompass elements like nutrition, blood glucose monitoring, clinical support, physical activity tracking, medication management, and tailored features. Moreover, this proposed diabetes self-care app would adopt an extensive feedback mechanism, fostering effective communication with all involved parties. Additionally, it would integrate behavioral intervention techniques guided by theories and artificial intelligence, promoting prolonged adherence to patients' self-care regimens.

VI. Discussion

A total of 36 therapies from multiple investigations were analysed and evaluated for this research. The SLR seeks to compile and evaluate the literature on diabetic self-care apps in order to assess the effectiveness of treatments for diabetes management. The Systematic Literature Review also looks for the best behavior change methods (BCTs) and application features that are frequently employed in the research investigations that are already out there. This study showed that, in the short term, a substantial number of diabetic self-care strategies resulted in noticeable weight loss, as evidenced by an average weight reduction of at least 3% from the original level, based on the evaluations that were chosen. However, after taking into account the longer time, the majority of therapies did not meet the clinically significant threshold of 5% weight loss. Previous reports [9]–[11], [128], [129] on the effectiveness of diabetes self-care applications found similar results and heterogeneity among studies. According to earlier research [121], applications that used more behaviour change methods (BCTs) typically had higher efficacy. Within the interventions, seven typical behaviour modification strategies were found, including goal formulation, self-monitoring, feedback on behaviour, problem-solving outcome, self-monitoring, and social support. The suggested behavior modification elements listed in the IMAGE toolkit for diabetes prevention are in line with these identified BCTs, which is significant [185]. The most successful behavior change method involves participants in problem-solving activities that encourage them to come up with potential behavioural modification methods, choose the best one, and implement it. According to the research, applications that included more behavior change methods were generally more likely to be more successful. Furthermore, consistent patterns of Behavior Change Techniques (BCTs) were identified in both long-term and short-term therapeutic interventions. Notably, interventions with a higher number of distinctive attributes exhibited greater effectiveness, aligning with behavior change strategies. Similar findings were documented in studies [186] and [187], illustrating that self-care applications yielded enhanced efficacy in diabetes management through the incorporation of interactive features. Three elements have been frequently mentioned as useful interventions, indicating that they may make up an efficient core collection that would serve as the foundation for all subsequent applications.

In order to overcome the constraints to face-to-face interventions' connectivity, self-care applications have been developed. According to the present research, interventions that use more BCTs and characteristics are more effective, and because of their enhancing capabilities and adoption rates, websites and smartphones might serve as the best platforms for these strategies. Given that these behaviors are similarly comparable to the evidence-based treatment, that mostly depends on how the concepts are applied in the intervention layout, health behavioral theories have been shown to be an essential strategy for promoting behavioural modifications such as physical activity and nutritious eating [188]–[190]. While technology has the potential to positively impact self-care in diseases like diabetes, it alone is not enough. Effective outcomes rely on tailoring information appropriately and ensuring patients are highly motivated [191]. According to research, the broad implementation of BCTs, features, and theories into mobile and web-based therapies increases their effectiveness [188], [189]. Because there has been less prior research in this field, the creation of self-care interventions is an essential and developing direction in information science. However, current studies in the sector have shown that programmes created with the integration of BCTs and behavioural change theories produce better clinical results in [188], [189]. It may be concluded that in order to attain long-term effectiveness and help users reach their therapeutic goals, an ideal self-management intervention should incorporate BCTs and behavioural health theories during the design process.

Theoretical frameworks for influencing behaviors to improve medical results are crucial. Due to their ability to provide light on human behaviour and change, these theories are crucial components of successful intervention. By incorporating methods for behavioral change, these theories could be utilised in the creation of fresh apps. Researchers offer encouraging recommendations for developing, putting into practice, and assessing health promotion programmes that might be incorporated into the creation of self-care interventions dealing with health-related behaviours [187]. BCT-based therapies may be employed to encourage users to improve their health-related behaviours [131].

Any health support programmes that include more behavioral change theories are thought to be more successful at achieving the intended behavioral change. Many research investigations have looked into how health behavioral change theories could be included into the creation of medical assistance apps. However, few researches have focused on such incorporation in prediabetes self-care strategies.

According to the findings of the prediabetes research, it would be achieved to avoid diabetes and manage prediabetes—but only when prediabetics are inspired to take charge of their well-being by altering their attitudes through self-care behaviors. In the present research, examine the efficacy of existing theories of health behavior change as they are applied to prediabetes therapies worldwide and assess the efficacy of self-care apps that combine these concepts. The development of self-care strategies that target behaviours associated with health could be influenced by behavioural change concepts and approaches, which offer promising principles for creating, carrying out, and evaluating health promotion programmes [192]. Understandings how individuals act and modification could assist us achieve better health effects, according to behavioural change concepts [64]. Incorporating ideas of wellness behavior modification into the creation of healthcare applications has been the subject of several research. However, few researchers have focused on this inclusion in diabetic self-care programs [91], [93]. According to the findings of the mellitus research, managing and preventing diabetic is only feasible if individuals are inspired to take control of their well-being by altering their attitudes through self-care behaviors. As a result, researchers advise the investigators to create diabetes self-management software that includes both simple and sophisticated features, including dietary advice, fitness advice, calorie prediction, and insulin bolus calculations. The software should also facilitate stakeholder communication, incorporate theory based on artificial intelligence that improves the programme's effectiveness in managing diabetes, and allow diabetic patients to commit to their self-management regimens progressively over time.

As previously mentioned, this study's investigation of the effectiveness of self-care applications for managing diabetes and the effects of the BCTs and application features is one of its contributions. As a result, the information obtained from the examined papers was presented and organized using a narrative synthesis technique, with tables that summarised the descriptive analysis and statistical data. The data are more than adequate to perform a complete meta-analysis, but, the majority of the examined articles included in the primary efficiency analysis of the therapies did not present a percentage of weight loss and other essential requirements.

Furthermore, it was believed that body weight and glycemic status (A1c) were the main outcomes of importance. Due to its relationship to diabetic issues and the fact that diabetic self-care research commented on it more often than publications in other fields, body weight was seen as the major measure of success [193]–[195]. Since this value is considered to be clinically important [196] and usually complies with standards of weight loss for twelve-month diabetes self-care therapy [195], [197]. and the effectiveness of the intervention was assessed in terms of an average weight loss of fewer than five per cent from the starting weight.

In essence, interventions lasting less than six months were deemed successful if an average weight loss of over 3% occurred within this timeframe. For interventions extending beyond twelve months, success was determined if an average weight reduction of 5% or more was achieved within a twelve-month follow-up period. Based on these criteria, the applications in the studies under review were categorized as either short-term effective, short-term ineffective, long-term effective, or long-term ineffective. Specifically, interventions exceeding twelve months were grouped into short-term (ST) and long-term (LT) follow-ups. The study investigated relationships between types of Behavior Change Techniques (BCTs) and intervention attributes identified in long-term compared to short-term interventions. Similar to pertinent findings in reference [196], effective BCTs and features were identified for each respective time (ST or LT) if present in a minimum of 55% of effective interventions.

VII. Conclusion

This study focused on assessing the impact of self-care apps, particularly those integrating Behavioral Change Techniques (BCTs) and related concepts, in managing diabetes compared to standard treatment. The findings from the analysis of various studies suggest that the use of self-care apps can lead to improvements in A1c levels and weight loss for individuals with diabetes when compared to standard care. These results align with previous research, reinforcing the potential benefits of self-care apps in diabetes management. It also demonstrated that previous studies that utilised behavioral health concepts and BCTs in the creation of diabetic self-management treatments tended to be more successful. Importantly, the analysis highlights that the incorporation of BCTs and related concepts into interventions is associated with a reduction in A1c levels. This underscores the significance of integrating these strategies into self-care applications, even though the precise influence on application features can sometimes be unclear.

A. Limitations and Future Directions

After determining the possibility for incorporating BCT theories and practises into the creation of self-management interventions, it is vital to build a paradigm for creating successful self-care programmes based on particular BCT. As a foundation for developing future applications, it is also necessary to explicitly elaborate on the use of BCTs and concept. While this systematic literature review (SLR) provides valuable insights, it's important to acknowledge its limitations. The studies included in this review varied in terms of methodology, participant characteristics, and intervention design, which may introduce heterogeneity into the findings. To build on these findings, future research should consider more standardized methodologies and explore the long-term effects of self-care apps. Furthermore, research should focus on elucidating the specific mechanisms through which BCTs and related concepts influence the efficacy of self-care interventions for diabetes management. Such efforts could provide a clearer foundation for the development of more effective self-care programs and applications in the future.

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REFERENCES

[1] S. Joachim, N. Wickramasinghe, P. P. Jayaraman, A. Forkan, and A. Morshed, "Design and development of a diabetes self-management platform: a case for responsible information system development," 2021.

[2] Kusnanto, K. A. J. Widyanata, Suprajitno, and H. Arifin, "DM-calendar app as a diabetes self-management education on adult type 2 diabetes mellitus: a randomized controlled trial," J Diabetes Metab Disord, vol. 18, no. 2, pp. 557–563, Dec. 2019, doi: 10.1007/s40200-019-00468-1.

[3] D. Tomic, J. E. Shaw, and D. J. Magliano, "The burden and risks of emerging complications of diabetes mellitus," Nature Reviews Endocrinology, vol. 18, no. 9, pp. 525–539, 2022.

[4] M. M. McCarthy, R. Whittemore, G. Gholson, and M. Grey, "Diabetes Distress, Depressive Symptoms and Cardiovascular Health in Adults with Type 1 Diabetes," Nursing research, vol. 68, no. 6, p. 445, 2019.

[5] X. Lin et al., "Global, regional, and national burden and trend of diabetes in 195 countries and territories: an analysis from 1990 to 2025," Scientific reports, vol. 10, no. 1, p. 14790, 2020.

[6] H. Sun et al., "IDF Diabetes Atlas: Global, regional and country-level diabetes prevalence estimates for 2021 and projections for 2045," Diabetes research and clinical practice, vol. 183, p. 109119, 2022.

[7] O. El-Gayar, P. Timsina, N. Nawar, and W. Eid, "Mobile applications for diabetes self-management: status and potential," Journal of diabetes science and technology, vol. 7, no. 1, pp. 247–262, 2013.

[8] B. Hansel et al., "A Fully Automated Web-Based Program Improves Lifestyle Habits and HbA1c in Patients With Type 2 Diabetes and Abdominal Obesity: Randomized Trial of Patient E-Coaching Nutritional Support (The ANODE Study)," J Med Internet Res, vol. 19, no. 11, p. e360, Nov. 2017, doi: 10.2196/jmir.7947.

[9] K. Liu, Z. Xie, C. K. Or, and others, "Effectiveness of mobile app-assisted self-care interventions for improving patient outcomes in type 2 diabetes and/or hypertension: systematic review and meta-analysis of randomized controlled trials," JMIR mHealth and uHealth, vol. 8, no. 8, p. e15779, 2020.

[10] Y. Mao, W. Lin, J. Wen, and G. Chen, "Impact and efficacy of mobile health intervention in the management of diabetes and hypertension: a systematic review and meta-analysis," BMJ Open Diabetes Research and Care, vol. 8, no. 1, p. e001225, 2020.

[11] X. Wu, X. Guo, and Z. Zhang, "The Efficacy of Mobile Phone Apps for Lifestyle Modification in Diabetes: Systematic Review and Meta-Analysis," JMIR Mhealth Uhealth, vol. 7, no. 1, p. e12297, Jan. 2019, doi: 10.2196/12297.

[12] H. B. Aminuddin, N. Jiao, Y. Jiang, J. Hong, and W. Wang, "Effectiveness of smartphone-based self-management interventions on self-efficacy, self-care activities, health-related quality of life and clinical outcomes in patients with type 2 diabetes: A systematic review and meta-analysis," International journal of nursing studies, vol. 116, p. 103286, 2021.

[13] M. Hood, R. Wilson, J. Corsica, L. Bradley, D. Chirinos, and A. Vivo, "What do we know about mobile applications for diabetes self-management? A review of reviews," Journal of behavioral medicine, vol. 39, pp. 981–994, 2016.

[14] E. Gong et al., "Quality, functionality, and features of Chinese mobile apps for diabetes self-management: systematic search and evaluation of mobile apps," JMIR mHealth and uHealth, vol. 8, no. 4, p. e14836, 2020.

[15] J. Pavlas, O. Krejcar, P. Maresova, and A. Selamat, "Prototypes of User Interfaces for Mobile Applications for Patients with Diabetes," Computers, vol. 8, no. 1, p. 1, Dec. 2018, doi: 10.3390/computers8010001.

[16] R. H. Franklin, M. Waite, and C. Martin, "The use of mobile technology to facilitate self-management in adults with type 1 diabetes: A qualitative explorative approach," Nursing open, vol. 6, no. 3, pp. 1013–1021, 2019.

[17] M. D. Adu, U. H. Malabu, A. E. O. Malau-Aduli, and B. S. Malau-Aduli, "The development of My Care Hub Mobile-Phone App to Support Self-Management in Australians with Type 1 or Type 2 Diabetes," Sci Rep, vol. 10, no. 1, p. 7, Jan. 2020, doi: 10.1038/s41598-019-56411-0.

[18] S. Baptista, S. Trawley, F. Pouwer, B. Oldenburg, G. Wadley, and J. Speight, "What do adults with type 2 diabetes want from the 'perfect' app? Results from the second diabetes MILES: Australia (MILES-2) study," Diabetes technology & therapeutics, vol. 21, no. 7, pp. 393–399, 2019.

[19] L. F. Garabedian, D. Ross-Degnan, R. F. LeCates, and J. F. Wharam, "Uptake and use of a diabetes management program with a mobile glucometer," Primary Care Diabetes, vol. 13, no. 6, pp. 549–555, 2019.

[20] Y. Shen et al., "Effectiveness of internet-based interventions on glycemic control in patients with type 2 diabetes: meta-analysis of randomized controlled trials," Journal of medical Internet research, vol. 20, no. 5, p. e172, 2018.

[21] L. E. Pathak et al., "Developing messaging content for a physical activity smartphone app tailored to low-income patients: user-centered design and crowdsourcing approach," JMIR mHealth and uHealth, vol. 9, no. 5, p. e21177, 2021.

[22] L. A. Nelson, S. A. Mulvaney, K. B. Johnson, and C. Y. Osborn, "mHealth intervention elements and user characteristics determine utility: a mixed-methods analysis," Diabetes Technology & Therapeutics, vol. 19, no. 1, pp. 9–17, 2017.

[23] V. N. Shah and S. K. Garg, "Managing diabetes in the digital age," Clinical Diabetes and Endocrinology, vol. 1, pp. 1–7, 2015.

[24] M. A. Basar et al., "A review on diabetes patient lifestyle management using mobile application," in 2015 18th International Conference on Computer and Information Technology (ICCIT), IEEE, 2015, pp. 379–385.

[25] R. Itumalla, R. Kumar, M. Tharwat Elabbasy, B. Perera, and M. R. Torabi, "Structural Factors and Quality of Diabetes Health Services in Hail, Saudi Arabia: A Cross-Sectional Study," in Healthcare, MDPI, 2021, p. 1691.

[26] C. M. Marx, "Economic implications of type 2 diabetes management," The American journal of managed care, vol. 19, no. 8 Suppl, pp. S143–S148, 2013.

[27] M. Aljofan, A. Altebainawi, and M. N. Alrashidi, "Public knowledge, attitude and practice toward diabetes mellitus in Hail region, Saudi Arabia," International Journal of General Medicine, pp. 255–262, 2019.

[28] A. B. Kaiser, N. Zhang, and W. V. Der Pluijm, "Global prevalence of type 2 diabetes over the next ten years (2018-2028)," Diabetes, vol. 67, no. Supplement_1, 2018.

[29] U. Asmat, K. Abad, and K. Ismail, "Diabetes mellitus and oxidative stress—A concise review," Saudi pharmaceutical journal, vol. 24, no. 5, pp. 547–553, 2016.

[30] L. Hernandez, H. Leutwyler, J. Cataldo, A. Kanaya, A. Swislocki, and C. Chesla, "The symptom experience of older adults with Type 2 diabetes and diabetes-related distress," Nursing research, vol. 68, no. 5, p. 374, 2019.

[31] D. García-Huidobro, M. Bittner, P. Brahm, and K. Puschel, "Family intervention to control type 2 diabetes: a controlled clinical trial," Family practice, vol. 28, no. 1, pp. 4–11, 2011.

[32] L. Huo, J. L. Harding, A. Peeters, J. E. Shaw, and D. J. Magliano, "Life expectancy of type 1 diabetic patients during 1997–2010: a national Australian registry-based cohort study," Diabetologia, vol. 59, pp. 1177–1185, 2016.

[33] J. Apelqvist, "The diabetic foot syndrome today: a pandemic uprise," in The Diabetic Foot Syndrome, Karger Publishers, 2018, pp. 1–18.

[34] A. A. Muche, O. O. Olayemi, and Y. K. Gete, "Prevalence and determinants of gestational diabetes mellitus in Africa based on the updated international diagnostic criteria: a systematic review and meta-analysis," Archives of Public Health, vol. 77, pp. 1–20, 2019.

[35] S. SH and M.-C. Huang, "Diabetes Self-Management Engagement: A Case Study Analysis of Respect for Patient's Autonomy," 2020.

[36] R. A. Pamungkas, K. Chamroonsawasdi, and P. Vatanasomboon, "A systematic review: family support integrated with diabetes self-management among uncontrolled type II diabetes mellitus patients," Behavioral Sciences, vol. 7, no. 3, p. 62, 2017.

[37] Y. M. Alneami and C. L. Coleman, "Risk factors for and barriers to control type-2 diabetes among Saudi population," Global journal of health science, vol. 8, no. 9, p. 10, 2016.

[38] L. B. Cohen, T. H. Taveira, S. A. M. Khatana, A. G. Dooley, P. A. Pirraglia, and W.-C. Wu, "Pharmacist-led shared medical appointments for multiple cardiovascular risk reduction in patients with type 2 diabetes," The Diabetes Educator, vol. 37, no. 6, pp. 801–812, 2011.

[39] W. T. Tong, S. R. Vethakkan, and C. J. Ng, "Why do some people with type 2 diabetes who are using insulin have poor glycaemic control? A qualitative study," BMJ open, vol. 5, no. 1, p. e006407, 2015.

[40] T. D. Anekwe and I. Rahkovsky, "Self-management: a comprehensive approach to management of chronic conditions," American Journal of Public Health, vol. 108, no. S6, pp. S430–S436, 2018.

[41] P. A. Grady and L. L. Gough, "Self-management: a comprehensive approach to management of chronic conditions," American journal of public health, vol. 104, no. 8, pp. e25–e31, 2014.

[42] A. M. AlHaidar, N. A. AlShehri, and M. A. AlHussaini, "Family Support and Its Association with Glycemic Control in Adolescents with Type 1 Diabetes Mellitus in Riyadh, Saudi Arabia," Journal of Diabetes Research, vol. 2020, pp. 1–6, Mar. 2020, doi: 10.1155/2020/5151604.

[43] K. K. Berhe, H. B. Gebru, and H. B. Kahsay, "Effect of motivational interviewing intervention on HgbA1C and depression in people with type 2 diabetes mellitus (systematic review and meta-analysis)," PloS one, vol. 15, no. 10, p. e0240839, 2020.

[44] X. Zhuo, P. Zhang, L. Barker, A. Albright, T. J. Thompson, and E. Gregg, "The lifetime cost of diabetes and its implications for diabetes prevention," Diabetes care, vol. 37, no. 9, pp. 2557–2564, 2014.

[45] M. Conner and P. Norman, EBOOK: predicting and changing health behaviour: research and practice with social cognition models. McGraw-hill education (UK), 2015.

[46] J. McSharry et al., "Behaviour change in diabetes: behavioural science advancements to support the use of theory," Diabetic Medicine, vol. 37, no. 3, pp. 455–463, 2020.

[47] N. C. Campbell et al., "Designing and evaluating complex interventions to improve health care," Bmj, vol. 334, no. 7591, pp. 455–459, 2007.

[48] W. Hardeman et al., "A causal modelling approach to the development of theory-based behaviour change programmes for trial evaluation," Health education research, vol. 20, no. 6, pp. 676–687, 2005.

[49] S. E. Linke, C. J. Robinson, and D. Pekmezi, "Applying psychological theories to promote healthy lifestyles," American Journal of Lifestyle Medicine, vol. 8, no. 1, pp. 4–14, 2014.

[50] E. L. Tuthill et al., "Exclusive breast-feeding promotion among HIV-infected women in South Africa: an Information–Motivation–Behavioural Skills model-based pilot intervention," Public health nutrition, vol. 20, no. 8, pp. 1481–1490, 2017.

[51] J. A. Lenio, "Analysis of the Transtheoretical Model of behavior change," 2006.

[52] J. O. Prochaska and C. C. DiClemente, "Transtheoretical therapy: Toward a more integrative model of change.," Psychotherapy: theory, research & practice, vol. 19, no. 3, p. 276, 1982.

[53] M. Hashemzadeh, A. Rahimi, F. Zare-Farashbandi, A. M. Alavi-Naeini, and A. Daei, "Transtheoretical model of health behavioral change: A systematic review," Iranian journal of nursing and midwifery research, vol. 24, no. 2, p. 83, 2019.

[54] H. Akbar, D. Anderson, and D. Gallegos, "Predicting intentions and behaviours in populations with or at-risk of diabetes: A systematic review," Preventive medicine reports, vol. 2, pp. 270–282, 2015.

[55] I. Ajzen, "The theory of planned behavior: Frequently asked questions," Human Behavior and Emerging Technologies, vol. 2, no. 4, pp. 314–324, 2020.

[56] I. Ajzen, "The theory of planned behaviour: Reactions and reflections," Psychology & health, vol. 26, no. 9. Taylor & Francis, pp. 1113–1127, 2011.

[57] R. M. Ryan and E. L. Deci, "Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being.," American psychologist, vol. 55, no. 1, p. 68, 2000.

[58] E. L. Deci and R. M. Ryan, "Self-determination theory: A macrotheory of human motivation, development, and health.," Canadian psychology/Psychologie canadienne, vol. 49, no. 3, p. 182, 2008.

[59] J. De Man et al., "What motivates people with (pre) diabetes to move? Testing self-determination theory in rural Uganda," Frontiers in Psychology, vol. 11, p. 404, 2020.

[60] A. S. Phillips and C. A. Guarnaccia, "Self-determination theory and motivational interviewing interventions for type 2 diabetes prevention and treatment: a systematic review," Journal of health psychology, vol. 25, no. 1, pp. 44–66, 2020.

[61] R. Koestner and N. Hope, "A self-determination theory approach to goals," The Oxford handbook of work engagement, motivation, and self-determination theory, pp. 400–413, 2014.

[62] K. Glanz, B. K. Rimer, and K. Viswanath, Health behavior: Theory, research, and practice. John Wiley & Sons, 2015.

[63] E. C. Green, E. M. Murphy, and K. Gryboski, "The health belief model," The Wiley encyclopedia of health psychology, pp. 211–214, 2020.

[64] M. Conner and P. Norman, "Social cognition models in health psychology." Taylor & Francis, 1998.

[65] S. W. S. Lo, S. Y. Chair, and F. K. Lee, "Factors associated with health-promoting behavior of people with or at high risk of metabolic syndrome: based on the health belief model," Applied Nursing Research, vol. 28, no. 2, pp. 197–201, 2015.

[66] A. Gopalan, I. S. Lorincz, C. Wirtalla, S. C. Marcus, and J. A. Long, "Awareness of prediabetes and engagement in diabetes risk–reducing behaviors," American journal of preventive medicine, vol. 49, no. 4, pp. 512–519, 2015.

[67] R. G. Lord, J. M. Diefendorff, A. M. Schmidt, and R. J. Hall, "Self-regulation at work," Annual review of psychology, vol. 61, pp. 543–568, 2010.

[68] S. Sultan, C. Attali, S. Gilberg, F. Zenasni, and A. Hartemann, "Physicians' understanding of patients' personal representations of their diabetes: accuracy and association with self-care," Psychology & health, vol. 26, no. sup1, pp. 101–117, 2011.

[69] S. Sullivan-Bolyai et al., "Tried and true: self-regulation theory as a guiding framework for teaching parents diabetes education using human patient simulation," ANS. Advances in nursing science, vol. 37, no. 4, p. 340, 2014.

[70] J. Troughton, J. Jarvis, C. Skinner, N. Robertson, K. Khunti, and M. Davies, "Waiting for diabetes: perceptions of people with pre-diabetes: a qualitative study," Patient education and counseling, vol. 72, no. 1, pp. 88–93, 2008.

[71] K. W. Watkins, C. M. Connell, J. T. Fitzgerald, L. Klem, T. Hickey, and B. Ingersoll-Dayton, "Effect of adults' self-regulation of diabetes on quality-of-life outcomes.," Diabetes care, vol. 23, no. 10, pp. 1511–1515, 2000.

[72] A. P. Cotter, N. Durant, A. A. Agne, and A. L. Cherrington, "Internet interventions to support lifestyle modification for diabetes management: a systematic review of the evidence," Journal of Diabetes and its Complications, vol. 28, no. 2, pp. 243–251, 2014.

[73] E. J. Lyons, Z. H. Lewis, B. G. Mayrsohn, and J. L. Rowland, "Behavior change techniques implemented in electronic lifestyle activity monitors: a systematic content analysis," Journal of medical Internet research, vol. 16, no. 8, p. e192, 2014.

[74] A. Bandura, "Health promotion from the perspective of social cognitive theory," in Understanding and changing health behaviour, Psychology Press, 2013, pp. 299–339.

[75] B. H. Marcus and L. H. Forsyth, Motivating people to be physically active. Human Kinetics, 2008.

[76] D. O'Sullivan and D. R. Strauser, "Operationalizing self-efficacy, related social cognitive variables, and moderating effects: implications for rehabilitation research and practice," Rehabilitation Counseling Bulletin, vol. 52, no. 4, pp. 251–258, 2009.

[77] E. S. Anderson-Bill, R. A. Winett, and J. R. Wojcik, "Social cognitive determinants of nutrition and physical activity among web-health users enrolling in an online intervention: the influence of social support, self-efficacy, outcome expectations, and self-regulation," Journal of medical Internet research, vol. 13, no. 1, p. e1551, 2011.

[78] M. Klein, N. Mogles, and A. van Wissen, "An intelligent coaching system for therapy adherence," IEEE pervasive computing, vol. 12, no. 3, pp. 22–30, 2013.

[79] J. D. Fisher and W. A. Fisher, "Changing AIDS-risk behavior.," Psychological bulletin, vol. 111, no. 3, p. 455, 1992.

[80] W. A. Fisher, J. D. Fisher, and J. Harman, "The information-motivation-behavioral skills model: A general social psychological approach to understanding and promoting health behavior," Social psychological foundations of health and illness, pp. 82–106, 2003.

[81] L. S. Mayberry, R. L. Rothman, and C. Y. Osborn, "Family members' obstructive behaviors appear to be more harmful among adults with type 2 diabetes and limited health literacy," Journal of health communication, vol. 19, no. sup2, pp. 132–143, 2014.

[82] W. A. Fisher, J. D. Fisher, and J. Harman, "The information-motivation-behavioral skills model: A general social psychological approach to understanding and promoting health behavior," Social psychological foundations of health and illness, pp. 82–106, 2003.

[83] C. Y. Osborn, K. Rivet Amico, W. A. Fisher, L. E. Egede, and J. D. Fisher, "An information-motivation-behavioral skills analysis of diet and exercise behavior in Puerto Ricans with diabetes," Journal of health psychology, vol. 15, no. 8, pp. 1201–1213, 2010.

[84] J. Gao, J. Wang, Y. Zhu, and J. Yu, "Validation of an information–motivation–behavioral skills model of self-care among Chinese adults with type 2 diabetes," BMC Public Health, vol. 13, no. 1, pp. 1–6, 2013.

[85] E. Jeon and H.-A. Park, "Development of the IMB model and an evidence-based diabetes self-management mobile application," Healthcare informatics research, vol. 24, no. 2, pp. 125–138, 2018.

[86] T. Alanzi, R. Istepanian, and N. Philip, "Design and Usability Evaluation of Social Mobile Diabetes Management System in the Gulf Region," JMIR Res Protoc, vol. 5, no. 3, p. e93, Sep. 2016, doi: 10.2196/resprot.4348.

[87] M. M. Alotaibi, R. Istepanian, and N. Philip, "A mobile diabetes management and educational system for type-2 diabetics in Saudi Arabia (SAED)," Mhealth, vol. 2, 2016.

[88] E. J. Aguiar, P. J. Morgan, C. E. Collins, R. C. Plotnikoff, M. D. Young, and R. Callister, "Efficacy of the type 2 diabetes prevention using lifestyle education program RCT," American journal of preventive medicine, vol. 50, no. 3, pp. 353–364, 2016.

[89] V. H. Buss, M. Varnfield, M. Harris, and M. Barr, "A mobile app for prevention of cardiovascular disease and type 2 diabetes mellitus: development and usability study," JMIR Human Factors, vol. 9, no. 2, p. e35065, 2022.

[90] M. D. Adu, U. H. Malabu, A. E. Malau-Aduli, and B. S. Malau-Aduli, "The development of My Care Hub mobile-phone app to support self-management in Australians with type 1 or type 2 diabetes," Scientific reports, vol. 10, no. 1, p. 7, 2020.

[91] G. Block et al., "Diabetes prevention and weight loss with a fully automated behavioral intervention by email, web, and mobile phone: a randomized controlled trial among persons with prediabetes," Journal of medical Internet research, vol. 17, no. 10, p. e240, 2015.

[92] C. M. Castro Sweet et al., "Outcomes of a digital health program with human coaching for diabetes risk reduction in a Medicare population," Journal of aging and health, vol. 30, no. 5, pp. 692–710, 2018.

[93] E. Cha et al., "A feasibility study to develop a diabetes prevention program for young adults with prediabetes by using digital platforms and a handheld device," The Diabetes Educator, vol. 40, no. 5, pp. 626–637, 2014.

[94] E. Everett, B. Kane, A. Yoo, A. Dobs, and N. Mathioudakis, "A novel approach for fully automated, personalized health coaching for adults with prediabetes: pilot clinical trial," Journal of medical Internet research, vol. 20, no. 2, p. e72, 2018.

[95] H. H. Fischer et al., "Text message support for weight loss in patients with prediabetes: a randomized clinical trial," Diabetes care, vol. 39, no. 8, pp. 1364–1370, 2016.

[96] Y. Fukuoka, C. L. Gay, K. L. Joiner, and E. Vittinghoff, "A novel diabetes prevention intervention using a mobile app: a randomized controlled trial with overweight adults at risk," American journal of preventive medicine, vol. 49, no. 2, pp. 223–237, 2015.

[97] M. K. Kramer et al., "A novel approach to diabetes prevention: evaluation of the Group Lifestyle Balance program delivered via DVD," Diabetes research and clinical practice, vol. 90, no. 3, pp. e60–e63, 2010.

[98] J. Ma et al., "Translating the Diabetes Prevention Program lifestyle intervention for weight loss into primary care: a randomized trial," JAMA internal medicine, vol. 173, no. 2, pp. 113–121, 2013.

[99] A. Michaelides, C. Raby, M. Wood, K. Farr, and T. Toro-Ramos, "Weight loss efficacy of a novel mobile Diabetes Prevention Program delivery platform with human coaching," BMJ Open Diabetes Research and Care, vol. 4, no. 1, p. e000264, 2016.

[100] G. A. Piatt, M. C. Seidel, R. O. Powell, and J. C. Zgibor, "Comparative effectiveness of lifestyle intervention efforts in the community: results of the Rethinking Eating and ACTivity (REACT) study," Diabetes Care, vol. 36, no. 2, pp. 202–209, 2013.

[101] S. C. Sepah, L. Jiang, and A. L. Peters, "Translating the diabetes prevention program into an online social network: validation against CDC standards," The Diabetes Educator, vol. 40, no. 4, pp. 435–443, 2014.

[102] M. G. Wilson et al., "Evaluation of a digital behavioral counseling program for reducing risk factors for chronic disease in a workforce," Journal of occupational and environmental medicine, vol. 59, no. 8, p. e150, 2017.

[103] J. H. Arens, W. Hauth, and J. Weissmann, "Novel app-and web-supported diabetes prevention program to promote weight reduction, physical activity, and a healthier lifestyle: observation of the clinical application," Journal of diabetes science and technology, vol. 12, no. 4, pp. 831–838, 2018.

[104] T. Limaye et al., "Efficacy of a virtual assistance-based lifestyle intervention in reducing risk factors for Type 2 diabetes in young employees in the information technology industry in India: LIMIT, a randomized controlled trial," Diabetic medicine, vol. 34, no. 4, pp. 563–568, 2017.

[105] A. Ramachandran et al., "Effectiveness of mobile phone messaging in prevention of type 2 diabetes by lifestyle modification in men in India: a prospective, parallel-group, randomised controlled trial," The lancet Diabetes & endocrinology, vol. 1, no. 3, pp. 191–198, 2013.

[106] A. Rose, B. M. Deros, and M. A. Rahman, "A study on lean manufacturing implementation in Malaysian automotive component industry," International Journal of Automotive and Mechanical Engineering, vol. 8, pp. 1467–1476, 2013.

[107] A. M. Boels, R. C. Vos, L.-T. Dijkhorst-Oei, and G. E. Rutten, "Effectiveness of diabetes self-management education and support via a smartphone application in insulin-treated patients with type 2 diabetes: results of a randomized controlled trial (TRIGGER study)," BMJ Open Diabetes Research and Care, vol. 7, no. 1, p. e000981, 2019.

[108] K. A. Cradock et al., "Design of a planner-based intervention to facilitate diet behaviour change in type 2 diabetes," Sensors, vol. 22, no. 7, p. 2795, 2022.

[109] D. Y. Chao, T. M. Lin, and W.-Y. Ma, "Enhanced self-efficacy and behavioral changes among patients with diabetes: cloud-based mobile health platform and mobile app service," JMIR diabetes, vol. 4, no. 2, p. e11017, 2019.

[110] C. Sun et al., "Mobile phone–based telemedicine practice in older chinese patients with type 2 diabetes mellitus: randomized controlled trial," JMIR mHealth and uHealth, vol. 7, no. 1, p. e10664, 2019.

[111] T. Alanzi, R. Istepanian, N. Philip, and others, "Design and usability evaluation of social mobile diabetes management system in the Gulf Region," JMIR research protocols, vol. 5, no. 3, p. e4348, 2016.

[112] E. Mehraeen et al., "Design and development of a mobile-based self-care application for patients with type 2 diabetes," Journal of Diabetes Science and Technology, vol. 16, no. 4, pp. 1008–1015, 2022.

[113] S. Subramaniam, J. S. Dhillon, and W. F. Wan Ahmad, "Behavioral Theory-Based Framework for Prediabetes Self-Care System—Design Perspectives and Validation Results," International journal of environmental research and public health, vol. 18, no. 17, p. 9160, 2021.

[114] D. H. Frøisland, E. Årsand, and F. Skårderud, "Improving diabetes care for young people with type 1 diabetes through visual learning on mobile phones: mixed-methods study," Journal of medical Internet research, vol. 14, no. 4, p. e2155, 2012.

[115] H. Holmen et al., "A mobile health intervention for self-management and lifestyle change for persons with type 2 diabetes, part 2: one-year

results from the Norwegian randomized controlled trial RENEWING HEALTH," JMIR mHealth and uHealth, vol. 2, no. 4, p. e3882, 2014.

[116]R. A. Sowah, A. A. Bampoe-Addo, S. K. Armoo, F. K. Saalia, F. Gatsi, and B. Sarkodie-Mensah, "Design and development of diabetes management system using machine learning," International journal of telemedicine and applications, vol. 2020, 2020.

[117]Kusnanto, K. A. J. Widyanata, Suprajitno, and H. Arifin, "DM-calendar app as a diabetes self-management education on adult type 2 diabetes mellitus: a randomized controlled trial," Journal of Diabetes & Metabolic Disorders, vol. 18, pp. 557–563, 2019.

[118]L. Ledderer, A. Møller, and A. Fage-Butler, "Adolescents' participation in their healthcare: A sociomaterial investigation of a diabetes app," Digital health, vol. 5, p. 2055207619845448, 2019.

[119]K. Waki et al., "DialBetics: a novel smartphone-based self-management support system for type 2 diabetes patients," Journal of diabetes science and technology, vol. 8, no. 2, pp. 209–215, 2014.

[120]C. C. Quinn, M. D. Shardell, M. L. Terrin, E. A. Barr, S. H. Ballew, and A. L. Gruber-Baldini, "Cluster-randomized trial of a mobile phone personalized behavioral intervention for blood glucose control," Diabetes care, vol. 34, no. 9, pp. 1934–1942, 2011.

[121]K. A. Cradock, G. ÓLaighin, F. M. Finucane, H. L. Gainforth, L. R. Quinlan, and K. A. M. Ginis, "Behaviour change techniques targeting both diet and physical activity in type 2 diabetes: A systematic review and meta-analysis," International Journal of Behavioral Nutrition and Physical Activity, vol. 14, no. 1, pp. 1–17, 2017.

[122]H. Fu, S. K. McMahon, C. R. Gross, T. J. Adam, and J. F. Wyman, "Usability and clinical efficacy of diabetes mobile applications for adults with type 2 diabetes: A systematic review," Diabetes research and clinical practice, vol. 131, pp. 70–81, 2017.

[123]J. Singh, B. C. Wünsche, and C. Lutteroth, "Framework for Healthcare4Life: a ubiquitous patient-centric telehealth system," in Proceedings of the 11th International Conference of the NZ Chapter of the ACM Special Interest Group on Human-Computer Interaction, 2010, pp. 41–48.

[124]S. Subramaniam, J. S. Dhillon, and W. F. Wan Ahmad, "Behavioral Theory-Based Framework for Prediabetes Self-Care System—Design Perspectives and Validation Results," IJERPH, vol. 18, no. 17, p. 9160, Aug. 2021, doi: 10.3390/ijerph18179160.

[125]G. Block et al., "Diabetes prevention and weight loss with a fully automated behavioral intervention by email, web, and mobile phone: a randomized controlled trial among persons with prediabetes," Journal of medical Internet research, vol. 17, no. 10, p. e240, 2015.

[126]A. Kankanhalli, J. Shin, H. Oh, and others, "Mobile-based interventions for dietary behavior change and health outcomes: scoping review," JMIR mHealth and uHealth, vol. 7, no. 1, p. e11312, 2019.

[127]E. Jeon and H.-A. Park, "Experiences of Patients With a Diabetes Self-Care App Developed Based on the Information-Motivation-Behavioral Skills Model: Before-and-After Study," JMIR Diabetes, vol. 4, no. 2, p. e11590, Apr. 2019, doi: 10.2196/11590.

[128]Y. Wu et al., "Mobile App-Based Interventions to Support Diabetes Self-Management: A Systematic Review of Randomized Controlled Trials to Identify Functions Associated with Glycemic Efficacy," JMIR Mhealth Uhealth, vol. 5, no. 3, p. e35, Mar. 2017, doi: 10.2196/mhealth.6522.

[129]B. C. Bonoto et al., "Efficacy of mobile apps to support the care of patients with diabetes mellitus: a systematic review and meta-analysis of randomized controlled trials," JMIR mHealth and uHealth, vol. 5, no. 3, p. e6309, 2017.

[130]S. Michie et al., "The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: Building an international consensus for the reporting of behavior change interventions," Annals of Behavioral Medicine, vol. 46, no. 1, pp. 81–95, Aug. 2013, doi: 10.1007/s12160-013-9486-6.

[131]S. Michie, M. M. Van Stralen, and R. West, "The behaviour change wheel: A new method for characterising and designing behaviour change interventions," Implementation Sci, vol. 6, no. 1, p. 42, Dec. 2011, doi: 10.1186/1748-5908-6-42.

[132]K. L. Joiner, S. Nam, and R. Whittemore, "Lifestyle interventions based on the diabetes prevention program delivered via eHealth: a systematic review and meta-analysis," Preventive medicine, vol. 100, pp. 194–207, 2017.

[133]R. R. Bian et al., "The effect of technology-mediated diabetes prevention interventions on weight: a meta-analysis," Journal of medical Internet research, vol. 19, no. 3, p. e76, 2017.

[134]V. Braun and V. Clarke, "Using thematic analysis in psychology," Qualitative research in psychology, vol. 3, no. 2, pp. 77–101, 2006.

[135]P. Ince, G. Haddock, and S. Tai, "A systematic review of the implementation of recommended psychological interventions for schizophrenia: rates, barriers, and improvement strategies," Psychology and Psychotherapy: Theory, Research and Practice, vol. 89, no. 3, pp. 324–350, 2016.

[136]M. Taloyan, M. Kia, F. Lamian, M. Peterson, and E. Rydwik, "Web-based support for individuals with type 2 diabetes-a feasibility study," BMC Health Services Research, vol. 21, no. 1, pp. 1–8, 2021.

[137]Y. Wang et al., "Effects of continuous care for patients with type 2 diabetes using mobile health application: a randomised controlled trial," The International journal of health planning and management, vol. 34, no. 3, pp. 1025–1035, 2019.

[138]B. E. Holtz et al., "The design and development of MyT1DHero: A mobile app for adolescents with type 1 diabetes and their parents," J Telemed Telecare, vol. 25, no. 3, pp. 172–180, Apr. 2019, doi: 10.1177/1357633X17745470.

[139]M. Afarideh et al., "Complex association of serum alanine aminotransferase with the risk of future cardiovascular disease in type 2 diabetes," Atherosclerosis, vol. 254, pp. 42–51, 2016.

[140]E. Cha et al., "Health literacy, self-efficacy, food label use, and diet in young adults," American journal of health behavior, vol. 38, no. 3, pp. 331–339, 2014.

[141]E. J. Aguiar, P. J. Morgan, C. E. Collins, R. C. Plotnikoff, M. D. Young, and R. Callister, "Efficacy of the Type 2 Diabetes Prevention Using LifeStyle Education Program RCT," American Journal of Preventive Medicine, vol. 50, no. 3, pp. 353–364, 2016, doi: 10.1016/j.amepre.2015.08.020.

[142]M. D. Adu, U. H. Malabu, A. E. O. Malau-Aduli, and B. S. Malau-Aduli, "The development of My Care Hub Mobile-Phone App to Support Self-Management in Australians with Type 1 or Type 2 Diabetes," Scientific Reports, vol. 10, no. 1, pp. 1–10, 2020, doi: 10.1038/s41598-019-56411-0.

[143]G. Block et al., "Diabetes prevention and weight loss with a fully automated behavioral intervention by email, web, and mobile phone: A randomized controlled trial among persons with prediabetes," Journal of Medical Internet Research, vol. 17, no. 10, p. e4897, 2015, doi: 10.2196/jmir.4897.

[144]S. Subramaniam, J. S. Dhillon, and W. F. Wan Ahmad, "Behavioral theory-based framework for prediabetes self-care system—design perspectives and validation results," International Journal of Environmental Research and Public Health, vol. 18, no. 17, 2021, doi: 10.3390/ijerph18179160.

[145]C. M. Castro Sweet et al., "Outcomes of a Digital Health Program With Human Coaching for Diabetes Risk Reduction in a Medicare Population," Journal of Aging and Health, vol. 30, no. 5, pp. 692–710, 2018, doi: 10.1177/0898264316688791.

[146]A. M. Boels, R. C. Vos, L. T. Dijkhorst-Oei, and G. E. H. M. Rutten, "Effectiveness of diabetes self-management education and support via a smartphone application in insulin-treated patients with type 2 diabetes: Results of a randomized controlled trial (TRIGGER study)," BMJ Open Diabetes Research and Care, vol. 7, no. 1, pp. 1–4, 2019, doi: 10.1136/bmjdrc-2019-000981.

[147]M. Afarideh, A. Ghajar, S. Noshad, and A. Esteghamati, "Text message support for weight loss in patients with prediabetes: A randomized clinical trial," Diabetes Care, vol. 39, no. 11, p. e206, 2016, doi: 10.2337/dc16-1210.

[148]B. E. Holtz et al., "The design and development of MyT1DHero: A mobile app for adolescents with type 1 diabetes and their parents," Journal of Telemedicine and Telecare, vol. 25, no. 3, pp. 172–180, Dec. 2019, doi: 10.1177/1357633X17745470.

[149]A. M. Boels, R. C. Vos, L. T. Dijkhorst-Oei, and G. E. H. M. Rutten, "Effectiveness of diabetes self-management education and support via a

smartphone application in insulin-treated patients with type 2 diabetes: Results of a randomized controlled trial (TRIGGER study)," BMJ Open Diabetes Research and Care, vol. 7, no. 1, pp. 1–4, 2019, doi: 10.1136/bmjdrc-2019-000981.

[150]K. A. Cradock et al., "Design of a Planner-Based Intervention to Facilitate Diet Behaviour Change in Type 2 Diabetes," Sensors, vol. 22, no. 7, pp. 1–28, 2022, doi: 10.3390/s22072795.

[151]E. Everett, B. Kane, A. Yoo, A. Dobs, and N. Mathioudakis, "A Novel Approach for Fully Automated, Personalized Health Coaching for Adults with Prediabetes: Pilot Clinical Trial," Journal of medical Internet research, vol. 20, no. 2, p. e72, 2018, doi: 10.2196/jmir.9723.

[152]Kusnanto, K. A. J. Widyanata, Suprajitno, and H. Arifin, "DM-calendar app as a diabetes self-management education on adult type 2 diabetes mellitus: a randomized controlled trial," Journal of Diabetes and Metabolic Disorders, vol. 18, no. 2, pp. 557–563, 2019, doi: 10.1007/s40200-019-00468-1.

[153]C. M. Castro Sweet et al., "Outcomes of a Digital Health Program With Human Coaching for Diabetes Risk Reduction in a Medicare Population," Journal of Aging and Health, vol. 30, no. 5, pp. 692–710, 2018, doi: 10.1177/0898264316688791.

[154]E. Cha et al., "A Feasibility Study to Develop a Diabetes Prevention Program for Young Adults With Prediabetes by Using Digital Platforms and a Handheld Device," The Diabetes Educator, vol. 40, no. 5, pp. 626–637, 2014, doi: 10.1177/0145721714539736.

[155]H. H. Fischer et al., "Text message support for weight loss in patients with prediabetes: A randomized clinical trial," Diabetes Care, vol. 39, no. 11, p. e206, 2016, doi: 10.2337/dc16-1210.

[156]Y. Fukuoka, C. L. Gay, K. L. Joiner, and E. Vittinghoff, "A Novel Diabetes Prevention Intervention Using a Mobile App," American Journal of Preventive Medicine, vol. 49, no. 2, pp. 223–237, 2015, doi: 10.1016/j.amepre.2015.01.003.

[157]M. K. Kramer et al., "A novel approach to diabetes prevention: Evaluation of the Group Lifestyle Balance program delivered via DVD," Diabetes Research and Clinical Practice, vol. 90, no. 3, pp. e60–e63, 2010, doi: 10.1016/j.diabres.2010.08.013.

[158]A. Michaelides, C. Raby, M. Wood, K. Farr, and T. Toro-Ramos, "Weight loss efficacy of a novel mobile diabetes prevention program delivery platform with human coaching," BMJ Open Diabetes Research and Care, vol. 4, no. 1, p. e000264, 2016, doi: 10.1136/bmjdrc-2016-000264.

[159]R. R. Bian et al., "The effect of technology-mediated diabetes prevention interventions on weight: A meta-analysis," Journal of Medical Internet Research, vol. 19, no. 3, p. e4709, 2017, doi: 10.2196/jmir.4709.

[160]G. A. Piatt, M. C. Seidel, R. O. Powell, and J. C. Zgibor, "Comparative effectiveness of lifestyle intervention efforts in the community: Results of the rethinking eating and ACTivity (REACT) study," Diabetes Care, vol. 36, no. 2, pp. 202–209, 2013, doi: 10.2337/dc12-0824.

[161]S. C. Sepah, L. Jiang, and A. L. Peters, "Translating the Diabetes Prevention Program into an Online Social Network: Validation against CDC Standards," The Diabetes Educator, vol. 40, no. 4, pp. 435–443, 2014, doi: 10.1177/0145721714531339.

[162]M. G. Wilson et al., "Evaluation of a Digital Behavioral Counseling Program for Reducing Risk Factors for Chronic Disease in a Workforce," Journal of Occupational and Environmental Medicine, vol. 59, no. 8, pp. e150–e155, 2017, doi: 10.1097/JOM.0000000000001091.

[163]E. Mehraeen et al., "Design and Development of a Mobile-Based Self-Care Application for Patients with Type 2 Diabetes," Journal of Diabetes Science and Technology, vol. 16, no. 4, pp. 1008–1015, 2022, doi: 10.1177/19322968211007124.

[164]C. K. H. Wong et al., "A short message service (SMS) intervention to prevent diabetes in Chinese professional drivers with pre-diabetes: A pilot single-blinded randomized controlled trial," Diabetes Research and Clinical Practice, vol. 102, no. 3, pp. 158–166, Dec. 2013, doi: 10.1016/j.diabres.2013.10.002.

[165]A. L. Orsama et al., "Active assistance technology reduces glycosylated hemoglobin and weight in individuals with type 2 diabetes: Results of a theory-based randomized trial," Diabetes Technology and Therapeutics, vol. 16, no. SUPPL. 1, 2014, doi: 10.1089/dia.2014.1507.

[166]J. Ma et al., "Translating the diabetes prevention program lifestyle intervention for weight loss into primary care: A randomized trial," JAMA Internal Medicine, vol. 173, no. 2, pp. 113–121, 2013, doi: 10.1001/2013.jamainternmed.987.

[167]A. Ramachandran et al., "Effectiveness of mobile phone messaging in prevention of type 2 diabetes by lifestyle modification in men in India: A prospective, parallel-group, randomized controlled trial," Diabetes Technology and Therapeutics, vol. 17, no. 3, pp. S65–S66, 2015, doi: 10.1089/dia.2015.1507.

[168]T. Alanzi, R. Istepanian, and N. Philip, "Design and Usability Evaluation of Social Mobile Diabetes Management System in the Gulf Region," JMIR Research Protocols, vol. 5, no. 3, p. e93, 2016, doi: 10.2196/resprot.4348.

[169]H. Holmen et al., "A mobile health intervention for self-management and lifestyle change for persons with type 2 diabetes, part 2: One-year results from the norwegian randomized controlled trial RENEWING HEALTH," JMIR mHealth and uHealth, vol. 2, no. 4, pp. 1–16, 2014, doi: 10.2196/mhealth.3882.

[170]L. Ledderer, A. Møller, and A. Fage-Butler, "Adolescents' participation in their healthcare: A sociomaterial investigation of a diabetes app," Digital Health, vol. 5, Apr. 2019, doi: 10.1177/2055207619845448.

[171]V. H. Buss, M. Varnfield, M. Harris, and M. Barr, "A Mobile App for Prevention of Cardiovascular Disease and Type 2 Diabetes Mellitus: Development and Usability Study," JMIR Human Factors, vol. 9, no. 2, pp. 1–20, 2022, doi: 10.2196/35065.

[172]G. Block et al., "Diabetes prevention and weight loss with a fully automated behavioral intervention by email, web, and mobile phone: A randomized controlled trial among persons with prediabetes," Journal of Medical Internet Research, vol. 17, no. 10, p. e4897, 2015, doi: 10.2196/jmir.4897.

[173]A. Michaelides, C. Raby, M. Wood, K. Farr, and T. Toro-Ramos, "Weight loss efficacy of a novel mobile diabetes prevention program delivery platform with human coaching," BMJ Open Diabetes Research and Care, vol. 4, no. 1, p. e000264, 2016, doi: 10.1136/bmjdrc-2016-000264.

[174]S. C. Sepah, L. Jiang, and A. L. Peters, "Translating the Diabetes Prevention Program into an Online Social Network: Validation against CDC Standards," The Diabetes Educator, vol. 40, no. 4, pp. 435–443, 2014, doi: 10.1177/0145721714531339.

[175]D. Y. P. Chao, T. M. Y. Lin, and W. Y. Ma, "Enhanced self-efficacy and behavioral changes among patients with diabetes: Cloud-based mobile health platform and mobile app service," JMIR Diabetes, vol. 4, no. 2, 2019, doi: 10.2196/11017.

[176]T. L. Webb, J. Joseph, L. Yardley, and S. Michie, "Using the Internet to promote health behavior change: A systematic review and meta-analysis of the impact of theoretical basis, use of behavior change techniques, and mode of delivery on efficacy," Journal of Medical Internet Research, vol. 12, no. 1, p. e1376, Feb. 2010, doi: 10.2196/jmir.1376.

[177]L. Van Rhoon, M. Byrne, E. Morrissey, J. Murphy, and J. McSharry, "A systematic review of the behaviour change techniques and digital features in technology-driven type 2 diabetes prevention interventions," Digital Health, vol. 6, 2020, doi: 10.1177/2055207620914427.

[178]D. Y. P. Chao, T. M. Y. Lin, and W. Y. Ma, "Enhanced self-efficacy and behavioral changes among patients with diabetes: Cloud-based mobile health platform and mobile app service," JMIR Diabetes, vol. 4, no. 2, 2019, doi: 10.2196/11017.

[179]Kusnanto, K. A. J. Widyanata, Suprajitno, and H. Arifin, "DM-calendar app as a diabetes self-management education on adult type 2 diabetes mellitus: a randomized controlled trial," Journal of Diabetes and Metabolic Disorders, vol. 18, no. 2, pp. 557–563, 2019, doi: 10.1007/s40200-019-00468-1.

[180]P. Craig, P. Dieppe, S. Macintyre, S. Michie, I. Nazareth, and M. Petticrew, "Developing and evaluating complex interventions: the new Medical Research Council guidance," Bmj, vol. 337, 2008.

[181]S. Michie and A. Prestwich, "Are interventions theory-based? Development of a theory coding scheme.," Health psychology, vol. 29, no. 1, p. 1, 2010.

[182]V. Braun and V. Clarke, "Using thematic analysis in psychology," Qualitative Research in Psychology, vol. 3, no. 2, pp. 77–101, 2006, doi: 10.1191/1478088706qp063oa.

[183]S. B. Donevant, R. D. Estrada, J. M. Culley, B. Habing, and S. A. Adams, "Exploring app features with outcomes in mHealth studies involving chronic respiratory diseases, diabetes, and hypertension: a targeted exploration of the literature," Journal of the American Medical Informatics Association, vol. 25, no. 10, pp. 1407–1418, Oct. 2018, doi: 10.1093/jamia/ocy104.

[184]L. S. Holcomb, "A taxonomic integrative review of short message service (SMS) methodology: a framework for improved diabetic outcomes," Journal of diabetes science and technology, vol. 9, no. 6, pp. 1321–1326, 2015.

[185]J. Lindström et al., "Take action to prevent diabetes- The IMAGE toolkit for the prevention of type 2 diabetes in Europe," Hormone and Metabolic Research, vol. 42, no. SUPPL. 1, pp. S37–S55, 2010, doi: 10.1055/s-0029-1240975.

[186]S. Michie et al., "The Behavior Change Technique Taxonomy (v1) of 93 Hierarchically Clustered Techniques : Building an International Consensus for the Reporting of Behavior Change Interventions," pp. 81–95, 2013, doi: 10.1007/s12160-013-9486-6.

[187]Q. Yang and S. K. Van Stee, "The comparative effectiveness of mobile phone interventions in improving health outcomes: Meta-analytic review," JMIR mHealth and uHealth, vol. 7, no. 4, pp. 1–14, 2019, doi: 10.2196/11244.

[188]K. Liu, Z. Xie, and C. K. Or, "Effectiveness of mobile app-assisted self-care interventions for improving patient outcomes in type 2 diabetes and/or hypertension: Systematic review and meta-analysis of randomized controlled trials," JMIR mHealth and uHealth, vol. 8, no. 8, pp. 1–23, 2020, doi: 10.2196/15779.

[189]Y. Mao, W. Lin, J. Wen, and G. Chen, "Impact and efficacy of mobile health intervention in the management of diabetes and hypertension : a systematic analysis review and meta," pp. 1–11, 2020, doi: 10.1136/bmjdrc-2020-001225.

[190]Y. Wu et al., "Mobile app-based interventions to support diabetes self-management: A systematic review of randomized controlled trials to identify functions associated with glycemic efficacy," JMIR mHealth and uHealth, vol. 5, no. 3, 2017, doi: 10.2196/mhealth.6522.

[191]X. Wu, X. Guo, and Z. Zhang, "The efficacy of mobile phone apps for lifestyle modification in diabetes: Systematic review and meta-analysis," JMIR mHealth and uHealth, vol. 7, no. 1, pp. 1–13, 2019, doi: 10.2196/12297.

[192]J. P. Riley, J. P. Gabe, and M. R. Cowie, "Does telemonitoring in heart failure empower patients for self-care? A qualitative study," J Clin Nurs, vol. 22, no. 17–18, pp. 2444–2455, Sep. 2013, doi: 10.1111/j.1365-2702.2012.04294.x.

[193]R. R. Bian et al., "The effect of technology-mediated diabetes prevention interventions on weight: A meta-analysis," Journal of Medical Internet Research, vol. 19, no. 3, p. e4709, 2017, doi: 10.2196/jmir.4709.

[194]Y. Mao, W. Lin, J. Wen, and G. Chen, "Impact and efficacy of mobile health intervention in the management of diabetes and hypertension : a systematic analysis review and meta," pp. 1–11, 2020, doi: 10.1136/bmjdrc-2020-001225.

[195]A. J. Dunkley et al., "Diabetes prevention in the real world: Effectiveness of pragmatic lifestyle interventions for the prevention of type 2 diabetes and of the impact of adherence to guideline recommendations: A systematic review and meta-analysis (Diabetes Care (201," Diabetes Care, vol. 37, no. 6, pp. 1775–1776, 2014, doi: 10.2337/dc14-er06.

[196]J. E. Donnelly, S. N. Blair, J. M. Jakicic, M. M. Manore, J. W. Rankin, and B. K. Smith, "Appropriate physical activity intervention strategies for weight loss and prevention of weight regain for adults," Medicine and Science in Sports and Exercise, vol. 41, no. 2, pp. 459–471, 2009, doi: 10.1249/MSS.0b013e3181949333.

[197]J. A. Dunbar et al., "Public Health Approaches to Type 2 Diabetes Prevention: The US National Diabetes Prevention Program and Beyond," Current Diabetes Reports, vol. 19, no. 11, pp. 1–11, 2019, doi: 10.1007/s11892-019-1262-y.