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REVIEW

The Impact of Virtual Care on Health-Related Quality of Life in Pediatric Diabetes Mellitus: A Systematic Review

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Background: The COVID-19 pandemic has escalated the utilization of virtual care platforms in pediatric diabetes mellitus. The impact of these interventions on the health-related quality of life (HRQOL) is unclear.

Objective: This systematic review evaluated the impact of virtual care, including eHealth and mHealth modalities, when compared to in-person care, on HRQOL in children with diabetes.

Methods: MEDLINE, EMBASE, EMCare, PsycInfo, and Web of Science, ProQuest Dissertations and Theses A&I, and ClinicalTrials.gov databases and registries were searched from database inception to October 2nd, 2023. Randomized and non-randomized comparative studies were eligible for inclusion.

Results: Thirteen studies were identified (12 randomized controlled trials, 1 cross-sectional study) involving 1566 children with type 1 diabetes mellitus (T1DM). The supplemental virtual care interventions utilized either web- or mobile-based platforms for intervention implementation. No interventions were detrimental to HRQOL, and a few improved the short-term HRQOL. No interventions worsened glycemic control. Patients and family's satisfaction with virtual care was high, perceiving it to be equal to or better than in-person care. There was no evidence for the use of virtual care and its effect on HRQOL in pediatric type 2 diabetes mellitus patients.

Conclusion: Virtual care is associated with a stable or improved HRQOL and patient and family satisfaction in pediatric T1DM. Decision makers need to consider expanding virtual access to pediatric diabetes care that can improve equitable access to quality care across healthcare systems globally.

Keywords: pediatric diabetes, health-related quality of life, virtual care

Introduction

The COVID-19 pandemic disrupted pediatric clinical care globally.[1–4] In the case of children living with diabetes, the pandemic significantly curtailed in-person clinic visits.[1,5–8] When available, diabetes care teams shifted rapidly to virtual care models to support children and families living with diabetes through these unprecedented times.[1,2]

While the pandemic significantly influenced care models to incorporate virtual components, advancements in digital technology and innovations in virtual pediatric diabetes care delivery present a significant area of opportunity. Virtual interventions in pediatric diabetes management have the potential to increase autonomy and may offer seamless integration of management strategies into the daily lives of children living with diabetes. It also offers the possibility

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of timely feedback and collaboration with healthcare providers.[8–11] Virtual pediatric diabetes clinics also support the equitable access to specialized care in remote regions where attending clinic visits may be a challenge.[12,13]

Integrating technology into glucose monitoring and insulin delivery has improved glycemic control and decreased the incidence of adverse events, and has the potential to improve the health-related quality of life (HRQOL) for patients living with diabetes.[14–19] HRQOL measures how a disease impacts a patient's sense of wellbeing, and the biopsychosocial effects of treatment; crucially, it is correlated with patient acceptance and tolerance of treatment.[20,21] The combined use of diabetes technologies, including mobile applications, texting services and virtual access to healthcare teams offers a unique opportunity to reshape health policy that can improve pediatric diabetes care and outcomes.[22,23]

There are many psychosocial challenges associated with diabetes management in the pediatric and adolescent populations including the progressive desire for increased autonomy, peer pressures leading to inconsistency in diabetes care tasks, as well as unpredictable schedules.[24,25] The carbohydrate counting for meals and snacks and the calculation and administration of insulin doses with and without activity and sick day management all pose additional burdens on patients and families.[24,25]

The complexity of diabetes management necessitates the evaluation of virtual interventions for their impacts on the HRQOL and emotional well-being, as well as glycemic control.[24,25]

This systematic review aimed to evaluate the impact of virtual interventions on HRQOL in pediatric diabetes patients.

Methods

The protocol for this systematic review was prospectively registered with PROSPERO (CRD42021235646) and published following the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) reporting guideline.[26,27] The PRISMA checklist is reported in Supplementary Table 1. This study is exempted from ethics review as it is a secondary synthesis of deidentified, aggregated, and publicly available data.

Search Strategy

The search strategy for this review was developed in consultation with a Senior Health Sciences Librarian (LB). The search strategies for the included databases are reported in Supplementary Tables 2–8. We searched MEDLINE, EMBASE, EMCare, PsycInfo, and Web of Science as well as ProQuest Dissertations and Theses A&I, and ClinicalTrials.gov for grey literature, from database inception to October 2nd, 2023. The reference lists of included studies and relevant systematic reviews were also hand-searched for potentially relevant studies.

Data Management

Search results were imported into Covidence[28] where duplicates were removed and data screening was completed. Data abstraction was conducted using a form developed in Microsoft Excel. The data abstraction form was pilot tested to ensure validity.

Eligibility Criteria

Eligible studies included randomized controlled trials (RCTs) and non-randomized comparative study designs. Studies were included if they recruited boys and girls 2–18 years of age, from all ethnicities with a diagnosis of type 1 diabetes mellitus (T1DM) or type 2 diabetes mellitus (T2DM) with HRQOL measured as the main or secondary outcome.

Participants were included regardless of their treatment type or presence of co-morbid conditions. For T1DM, co-morbid conditions included autoimmune thyroid conditions, as well as celiac disease. For T2DM, co-morbidities included associated nephropathy, retinopathy, and neuropathy. We excluded studies that reported children with other types of diabetes, patients who were pregnant, and patients who were treated with steroids or immunosuppressants.

We included studies reporting eHealth and mHealth interventions to deliver diabetes education and care. The eHealth platforms include Internet, virtual reality, or digital gaming applications that allow users to monitor, manage, or learn about their health through video, text, or interactive learning media.[29–31] The mHealth platforms include portable or wireless applications such as text messaging, mobile-compatible applications (apps), wearable devices, and social media platforms.[29,30,32] Diabetes education and care refers to personalized patient education and care that involves assessing, monitoring, and promoting adequate

glycemic control, with a focus on limiting comorbidities and promoting healthy living with diabetes.[6,33] We included virtual care interventions that either replaced or were an add-on to usual, in-person care. Eligible studies involved comparator groups that had in-person clinic visits with the diabetes teams.

Outcomes

The main outcome of this review was HRQOL. We included results from all the instruments that assessed the HRQOL regardless of the questionnaire used. Other important outcomes that were included involved the association of virtual care interventions with glycemic control as measured by glycosylated hemoglobin A1c (HbA1c). Additionally, we assessed the number and severity of diabetes-related morbidities, including hypoglycemia and diabetic ketoacidosis (DKA), body mass index (BMI)-based measures, and patient satisfaction.

Data Abstraction

Reviewers (RR, RD, MK, SY) independently screened titles, abstracts, and full-text articles for inclusion eligibility in duplicate. Data from included full-text articles were extracted into a standardized data abstraction form. The reviewers resolved any conflicts through discussion, and if necessary, an additional reviewer (MCS) was available to resolve persisting discrepancies. The abstracted data included first author name, year of publication, country, study design, the population (sample size, age, sex), intervention and control treatment descriptions and durations, analysis methods, and results for relevant outcomes.

Study and Evidence Appraisal

Reviewers independently performed the risk of bias assessment for each outcome of interest in duplicate. Any conflicts were discussed, and an expert reviewer (MCS) resolved disagreements. Randomized controlled trials were assessed for risk of bias using version 2 of the Cochrane risk of bias (RoB 2.0) tool.[34] Non-randomized studies were assessed for risk of bias using the Risk of Bias In Non-randomized Studies of Interventions (ROBINS-I) tool.[35,36]

The Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) approach was used to assess the overall confidence in the evidence, and was grouped by study design and outcome.[37]

Statistical Analysis

A meta-analysis was planned if a minimum of two studies with similar design, population, intervention, methods, analysis, and outcomes were defined. Clinical and methodological heterogeneity were assessed during data abstraction by assessing the included study designs, populations, interventions/comparators and HRQOL tools, as well as during study appraisal using the RoB 2.0 and ROBINS-I tools.[34–36] Statistical heterogeneity was assessed using the $\chi 2$ test p-value with a cut-off value of 0.1 and the I^2 statistic with a cut-off value of >75% defined as considerable heterogeneity.[36]

The studies were grouped according to the types of interventions, including virtual care being an add-on or replacing in-person clinic visits.

Results

Due to high heterogeneity of the interventions and the multiple HRQOL tools used, a meta-analysis was not possible. A narrative synthesis of the results was performed.

The study flowchart is reported in Figure 1. The search strategy identified 4,082 records from database searches, and 15 records from citation searches. There were 231 full-text articles assessed for eligibility, and 14 articles consisting of 13 independent studies involving 1,566 children with T1DM were included in this systematic review.[38–50] No relevant studies were found for children with T2DM.

Of the 13 studies, 12 were RCTs[38–49,51] and one was a cross-sectional study.[50] One independent RCT had two publications reporting on different outcomes; each article reported outcomes relevant to this review, thus both articles are included (Supplementary Table 11).[42,43]

The risk of bias was moderate in nine studies,[38,40–46,48] and high in five studies.[39,47,49–51] The increased risk of bias was related to reported randomization, missing data, and the self-reported nature of HRQOL measures. The quality of

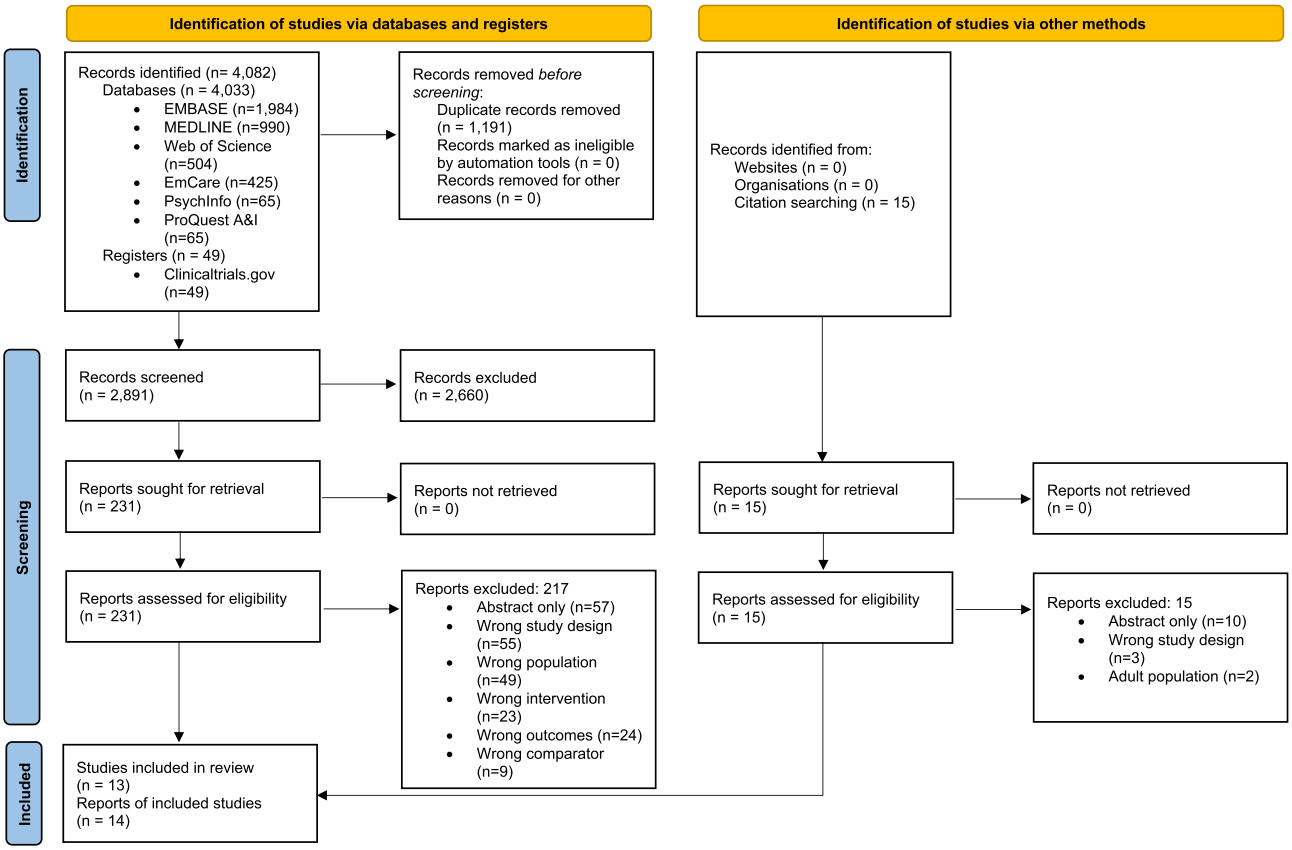

Figure 1 Screening Flow Diagram (PRISMA 2020). Adapted from Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;372:n71. Creative Commons.[26]

evidence was low in nine studies,[38,40–46,48] and very low in five studies (Supplementary Table 9).[39,47,49–51] This low confidence was predominantly due to the risk of bias and imprecision due to small sample sizes with high heterogeneity (Figures S1 and S2).[52]

Types of Interventions

The majority of virtual interventions in diabetes care were add-on visits supplementing in-person clinic visits,[38–46,48–51] with only one study reporting the delivery of a virtual consultation model that replaced in-person clinic visits.[47]

The studies reporting on the add-on virtual visits were further subdivided into two groups. The first group included studies that incorporated virtual psychosocial interventions with behavioral, emotional, and social components of diabetes care. These interventions aimed to support diabetes management via positive reinforcement techniques and behavioral therapy.[39,42,43] One study utilized a video game approach,[39] while the other utilized eHealth, in providing family-based behavioral therapy over Skype, a video-based telecommunication application.[42,43]

The second group included studies that implemented combined psychosocial interventions and biomarker data to support diabetes management and glycemic control.[38,40,41,44–46,48–51]

This group of studies still included behavioral, emotional, and social components of diabetes care similar to the first group, with the addition of data on glycemic control to help guide care decisions.[38,40,41,44–46,48–51] One study utilized mHealth-based modalities including text messaging and mobile apps,[40] while two RCTs utilized eHealth modality implementing phone calls.[38,41] The remainder of the studies included uploading the glucose data online or to a mobile app and reviewing the data through virtual consultations with the diabetes care team.[44–46,49–51]

Health-Related Quality of Life

All studies reporting on the HRQOL were generated from at least one tool per study. The included tools varied among studies and involved either self-reporting by participants, or information provided by a guardian, and some studies included data from both (Supplementary Tables 10 and 11).

The principal HRQOL concepts in these tools included self-efficacy, self-esteem, psychological wellbeing, perceptions of how well diabetes is being managed, and family functioning.

Virtual visits were associated with similarly reported HRQOL to the ones used in the in-person visits.[47] HRQOL was measured over five scales for both participants and their guardians, encompassing the concepts of functional capacity in everyday life, psychological well-being, physical state, and social relationships related to diabetes management.[47]

The virtual psychosocial add-on interventions reported on concepts of self-efficacy, self-care, and social supports,[39] perceptions of diabetes self-management,[42] conflict behaviors and levels of illness acceptance.[43] There was no significant deterioration in HRQOL scores for perceptions of diabetes self-management,[42] conflict behaviours,[43] and levels of illness acceptance[43] between groups. One study suggested a significant increase in self-efficacy, self-care, and social support with supplemental virtual care.[39]

Of the nine studies investigating virtual add-on therapies that targeted both biological and psychosocial aspects of diabetes management, the majority demonstrated that HRQOL was stable when comparing the intervention and control groups.[38,41,44–46,50,51] The domains of HRQOL specifically investigated in these studies included self-image, general quality of life,[38,45] family functioning,[38,44,51] strengths and difficulties of diabetes management,[41] general diabetes management,[44,46,51] self-care,[44] and diabetes-specific emotional distress.[50] Three studies using a mixed approach of psychosocial and biological supplemental virtual interventions demonstrated significant improvements in HRQOL with eHealth and mHealth modalities.[40,48,49] The domains of HRQOL included self-efficacy[40,48] and general diabetes management.[49]

Other Outcomes

The 12 papers reporting on glycemic control included pre- and post-intervention HbA1c or the HbA1c change scores.[38–42,44–47,49–51] The majority of studies reported maintained HbA1c with virtual interventions.[38–42,44,45,47,50] Three studies, all of which were mixed psychosocial and biological add-on therapies delivered via eHealth and mHealth modalities, demonstrated a significant decrease in HbA1c after three[46,51] and six months.[46,49] Some studies reported this finding specifically in participants with suboptimal HbA1c, defined as ≥8.0% at baseline.[46,51]

All papers reported mean baseline HbA1c ≥7.0%, which is consistent with current literature on glycemic control thresholds and challenges in managing diabetes in children and youth.[5]

One RCT of a supplemental, mixed psychosocial and biological virtual intervention reported a non-significant change in BMI SDS compared to in-person care.[40]

Four RCTs reported maintained or decreased number of hypoglycemic events with supplemental virtual interventions versus the control group.[40,44,46,49] Definitions of hypoglycemia varied from 2.8–3.9 mmol/L.

The use of WeChat and flash-glucose monitoring significantly reduced hypoglycemic events compared to flash-glucose monitoring alone.[49] The remaining studies reported no differences in hypoglycemic events between virtual intervention and comparator groups.[40,44,46] One RCT reported no significant differences in diabetic ketoacidosis (DKA) rates.[40]

Studies reported high satisfaction with supplemental virtual care technology from patients and families (Supplementary Table 11).[39,40,44,46,47,51] Some studies created specific questionnaires to assess patient and family satisfaction with the virtual intervention. Most participants were satisfied or very satisfied with the management *Bant* app, and 96% would continue to use the app if it was made available.[44] The majority (85.7%) of users of *Webdia* app positively rated their experience.[46] Similarly, satisfaction with the diabetes-related videogame was high.[39]

When interviewed about an automated text-messaging intervention, *Sweet Talk*,[40] 81% of participants felt the intervention supported their diabetes self-management, and 90% wanted to continue to receive text messages.[40] 97% of participants were satisfied with 1-2 texts/day.[40] Another study utilizing a modified version of the Diabetes Treatment Satisfaction Questionnaire[53] reported similar satisfaction rates in patients and caregivers for virtual and in-person clinic

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consultations.[47] When interviewed about *CloudConnect*, an eHealth algorithm, adolescents and parents rated the system highly for ease of use and usefulness in communicating about diabetes management.[51]

Discussion

The COVID-19 pandemic led to the early substitution of conventional in-person care models with virtual care approaches. Virtual care is now integrated into healthcare systems globally, and offers several advantages of clinical care delivery alternatives for children and families.[54]

While maintaining adequate glycemic control is a central goal of these care pathways, there remain unanswered questions about the impacts of virtual care on outcomes in pediatric diabetes. Some advantages of this approach relate to the potential for enhancing the equity and timeliness of access to high-quality care especially in remote communities.[55] Other considerations include improving the quality of care, optimizing the use of finite healthcare resources, reducing the economic burden on families, reducing school disruption, and increasing patient and family satisfaction.[10,55,56]

The impact of virtual care on HRQOL is a critical question to address, as it may support treatment adherence and the prevention and management of comorbidities and complications.[10,13,57]

Virtual interventions can maintain or even improve HRQOL,[38–51] HbA1c,[38–42,44–47,49–51] and lower hypoglycemia risk[40,44,46,49] in children living with T1DM. There was very limited evidence to suggest that virtual care may stabilize body mass.[40] Patient satisfaction with virtual interventions was high.[39,40,44,46,47,51]

While the results were encouraging, significant heterogeneity and a varied set of tools used to assess the HRQOL are limitations to consider when interpreting the results.

The main virtual care interventions identified involved supplemental in-person clinic visits using psychosocial approaches[39,42,43] or combined biological and psychosocial approaches via eHealth or mHealth modalities–the latter being a particularly successful approach.[38,40,41,44–46,48–51] A video game in one study improved HRQOL when compared to the control group.[39]

These results are promising, as high levels of self-efficacy in diabetes management are associated with improved glycemic control and engagement in self-management.[58–60] Self-efficacy can build patient confidence in performing diabetes care-related tasks.[58] While success in maintaining the HRQOL and glycemic control are not necessarily simultaneous,[60] sustained HRQOL may lead to positive effects on diabetes control and health-related outcomes, including meeting glycemic targets and preventing adverse events.[58–60]

The common characteristics of the promising supplemental virtual therapies involved the provision of diabetes management information and resources, such as bolus calculators, meal fact sheets, health records, and glucose data from sensors. In addition, text message reminders were reported to be helpful. Remote access to clinic feedback and consultation from a diabetes provider were crucial supports.

The combined in-person and virtual interventions were particularly helpful for patients with suboptimal glycemic control and who struggle with sustaining diabetes management routines.[5]

In addition, the use of a social platform for peer support and video gaming were helpful.[39,48] mHealth apps had a positive impact on diabetes management in patients with T1DM, as they are easy to access and use, versatile, and inexpensive.[46,61–63] mHealth apps also permitted a direct interaction between patients and health care providers that can lead to more impact on glycemic control than those designed solely for patient use.[46,64]

Integration of virtual care within the current diabetes care service models is resource intensive and, to make it successful, there is a need for appropriate resource allocation and training for patients and providers to maximize success. If done well, this approach to care is important in ensuring the success of these care modalities.[10,13]

While virtual interventions can be freely available, internet accessibility as well as device and access plan availability and affordability continue to be challenges.[12,13,65]

Most studies excluded participants with no access to technology that would allow them to use virtual care.[39,40,44] Equitable structures to access these care modalities is needed globally.[66] The case for global access of children living with diabetes to remote care needs to be evaluated through international collaborations to make technology use accessible to allow diabetes care delivery.

Strengths and Limitations

The strengths of this review include the well-designed protocol.

Most studies were of short duration, ranging from 2–12 months. Given the chronic nature of diabetes and changing developmental stages of children, long-term studies are required to determine whether virtual interventions can have a lasting impact on HRQOL and diabetes management.

Most studies had small sample sizes, and there were concerns for risk of bias and overall quality of evidence. Also, the high heterogeneity in the reported HRQOL tools precluded pooling the data to conduct a meta-analysis.

There were no studies reporting on virtual interventions in the pediatric T2DM, and further research is needed to address these gaps.

Conclusion

This review demonstrated that virtual diabetes care interventions, which supplement or replace in-person care, maintain HRQOL in children with T1DM. These virtual interventions can also maintain glycemic control and lower hypoglycemia risk. Most patients and families reported satisfaction with virtual care.

Insufficient evidence existed regarding the impact of virtual care on DKA frequency or BMI-based measures. No data were available to assess the association of HRQOL and virtual interventions in patients with T2DM.

Further research is required to determine the long-term impacts of virtual care on HRQOL and glycemic outcomes in both T1DM and T2DM. Using standardized HRQOL tools and patient-reported outcome measures can aid in the further validation of these interventions in pediatric diabetes care.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

The authors report no conflicts of interest in this work.

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