The use of video games, gamification and virtual environments in the self-management of diabetes: A systematic review of evidence

Theng Yin-Leng, Lee Jason W.Y., Patinadan Paul V., and Foo Schubert

Abstract

The use of video games in healthcare intervention is gaining popularity but there is still a gap in the understanding on how this intervention is used for the management of diabetes. The purpose of this review was to examine published research on the use of video games for diabetes management. With the increase use of mobile technology, this review was expanded to understand if games, gamification and virtual environments can be used for diabetes self-management. Results indicated that out of the 307 papers identified, only 10 papers met the inclusion criteria of the study. The duration of most studies was short with small sample sizes that consisted of those aged between 8 -16. All the interventions targeted behavioural changes examining the risk reduction of the diabetes-related risk and promotion of healthy behaviour among the study participants. Video games were found to be effective tools for education while gamification and virtual environment increases intrinsic motivation and positive reinforcement. The paper concludes by discussing the potentials of using video games and gamification for self-management of diabetes.

Introduction

Diabetes is a chronic metabolic condition that is especially costly for the sufferer (1). Complications that may arise from improper care and treatment include heart disease, blindness and renal failure. Regular monitoring of the condition and securing optimal glycemic control through effective self-management practice is critical in reducing unwarranted micro and macro vascular complications due to the disease (2).

Some of the issues with diabetes management is that patients display negative attitudes, coping difficulties and motivation towards self-monitoring and regimen adherence (3,4). One novel way to address this issue introduces elements from game based approaches or “gamification” into diabetes initiatives. Gamification has been described as the “use of game design elements in non-game contexts”(5). The process itself would be to equate activities in non-game contexts with points and the provision
of external rewards (e.g., points, badges, leadership board, cash incentives) for reaching point thresholds (6). This may be useful in the motivational, educational and empowering facets that seem to be lacking in diabetes management. By gamifying mundane tasks such as taking blood glucose reading, the patient may be more engaged to complete the task.

Playing video games has been shown to foster intrinsic motivation and increase positive emotion (8). Linking this to the sphere of health behavior, serious video games can be a promising novel avenue that seeks to entertain the user while attempting to elicit some form of change in behavior. Such games may be perceived as merely for entertainment which perhaps explains the gap in the number of clinical studies. However, serious games are designed with a specific purpose rather than purely for entertainment. Serious games can be designed to modify user attitudes, perceptions, knowledge and skills (9), and needs to be tailored to the targeted socio-demographic group (10).

This study extends the concept of gamification to a virtual environment (VE) where a person is represented as an avatar in the virtual “world”. The use of VE offers a unique opportunity to reach out to populations with diabetes (11) in a cost-effective manner. Within the VE, a multi-sensory, interactive and three-dimensional (3D) environment can be created for a specific purpose. These VE have been shown to augment traditional care in the management of diabetes (12) and allows patients with diabetes to “attend” group visits, learn about lifestyle change and social support.

There has been a steady increase on the use of technology for the management of diabetes. A majority of the studies focused on the glucose monitoring process such as allowing patients to upload their data so that the healthcare providers can adjust their medication (13,14). Technology interventions were effective and versatile in facilitating the management of the condition (15,16) and support the change in lifestyle (17).

With increasing interest in the use of games for healthcare, the objective of this study is to review the literature that focuses on the use of video games, gamification methods and virtual environments for day-to-day self-management of people with diabetes. This studies will be measured against four outcomes (behaviour, knowledge, biological and psychological) and the American Association of Diabetes Educators Seven Self-Care Behaviours (AAED7) (18).

**Methods**

*Research questions*

Three research questions (RQs) guided the design of this study. These are: what are the characteristics of video games, gamified apps or virtual environments studies for the management of diabetes? (RQ1); what are the targeted behaviour for these interventions? (RQ2); and what are the key findings from the studies? (RQ3).

*Data sources*

We searched 4 databases (PubMed, Web of Science, Scopus, PsychINFO) on 31st October 2014 using the keywords of diabetes with “gamification” OR “virtual reality” OR “virtual environment” OR “video game” OR “mobile game” OR “computer game” in the keyword search. The asterisk (*) was used in order to expand the search to include terms such as “games”, “gaming”, “gamification”, etc. We also confined the searches to only sub-headings, abstracts, title and keywords with a limit to the publication date between 2000 to 2014. Searches were confined to English language
journals and dissertations were excluded as access to the abstracts contained insufficient information to be used as evaluation.

The inclusion criteria were as follows: 1) The study was focused on people with diabetes in managing their health conditions; 2) At least one video game, virtual environment or gamified approach was used as the primary intervention; 3) The study included qualitative or/and quantitative measures; and 4) The study was an original article and not a review of other studies.

The publications shortlisted were measured against the 22-item STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) checklist for cohort studies (19) for the measurement of studies in epidemiology. The checklist aims to strengthen the reporting of observational studies by researchers. Incomplete and inadequate reporting of research often hampers the assessment of merits and weaknesses seen in literature. The STROBE checklist is highly endorsed and consists of a collaborative international initiative of epidemiologists, methodologists, statisticians, researchers and journal editors. Two authors measured against the checklist and shortlisted 10 publications, which met an average of 17.9 out of 22 quality criteria of the STROBE framework. One publication was removed, as it did not meet at least half of the items on the checklist.

The unit of analysis of this article is the intervention or project. If the same intervention was featured in more than one publication, the primary study was selected for this review.

Data extraction

The authors extracted the data from the articles using predetermined tables that were entered into an Excel spreadsheet for further analysis. The data extracted from the studies included: 1) author and year of publication; 2) description of the study; 3) theoretical background of the intervention; 4) intervention platform; 5) research design (study type, duration of study, sample size, age); 6) measured outcomes (behaviour, knowledge, self-efficacy, biological, psycho-social); 7) targeted behaviour for change; and 8) key outcomes.

Target behaviour for change is based on a modified American Association of Diabetes Educator’s AADE7 System (see Table 2) to measure behaviour change as a desired outcome for diabetes education (18). The AAED7 consists of 7 primary goals and two authors categorized the studies separately and sorted out any disagreement on the shortlisted studies through mutual agreement.

Results

Research Question 1 (RQ1): Characteristics of interventions

The search identified 307 papers (see Figure 1) and ten studies met all the inclusion criteria. Four studies were based on video games (20–23), three studies utilized virtual environments (24–26) and three studies employed principles of gamification for the management of diabetes (27–29).

Three studies reviewed employed a randomized control trial (RCT) design (20,23,26). Five were quasi-experimental (24,25,27–29), one was a qualitative focus group discussion (21) and one study was of an experimental design (22). In
addressing RQ1, a summary of the reviewed studies’ characteristics is presented in Table 1.

Figure 1. Flow diagram of search results
<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Description of study</th>
<th>Theory</th>
<th>Platform used</th>
<th>Study Type</th>
<th>Duration of study</th>
<th>Sample size</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anderson-Hanley et al., 2012</td>
<td>Exploratory on the neuropsychological effects of exercise among older adults with diabetes and feasibility of utilizing exergaming as a viable exercise</td>
<td>“CyberCycle” Exergame</td>
<td></td>
<td>Quantitative</td>
<td>3 months</td>
<td>20</td>
<td>60-88 years</td>
</tr>
<tr>
<td>Bason Henkemani et al., 2013</td>
<td>Assessed the effects of an educational play with a personalized robot on the enjoyment, motivation and acquisition of health knowledge of children with diabetes.</td>
<td>Self-Determination Theory (SDT), “Nao” the Robot</td>
<td></td>
<td>Mixed</td>
<td>9 weeks</td>
<td>5</td>
<td>8-12 years</td>
</tr>
<tr>
<td>Cafazzo et al., 2012</td>
<td>Adolescents with Type 1 diabetes were provided the “bat” app for the iPhone and a Bluetooth glucometer for automated reading transfer to the app. Routine health behaviours and actions were rewarded using iTunes gift cards</td>
<td>Behaviour Change Theory (BCT)</td>
<td>iPhone</td>
<td>Mixed</td>
<td>12 weeks</td>
<td>20 (12 for analysis)</td>
<td>12-16 years</td>
</tr>
<tr>
<td>DeShazo et al., 2012</td>
<td>Game design and usability of three mobile phone games developed for the delivery of diabetes education was investigated. The games were then refined after focus group discussions and field-tested.</td>
<td>Health Communication Theory and Education Theory</td>
<td>Mobile Phones</td>
<td>Qualitative</td>
<td>10 - 30 min</td>
<td>11</td>
<td>Average age of 38 years</td>
</tr>
<tr>
<td>Fuchsioch et al., 2011</td>
<td>The development and initial testing of a Flash based video game called Balance focusing on food and insulin intake. An implicit version of the game not alluding to diabetic management was also tested, to address concerns of adolescent reactance against diabetic management</td>
<td>Social Learning Theory (SLT)</td>
<td>Computer</td>
<td>Quantitative</td>
<td>15 minute session</td>
<td>20</td>
<td>11-16 years</td>
</tr>
<tr>
<td>Johnson et al., 2014</td>
<td>Feasibility and efficacy of participation in a digital virtual environment (Second Life Impacts Diabetes Education and Self-Management) for diabetes self-management and support was evaluated in a sample of individuals with diabetes.</td>
<td>Social Cognitive Theory (SCT) Virtual Environment Theories</td>
<td>Computer/Second Life Virtual World</td>
<td>Mixed</td>
<td>6 months</td>
<td>20</td>
<td>39-72 years</td>
</tr>
<tr>
<td>Authors</td>
<td>Description</td>
<td>Methodology</td>
<td>Duration</td>
<td>Sample Size</td>
<td>Age Range</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------</td>
<td>-------------------------------------------------------------------------------------------------------</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Kempf et al., 2013</td>
<td>A randomized controlled trial testing the effect of playing the exergame “Wii Fit Plus” on metabolic control and physical activity in participants with type 2 diabetes.</td>
<td>Nintendo Wii Gaming Console</td>
<td>12 weeks</td>
<td>220</td>
<td>50-75 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Klingensmith et al., 2013</td>
<td>The acceptability and performance of a glucose meter that was coupled with a gaming system was assessed in a sample of children, adolescents and young adults with type 1 diabetes</td>
<td>Didget glucomonit with Nintendo DS Lite</td>
<td>Quantitative</td>
<td>3-5 day testing phase</td>
<td>147</td>
<td>5-24 years</td>
<td></td>
</tr>
<tr>
<td>Ruggiero et al., 2014</td>
<td>The acceptability, usage and preliminary outcome of a virtual world (Diabetes Island) examined in a sample of low-income African-American individuals with type 2 diabetes.</td>
<td>Social Cognitive Theory (SCT)</td>
<td>Computer/Second Life Virtual World</td>
<td>Mixed</td>
<td>6 months</td>
<td>41</td>
<td>Average age of 55 years</td>
</tr>
<tr>
<td>Rosal et al., 2014</td>
<td>A randomized clinical trial designed to test the feasibility and comparative effectiveness of a virtual world versus face-to-face diabetes self-management group intervention</td>
<td>Social Cognitive Theory (SCT), Evidence-based Practice, Cultural Tailoring</td>
<td>Computer/Second Life Virtual World</td>
<td>Quantitative</td>
<td>8-week program 4 month follow-up</td>
<td>89</td>
<td>Average age of 52 years</td>
</tr>
</tbody>
</table>
Table 2. Measurement, targeted behaviours and key findings of the study

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Instruments</th>
<th>Targeted Behaviour (AADTF)</th>
<th>Measured Outcome</th>
<th>Key Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anderson-Harley et al., 2012</td>
<td>Neurological Evaluation of Executive Function (Color Trails 2, Stroop Test, Digit Span Backwards)</td>
<td>x x x</td>
<td>Exercise Outcomes (Frequency, Intensity, Duration)</td>
<td>Cognition and executive function</td>
</tr>
<tr>
<td>Elston-Flansikens et al., 2013</td>
<td>Mind Youth Questionnaire, Tunness’ Questionnaire, Diabetes Knowledge Questionnaire</td>
<td>x x x</td>
<td>Self-care Knowledge about diabetes</td>
<td>Self-efficacy</td>
</tr>
<tr>
<td>Cada et al., 2012</td>
<td>Interview, Self-Care Inventory, Diabetes Family Responsibility Questionnaire, Diabetes Quality of Life for Youth Instrument,</td>
<td>x</td>
<td>Blood glucose monitoring, Exercise</td>
<td>HbA1c Social support, Self-efficacy, Quality of life</td>
</tr>
<tr>
<td>DeSazo et al., 2012</td>
<td>Focus group discussion, Questionnaire to assess perceived attitudes and self-reported experiences</td>
<td>x</td>
<td>Analytic Metrics (Game selection, Time spent on game, etc.)</td>
<td>Knowledge about diabetes</td>
</tr>
<tr>
<td>Fuchslocher et al., 2011</td>
<td>Game Enjoyment Scale, Adapted Self-Efficacy Scale, Locus of Control Scale</td>
<td>x</td>
<td>x x x</td>
<td></td>
</tr>
</tbody>
</table>
| Johnson et al., 2014 | Focus group discussion, Perceived usefulness scale, Perceived ease of use scale, | x x x x | Frequency of login | Knowledge about diabetes, HbA1c, Blood pressure, Social support | High scores on rated usefulness and ease of use with regular log-ins. Self-efficacy, social support and foot care behavior had significant improvement. Small
<table>
<thead>
<tr>
<th>Study</th>
<th>Measures Used</th>
<th>Findings</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kempf et al., 2013</td>
<td>Problem Areas in Diabetes (PAID) questionnaire, Short Form-12 health survey (SF-12), WHO-5 Wellbeing Index, CES-D Self-Report Depression Scale (Cowan)</td>
<td>x</td>
<td>Exercise, Medication adherence</td>
</tr>
<tr>
<td>Klangenstich et al., 2013</td>
<td>Health Care Professionals’ evaluation of subjects’ comprehension of instructional materials, Preloaded meter with simulated glucose result to measure parent/guardian comprehension of interface, Satisfaction surveys</td>
<td>x</td>
<td>Blood glucose monitoring, Glucometer readings</td>
</tr>
<tr>
<td>Ruggiero et al., 2014</td>
<td>Summary of Diabetes Self-care Activities (SDACA), Environmental Barriers to Adherence Scale (EBAS), Fat-related Diet Habits Questionnaire (DHQ), Diabetes Empowerment Scale-Short Form, Diabetes Distress Scale, Intervention acceptability questions</td>
<td>x</td>
<td>Diet, Physical activity, Discrete behaviors (foot care, medication use) Frequency of login</td>
</tr>
</tbody>
</table>
AED7 Description

1 Healthy eating – Making informed and appropriate healthy food choices, eating times and weight management to achieve optimal blood glucose levels
2 Being active – Engaging in appropriate levels of exercise and physical activity
3 Monitoring – Daily self-monitoring of glucose level to assess food, physical activity and medication effect on their blood glucose level
4 Taking medication – To be knowledgeable about each medication information and effect on oneself
5 Problem solving – To be able to use their problem solving skills to make rapid, informed decision about food, activity and medication
6 Reducing risk – Learning to understand, seek and regularly obtain an array of preventive services to reduce the effects of risks associated with the condition
7 Healthy coping – Helping the individual’s motivation to change behaviour and setting goals and guiding individuals through multiple obstacles

Virtual world intervention slightly superior to face-to-face intervention in promoting physical activity. HbA1C and depressive symptom reductions were greater for face-to-face intervention.
Platform – Three studies adopted the Second Life program as a medium for intervention (24–26). Two used mobile phones (21,28). One study utilized a humanoid robot called “Nao” (27), one used modified exercise cycles with a video game attachment (20), one used the Nintendo Wii (23) and one developed an Flash video game (22). The final study tested the effects of the glucometer in conjunction with the Nintendo DS (29).

Study methodology – Of the studies reviewed, five studies were quantitative (20,22,23,26,29), four mixed methodologies (24,25,27,28) and one was qualitative (21). A shared feature across the quantitative studies was measures of satisfaction and acceptability. There were only three studies in those reviewed that utilized a randomized control trial research method (RCT) (20,23,26) and there appears to be a veritable gap in publications that employ this “gold standard” of methodological processes.

Duration – Duration of the studies range from single 10 to 30 minute sessions for video games and up to six months for more immersive conditions.

Sample size – Sample sizes for a majority studies reviewed were small; having less than 50 participants (20–22,24,25,27,28). Only three studies had sample sizes above 50 (23,26,29).

Age – Four studies focused their interventions on children, youth and young adults, with ages ranging from 5–24 (22,27–29). The remaining studies recruited adult and elderly participants, with individuals ranging from 38 to 88 years (20,21,23–26).

Research Question 2 (RQ2): Targeted behaviour

The targeted behaviour section in Table 2 summarizes key findings addressing RQ2. To standardize behavioural outcomes, shortlisted studies were compared against behavioural outcomes set by the AADE7. Table 2 also summarizes the original authors’ findings and methodologies employed in the respective studies.

Four studies encouraged “healthy eating” (21,22,24,25). Five studies sought to motivate participants “be active” (20,23–26). Three studies had a focus on improving blood glucose “monitoring” (24,28,29). Three studies stressed the impact of and directly encouraged “taking medication” (22,24,25). Four studies (22,24,25,27) promoted “problem-solving” skills. All the interventions investigated in this study were aimed at “reducing risk” of diabetes. Furthermore, the majority of the studies (n=9) also advocated “health coping” behaviour.

Research Question 3 (RQ3): Key findings

Due to the heterogeneity of the studies, we extracted the findings and measured them against four facets of outcomes in RQ3: a) behavioural; b) knowledge and self-efficacy; c) biological; and d) psychological. Table 2 describes the instruments reported by the authors, which we measured against the four outcomes and key findings.
Comparison of key findings

All studies measured some form of behavioural outcome (refer to Table 2). Participants’ knowledge on diabetes was a key focus and outcome measure in four studies (21,24,25,27). The primary biological measure of glycated haemoglobin (HbA1c levels) was featured in a half of the studies reviewed (23–26,28). One study evaluated participants’ cognitive and executive functions (20), one study employed glucometer readings (29) and one study included cardio-metabolic risk factors and diabetes dependent impairment (23). Secondary outcome measures such as Body Mass Index (BMI), weight, blood pressure, total cholesterol and waist circumference were utilized by three studies (24–26). Two studies included psychosocial measures, evaluating social support(24,28) and (24) included an evaluation of copresence. A majority of reviewed studies also had other miscellaneous outcome measures, including participants’ self-efficacy, quality of life and well-being (refer to Table 2).

Intervention specific findings

All studies attested to the feasibility and potential of game-based directives in bettering the lives of individuals with diabetes. The four studies (20–23) with video game interventions observed the following: (i) game-based VR enhanced exercise in older adults, also increasing levels of cognition for individuals with diabetes (20); (ii) participants learnt more about nutrition while playing mobile games (21); (iii) participants recorded greater enjoyment when a game protagonist shared their condition (22); and (iv) participants saw enhancements in glycated haemoglobin levels, fasting blood glucose, weight, BMI, diabetes related impairment as well as mental health, well-being and quality of life (23).

Three studies employed virtual world interventions, one (24) recorded significant improvements in self-efficacy, social support and foot care behaviour of participants post-intervention, another (25) found impacts on BMI, diabetes-related distress, barriers to self-care, physical activity and dietary intake, with (26) revealing that virtual world interventions were more effective as compared to face-to-face interventions in promoting physical activity. The latter study, however, also found that glycated haemoglobin levels and depressive symptoms were greater reduced by face-to-face intervention.

The last three studies in the review used gamification principles. Health literacy of children was seen to improve when learning was facilitated by a personalized robot (27), while the use of rewards for motivation saw increases in glucose monitoring (28). The Didget system (29) saw a majority of participants and healthcare professional attest to its value as a blood glucose monitoring aid, and that the system “solved a problem and fulfilled a need”.

Many of the studies that were reviewed had small sample sizes. Therefore, it remained difficult for any statistically significant analyses and results to be drawn conclusively. In addition, the intervention lengths for the studies were especially short, allowing interpretation of long-term effects challenging. Only gamification studies were longer in duration but relatively small sample sizes do not necessarily translate to generalizability of findings.
Discussion

This review synthesized evidence on using video games, gamification and virtual environment for diabetes management. Of the 307 papers that were identified, only ten papers met the inclusion criteria. Four studies employed video games as their intervention, three utilized virtual reality environments and three studies adopted principles from gamification and relevant theory. Given the state of technology and the popularity of the medium in entertainment, the number of studies that investigated video games in the context of diabetes management was much lower than anticipated.

Games for health change

Alluding to the maturity of gaming technologies, “serious video games” (7) provide a promising avenue that seeks to entertain while attempting to elicit behavior change. Such games are tasked with modifying user behaviour and knowledge by inserting the procedure into the process of playing the game and embedding concepts into the story of a game (30) for risk reduction. Two studies (20,23) adopted the former method, via “exergames” that introduced the behavior to be internalized (physical activity) directly as an aspect of the game while (22) employed the latter method, with one group of participants playing as a protagonist with diabetes whose insulin and dietary intake they had to manage. Another casual mobile game study (21) does not fall clearly into either category as proposed by(30) although the application were favorably accepted for their informative value. Therefore, solely creating knowledge structures, as such, may not be enough to induce behavioral change.

Three studies reviewed (24–26) embedded their interventions in the Second Life virtual reality system. Second Life is a simulated multi-media environment that allows the creation of interactive avatars (graphical self-representations) that inhabit a virtual world (11). Studies that employed Second Life observed positive effects in the lives of participants (refer to Table 2). However, the small sample size of two studies (24,25) was seen to restrict the drawing of otherwise significant conclusions. The merit of all three studies remains the effective demonstration of the feasibility, usability and quick acceptance of virtual world interventions, as evidenced by high participant satisfaction and interest rates (24–26). A defining value of a virtual world intervention is its reach and provide an easily disseminated alternative model of diabetes self-management while negating geographic boundaries (24) or the underserved populations (25).

Increasing motivation through games

The novelty of even a generic rewards system in the practice of monotonous and at times uncomfortable (such as in glucose monitoring) behavior might have been enough to motivate participants to effectively learn and practice them. The adoption of game-elements for serious purposes extrinsically motivates the practice of target behavior by the provision of external rewards. Behavioral intentions towards continued use (31) should be considered for future research.

The challenge shifts to internalizing extrinsically motivated behavior enough to be assimilated into an individual’s sense of self. Internalization has been associated to greater medication adherence in patients with chronic illnesses and improved glucose control in individuals with diabetes (32). Feelings of volition and empowerment towards management of diabetes as well as supportive relationships
with caregivers and health professionals can shift individual goals from extrinsic to intrinsic in nature.

Research gaps

One of the common issues in these interventions is the decline in user participation over time. This was attributed to the poor upkeep of site content (24) and therefore should be fluid and constantly renewed. With the culmination of the studies, there appears to be no intrinsic value to participants to continue their participation which saw a decline in the log-in patterns. Studies have shown that the effects of game-design elements change over time; diminishing in the long-term (33,34). A prominent novelty effect might be a critical confounding factor with the employment of game-design elements for the promotion of specific behavior.

A mediating factor in maintaining rates of use might be the social aspect of the intervention; a function absent in the other forms of gaming and gamification discussed in this review. Virtual communities allow for the creation of “third places” (35), allowing for informal cohesion away from work and home life could be the motivating factor to encourages continuous participation within a virtual world intervention.

Adhering to healthy behavior for chronic illnesses such as diabetes is one of the biggest challenges for healthcare professionals. With numerous benefits for control and maintenance of chronic conditions like diabetes and the many negative ramifications that may arise without the practice (17,3), self-monitoring as a health behavior is important for the patients. A majority of the studies reviewed employed games, gamification or virtual environment interventions as an educational tool, rather than a direct means to increase self-monitoring behavior. Only two studies (28,29) had interventions where the actual practice of self-monitoring behavior was inculcated via gamification processes.

Medication adherence is the foundation of effective diabetes care and management. However, the current study did not find any research specifically targeting medication adherence as part of the behaviour change process. Interventions such as those from (24) and (25) facilitated medication adherence through information provision but did little to actively encourage the behaviour while (22) alluded to the importance of balancing insulin levels via medication. However, the authors did not have any direct measures as to how their interventions might have affected rates of adherence. Given the importance of medication adherence, future research should seek to address this concern.

Limitations

Despite our rigorous attempts to locate all relevant articles, a possibility exists that certain articles were missed or that publication biases led to overall underreporting. Our specified keyword search might not have been as efficacious due to these reasons. Secondly, the low number of relevant publications, low sample size, and the heterogeneity between the studies makes drawing strong conclusions from the studies a challenging process. Despite these limitations, our analysis framework provides readers with an important understanding of the gaps within the current literature and alludes to future directions for research in this sphere.
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