Impacts of Educational Interventions on Glycemic Control in Children and Adolescents with Type 1 Diabetes Mellitus

Sasha Muhammed Elamin[1], Adyani Md Redzuan[1], Siti Azdiah Abdul Aziz[1], Syazwani Hamdan[1], Masyarah Zulhaida Masmuzidin[2], Noraida Mohamed Shah[1]*

[1]Centre for Quality Management of Medicines, Faculty of Pharmacy, Universiti Kebangsaan Malaysia, Malaysia. [2]Edutainment Industrial Revolution 4.0 (EIR 4.0), Creative Multimedia and Animation Section, Malaysian Institute of Information Technology, Universiti Kuala Lumpur, Malaysia.

Abstract

Although insulin treatment has been proven effective in controlling blood glucose among type 1 diabetes mellitus (T1DM) children and adolescents, treatment adherence remains suboptimal throughout the years. Therefore, education intervention is a promising approach to improve insulin therapy adherence, thus improving glycemia control in children with T1DM. This review summarized the findings of available interventions and potential outcomes of education interventions among children and adolescents living with T1DM. The scoping study framework developed by Arksey and O'Malley was used in retrieving and reviewing relevant publications (2000 – 2021), thus, emphasizing the variations in studies, interventions, and patient characteristics. This scoping review comprised 49 papers after the screening of 5015 articles. Most of the education interventions were multidisciplinary and reported improvements in patients' glycated hemoglobin (HbA1c), with or without enhancements in other areas. In conclusion, various patient education interventions positively impact children and adolescents living with T1DM. The findings highlighted the efficacy of patient education interventions in ameliorating glycemic control. by reducing HbA1c, enhancing behavioral outcomes, improving psychological outcomes, patients' health state and quality of life (QOL).

Keywords: Children, Adolescents, Type 1 diabetes, Education

INTRODUCTION

In 2019, approximately 600,900 children below the age of 15 were diagnosed with type 1 diabetes (T1DM) worldwide. Furthermore, T1DM among these particular populations could increase globally to 98,200 cases annually [1]. T1DM therapy aims to prevent cardiovascular morbidity and mortality through intensive glycemic control [2]. Moreover, adherence to diabetes management improves glycemic control independent of age, sociodemographic, or disease characteristics [3]. Nevertheless, adherence to treatment among T1DM children and adolescents is only 30% to 70% [4].

Previous T1DM studies among children have revealed that educating the patient and family, apart from being more cost effective for the patient's caregivers, intensive diabetes care management and close communication with health care professionals were associated with a decrease in hospitalisations and emergency department visits [5]. Notably, the information provided and delivery style should be pediatric-friendly, where the content ranges from basic diabetes management skills that address the family dynamics and concerns involving the whole family [5]. Several contributing factors concerning gaps between guidelines and clinical practice have been identified, including the lack of medical training, educational tools familiarity with guidelines, and time constraints [6].

Patient engagement describes the process where patients are actively involved in deciding their course of treatment, identifying factors influencing their lives, and taking action towards positive changes [7]. This concept is primary in patients' self-management and realizing medical communication and relationship goals [8]. Therefore, patient education is crucial in the patient engagement intervention to support children and adolescents living with diseases [9]. In addition, various studies have reported a high interest in obtaining knowledge about diseases and their impacts on daily life among Children and adolescents with chronic medical conditions such as T1DM [10].

Address for correspondence: Noraida Mohamed Shah, Centre for Quality Management of Medicines, Faculty of Pharmacy, Universiti Kebangsaan Malaysia, Malaysia. noraida_mshah@ukm.edu.my

There are multiple forms of education interventions intended for children and adolescents, often recognized as complex interventions [11], led by healthcare providers or peers for groups or individuals [12]. Group sessions are effective in promoting health policies in many Western countries and essential in improving patients' self-management of chronic disease [13].

It is deemed urgent to clarify and assess the key components and impacts of patient education interventions to establish a successful program. Several publications have highlighted the evidence concerning the potential benefits of this intervention for children and adolescents with diabetes [9], but none of these studies specifically reported how the program affects young individuals with T1DM. Therefore, this review provides a comprehensive summary of published assessments and potential outcomes of patient education interventions among children and adolescents with T1DM.

This review assessed the literature in order to address the following questions:
1. What study design, type of participants, and interventions are suitable for patient education programs involving T1DM children and adolescents?
2. What are the possible outcomes of patient education interventions for children and adolescents living with T1DM?

MATERIALS AND METHODS
Search Strategy
Intervention studies from 2000 to 2021 that assessed glycemic control as glycated hemoglobin (hba1c) and/or other diabetes-related outcomes among children or adolescents with T1DM were identified from six databases: pubmed, Scopus, Scholar, Science Direct, Cochrane, and CINAL. The Arksey and O'Malley approach was used as a systematic method to identify the effects of patient education interventions on glycemic control in children and adolescents with T1DM [14]. This paper selected the scoping review approach, where various study designs were considered to answer the research questions and ultimately achieve a thorough review of the available literature [15].

First, 5015 articles were identified, and 4900 studies that did not fulfil the requirements for inclusion were ommitted (**Figure 1**). A total of 66 articles were later excluded. In addition, assessments of previous systematic reviews on similar topics led to the inclusion of six more studies in the current review. The disagreements about article inclusion were resolved via group discussion to reach a consensus. For example, five studies that included patients above 18 years old were considered in this review since the overall sample population consisted of children, adolescents, and young adults up to the age of of 25. A total of 49 articles were included in this review.
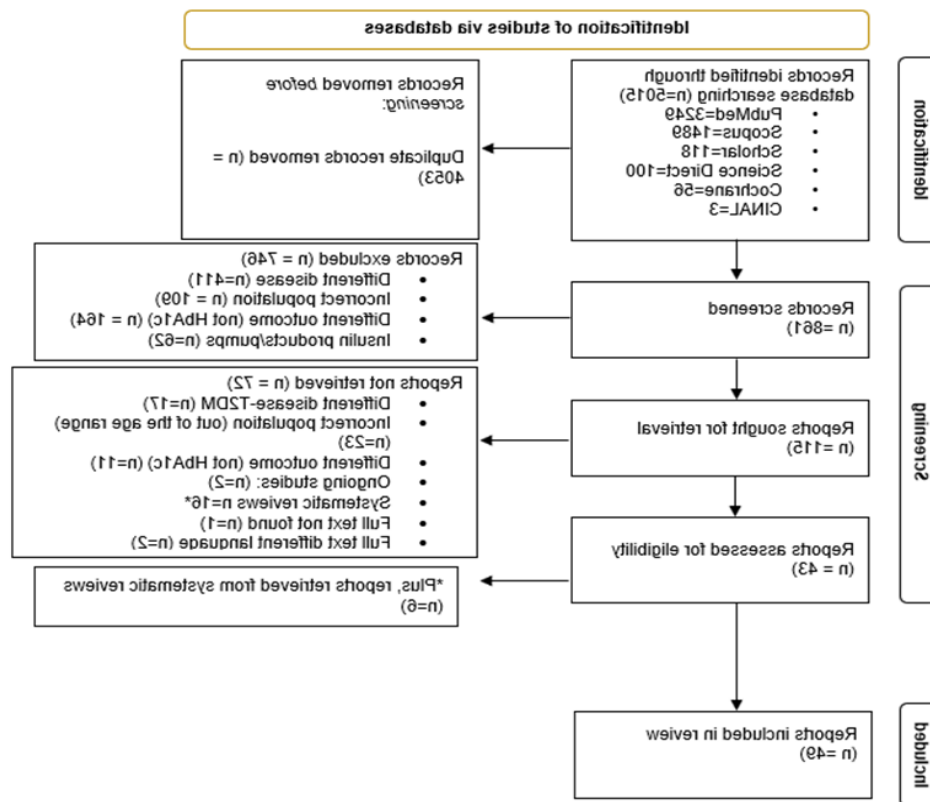
Figure 1. Flow diagram of identified, screened, and extracted studies

The literature search was performed based on the patient, intervention, comparison, and outcomes (PICO) principles. The following keywords were selected for the literature search: "children", "intervention", "education", "type 1 diabetes mellitus", "glycemic control", and "insulin".

This scoping review was conducted according to the following specifications:

- *Population:* Children and adolescents
- *Intervention:* physical or virtual patient education intervention led by healthcare professionals and/or trained participants focusing on enhancements of patients' self-management, glycemic control, and general welfare.
- *Comparisons:* routine treatment, different interventions, or pre/post-intervention effects.
- *Outcomes:* glycemic control reflected by hba1c and other impacts on patients' learning, behavioral, psychological, health status, and QOL.

The inclusion criteria for this review are presented as follows: 1) qualitative and quantitative studies, 2) published in English, and 3) focused on interventions to improve hba1c in children and/or adolescents with T1DM (at least one year before intervention). Meanwhile, the exclusion criteria were studies that did not include children or adolescents, included children in critical care or comorbidities, and did not consider hba1c as an outcome.

Data Extraction

This review highlighted how patient education interventions influence patients' hba1c levels. The studies included in this review conducted education interventions to improve diabetes outcomes in children and adolescents with type 1 diabetes, including their clinical, behavioral, psychological, health status, and QOL.

First, a data extraction sheet was prepared after deliberation among the authors. Two authors were then assigned to extract the relevant information according to the datasheet: general details [author(s), publication year, and country]; study population (age, gender); type of study (study design, duration); intervention program (type and description of intervention) and study findings (hba1c, learning, behavioral, psychological, patients' QOL, and health status). Finally, the findings were validated by another co-author and organised in accordance with the review's main questions **(Table 1)**.

Table 1. Description of the individual studies included in the scoping review

Study No. Author Year Country Study design Study duration	Sample description (ND: No data) N: No of participants T: C (test: control) F: M (female: male) Age range	Setting	Intervention Description	Clinical outcome Glycated hemoglobin (hba1c) (p-value)	Other outcomes
1 M. Afshar *et al.* [16] 2014 Iran Pre- and post-test control groups 6 months	56 75%F:25%M 12 - 18 Years	Diabetes Center/Out-patient clinic	**Intervention:** Peer- education education-based intervention **Description:** Group discussion sessions on QOL with DM, the group s' members shared their problems and experiences with each other and followed the discussed instructions by diabetic specialists. **Mode:** group with parents **Personnel:** specific technician, DM specialist **Duration:** 4 months **Delivery method:** face-to-face and phone calls	Significant reduction by 1% Mean of 8% to 7% (p=0.001)	Improved quality of life (QOL) and fasting blood glucose (FBG)

No.	Study	Setting	Intervention	Glycemic Control	Other Outcomes
2	S. Altundag *et al.* [17] 2016 Turkey Pre- and post-test control groups 9 months 38 18 T: 20 C 50%F:50%M 12 – 14 years	Pediatric endocrine clinic at a university hospital	**Intervention:** Peer education-based intervention **Description:** Introductory information about T1DM in adolescents with diabetes training sessions (warm-up games, narrating, question-answer, demonstration, discussion, and role-play) followed by providing a training guide. **Mode:** group **Personnel:** dieticians, nurses, and child psychiatrist **Duration:** 6 months **Delivery method:** face-to-face	Significant reduction from 10.23 ± 2.39 to 8.02 ± 1.66 ($p< 0.001$)	Improved diabetes knowledge, self-esteem, & social support
3	M. Edraki *et al.* [18] 2020 Iran Randomized control trial 3 months 96 48 T: 48 C 62%F: 38%M 12 - 18 years	Center for diabetic patients, affiliated with Shiraz University of Medical Sciences	**Intervention:** Peer education-based intervention **Description:** 4 peer-led workshops on diabetic self-care behaviours. **Mode:** group with parents **Personnel:** peer educators (Supervised by DM- specialists) **Duration:** 1 month **Delivery method:** face-to-face	Significant reduction ($p<0.001$)	Improved Self-care
4	A. F. Walker *et al.* [19] 2020 USA Randomized controlled study 9 months 42 teens 22 T: 20 C 77%F:23%M 11 - 17 years	Pediatric endocrinology clinic	**Intervention:** Peer mentorship program **Description:** Several key exposures were included in the All for ONE (Outreach, Networks, and Education) mentoring programme, including social events infused with diabetes education, daily SMS text reminders for mentors and mentees for blood glucose monitoring, weekly text exchanges between mentors and mentees, and clinic visits. **Mode:** group **Personnel:** college student mentors **Duration:** 9 months **Delivery method:** face-to-face and text-messages	No significant difference ($p=0.38$)	Improved psychosocial outcome, QOL (Satisfaction)
5	S. Likitmaskul *et al.* [20] 2002 Thailand Cohort study 6 months 52 24 T: 28 C Both Genders (unspecified) 7 - 9 years	Pediatrics department / /hospital	**Intervention:** Intensive diabetes education program **Description:** Multidisciplinary The multidisciplinary management team provides self-management training including information about T1DM, insulin therapy, diet and exercise, monitoring, interpretation, and self-management of hypoglycemia. **Mode:** group with families **Personnel:** pediatric endocrinologists, dieticians, psychologists, and nurses **Duration:** 10-12 days **Delivery method:** face-to-face and phone call	Significant reduction (T = 9.19% C = 11.54%) ($p=0.03$)	Less, by half, hospital stay or complications
6	Y.C. Wang *et al.* [21] 2010 U.S.A. Randomized controlled trial 9 months 44 21 T: 23 C 50%F: 50%M 12 - 18 years	Children's Medical Center	**Intervention:** motivational interviewing (MI)-–based diabetes education versus structured diabetes education education (MI) Vs structured diabetes education (SDE) group educational-based program **Description:** 2-day workshop with either SDE or MI recommended by the American Diabetes Association's (ADA) core content on medication, monitoring, and acute complicationsmi using core content recommended by the American Diabetes Association (ADA) on medication, monitoring, acute complications, plus two intervention sessions on lifestylelifestyle two intervention sessions. And two phone follow-ups **Mode:** group **Personnel:** diabetes educators/physicians **Duration:** 6 months **Delivery method:** face-to-face and phone calls	Significant Reduction ($p=0.03$)	Improved QOL

No.	Study	Design	Sample	Setting	Intervention	Outcome (HbA1c)	Other Outcomes
7	M. A. Abolfotouh *et al.* [22] 2011 Egypt	Cross-sectional / quasi-experimental study 10 months	243 121 T: 122 C 56.6%F: 43.4M 12 - 20 years	Diabetes outpatient clinics	**Intervention:** Education intervention program **Description:** Four 120-minute sessions with one session every month. The program covered i) short and long-term complications, ii) medicine and glucose monitoring, iii) diet and diabetes, and iv) physical activity and foot care.: i) short- and long-term complications of diabetes, ii) medication and glucose monitoring, iii) nutrition and diabetes, and iv) exercise and foot care. **Mode:** group with parents **Personnel:** Pediatricians **Duration:** 4 months **Delivery method:** face-to-face	No significant reduction in the experimental group compared to the control group (-0.18% T: +0.25% C) (p=0.12)	Poorer QOL was substantially/significantly associated with older age (P= 0.001), more hospitalization admissions in the last 6 months (P = 0.006), higher depression levels of depression (P= 0.001), poor self-esteem (P= 0.001), and poor self-efficacy (P= 0.001). After intervention, there was a substantial deteriorating in all categories of QOL in the experimental group. There was a significant deterioration in all domains of QOL in the experimental group after intervention. However, This deterioration was significantly less severe in the experimental group than in the control group.this deterioration was significantly less severe than in the control group
8	V. Coates *et al.* [23] 2013 Ireland	Multi-centered pragmatic randomized controlled trial 5 months	135 70 T: 65 C 53.4F:46.6%M 13 – 19 years	Seven hospital sites	**Intervention:** Structured diabetes educational program **Description:** Designed to allow adolescents to adjust their diets and insulin regimes, allowing them to live a more normal lifestyle close to their peers without diabetes. It was a 12 hours long Designed to enable adolescents to adjust their diet and insulin regimens, liberating their lifestyle to more closely match that of their peers without diabetes. It consisted of 12 hours with 3-hourly interactive, group-based sessions **Mode:** group with parents **Personnel:** research secretary and assistants **Duration:**1 month Delivery method: face-to-face and phone call (CHOICE)	No significant difference in hba1c between across groups in hba1c (p=0.22)	Improved dietary practice
9	D. Christie *et al.* [24] 2014 UK	Pragmatic, clustered Randomized trial 12 - 24 Months	362 181 T: 181 C Both Genders (unspecified) 8-16 years	General hospital clinic or teaching hospital / tertiary clinic	**Intervention:** Structured educational group program **Description:** Two one-day workshops were held to teach intervention deliverytwo 1-day workshops taught intervention delivery, adapted CASCADE intervention (Child and Adolescent Structured Competencies Approach to Diabetes Education) which includes 4-modules: Module 1: The relationship between diet, insulin, and blood glucose levels. Module 2: Blood glucose testing, Module 3: Insulin adjusting—pros and drawbacks, and Module 4: Living with diabetes.1: the The relationship between food, insulin and blood glucose, Module 2: blood Blood glucose testing, Module 3: adjusting insulin—pros and cons and Module 4: living with diabetes. **Mode:** group **Personnel:** pediatricians and nurses **Duration:** 2 days **Delivery method:** face-to-face	No significant difference in hba1c at 12 months (p = 0.584) Nor at 24 months (p = 0.891)	Improved diabetes diabetes-related management and QOL knowledge, family relationships, and motivation

No.	Author / Year / Country	Study design / Duration	Sample / Demographics	Setting	Intervention	Outcome (HbA1c)	Other outcomes
10	C. P. Hawkes *et al.* [25] 2019 USA	Retrospective cohort 2 years	675 391 T: 284 C 44%F: 56% M <18 years	Pediatrics hospital	**Intervention:** A structured education program **Description:** A 10-hour education curriculum was used to provide participants with intense coaching targeted to their family lifestyle and readiness to take independence, discussed nutrition-related challenges, reinforced carbohydrate Counting and dietary management. **Mode:** group with family **Personnel:** primary outpatient clinician, inpatient nurses, and certified diabetes educator **Duration:** 1 year **Delivery method:** face-to-face	Significant reduction in hba1c levels in the T1Y1 group; In 6 months: 6.7%, ($p<0.001$) In 12 months: 7.3%, ($p<0.001$) In 18 months: 7.6%, ($p=0.01$) In 24 months: ($p=0.14$)	Increased time spent in a clinic with a Certified Diabetes Educator (CDE) in the first year ($p<0.001$) - Technology was more utilized in the first year -More patients used CGM ($p = 0.001$) and insulin pump ($p = 0.2$)
11	F. Ramirez-Mendoza *et al.* [26] 2020 Mexico	Pre- and post- Test (no control) 6 months	121 ND 58.7%F:41.3%M 0 - 18 years	Local health centres, general hospitals, paediatric hospitals, the National Institutes of Health, children obesity clinics, and private hospitals referred patients.	**Intervention:** multidisciplinary Educational program **Description:** The PAANDA program (a program of care for adolescents and children with diabetes mellitus) educates the patient how to correct blood glucose levels and urges them to regularly test glucose levels **Mode:** group with caregiver **Personnel:** social workers, pediatric nurses, and endocrinologists **Duration:** 6 months **Delivery method:** face-to-face	Significant reduction average -1.8%, ($p=0.018$) Highest reduction occurred at ages 8-13 years by 2.3%	Reduction of incidences of glycemic complications
12	R. S. D'Souza *et al.* [27] 2021 UK	Retrospective- questionnaire-based service evaluation (pre-SEREN/post-SEREN) 12 months	221 115T:106C 49.8%:50.2% 4 - 17 years	Diabetes clinic/hospital	**Intervention:** Structured Education Reassuring Empowering Nurturing (SEREN) Educational program for cyps **Description:** SEREN program includes; Understanding the aetiology of T1DM, carbohydrate counting, insulin dosage adjustment, hypoglycemia management, sick-day plans, management of diabetic ketoacidosis, complications, and impact of exercise **Mode:** group with parents **Personnel:** pediatric diabetes services (specialists, nurses, and dieticians) **Duration:** 6 weeks **Delivery method:** face-to-face	No change in hba1c	Improved diabetes knowledge and QOL
13	G. Karagizel *et al.* [28] 2005 Turkey	Pre- and post-test control groups 12 months	25 64%F:36%M 7-17 years	Camp	**Intervention:** Summer camp and intensive insulin treatment **Description:** Techniques for injecting insulin, blood glucose monitoring, and recognition and management of hypoglycemia, hyperglycemia, and ketosisthe education program included insulin injection techniques, blood glucose monitoring, recognition and management of hypoglycemia, hyperglycemia, and ketosis, insulin dose modification depending on food and exercise plans, diabetic nutrition, carb counting, complications of diabetes, the importance for controlling diabetes, and novel therapies to test glycemic controldosage adjustment based on nutrition and activity schedules, diabetic nutrition, carbohydrate counting, complications of diabetes, importance of diabetes control and new therapies to test glycemic control, were all covered in the educational programme **Mode:** group **Personnel:** pediatric endocrinologists, nurses, dieticians, interns, and psychologists **Duration:** 7 days **Delivery method:** face-to-face	Significant reduction of HBA1c levels from pre-camp baseline up to 6 and 12 months; (about -1.5%) ($p<0.05$)	Significant improvement in knowledge and self-management at 6 and 12 months of camp. Significant improvement in total generic QOL scores ($p = 0.04$)

#	Study	Design / Follow-up	Sample / HbA1c / Age	Setting	Intervention & Description	HbA1c Results	Other Outcomes
14	J. Santiprabhob et al. [29] 2005 Thailand	Pre-/post - observational study 3 months	62 7.7%:32.3%M 14.1 +/- 4.3 years	Camp	**Intervention:** Camp-based diabetes education program **Description:** 5-day camp including small-group discussions on a range of diabetic self-management topics consisting of small group discussions on various topics on diabetes self-management skills and lectures on: insulin therapy and injection techniques, the significance of diabetes control, blood glucose monitoring, exercise and diabetes, diabetic nutrition, complications of diabetes, how to handle special events, novel therapies for diabetes, and social programmeslectures on: insulin therapy and injection techniques, the importance of diabetes control, blood glucose monitoring, exercise and diabetes, diabetic nutrition, complications of diabetes, how to handle special occasions, new therapies for diabetes and social programs. **Mode:** group **Personnel:** endocrinologists, fellows, nurses, psychologists, dieticians **Duration:** 5 days **Delivery method:** face-to-face	Significant reduction in mean pre-camp (10+/-3%) and post-camp (9 +/-2.6%) HBA1c levels (p=0.008)	Improved self-monitoring of blood glucose (SMBG) records, with an average of 1.8 recordings per day, led to improved glycemic control (statistically insignificant (p=0.091)
15	J. Santiprabhob et al. [30] 2008 Thailand	Pre-/post - observational study 6 months	60 68.3%F:31.7%M 16 +/- 7 years	Camp	**Intervention:** Camp-based diabetes education program **Description:** A 5-day program Programme including lectures, games, and small-group discussions on the aetiology and symptoms of the disease, insulin therapy, injection techniques, the significance of diabetes control, blood glucose monitoring, exercise and diabetes, diabetes nutrition, diabetic complications, and the recognition and management of hypo/hyperglycemia and ketosis, consisting of diabetic clinical and knowledge sessions; lectures, games, and small-group discussions on disease etiology and symptoms, insulin therapy, and injection techniques, the importance of diabetes control, blood glucose monitoring, exercise and diabetes, diabetes nutrition, diabetic complications, recognition and management of hypo/hyperglycemia and ketosis, insulin dosage adjustment when changing diet and activity schedules, the handling of unusual special events and activities, e.g., sick days followed by a 6-month post-camp glycemic control follow-up.followed by a 6-month post-camp glycemic control follow-up. **Mode:** group **Personnel:** endocrinologists, fellows, nurses, psychologists, dieticians **Duration:** 5 days **Delivery method:** face-to-face	Significant reduction in HBA1c levels after 3-months post camp (8.2+/-1.7, p<0.001), and no significant difference in HBA1c between 6-month post-camp and baseline (p=0.94)	Improved knowledge and psychosocial outcomes especially in coping, confidence, and self-esteem. Frequency of SMBG at 6-month follow-up, 14% remained for 3-4 times/day.
16	Y. C. A. Wang et al. [31] 2008 USA	Retrospective study 7 months	182 74 T: 108 C 52.7%F:47.3%M 12 - 18 years	Camp	**Intervention:** Summer camp educational program **Description:** With the daily educational lectures and discussions, the camp provided three 20-day programmes, four times daily and when needed glucose levels tests and insulin adjustment before each meal. The licenced dietitian planed all meals and all insulin injections were supervised.The camp offers three sessions of 20 days each, with daily education lectures and discussions. Blood glucose is tested on four times a day and as needed. Insulin is adjusted before each meal. All insulin injections are supervised, and all meals are planned by the registered dietitian. **Mode:** group **Personnel:** medical students and physicians **Duration:** 20 days **Delivery method:** camp-based (face-to-face)	Significant reduction 8.6 to 8.3% (p<0.005) Improvement in girls more than boys in (p=0.04)	Improved adherence to insulin
17	A. Troncone et al. [32] 2021 Italy	Follow-up investigation 3 months	20 ND 60%F:40%M 10 - 12 years	Camp	**Intervention:** Diabetes Summer Camp-Educational-based program **Description:** Activities that are didactic and interactive for children that focus on the causes of the disease, its symptoms, insulin therapy, blood glucose monitoring, diet, the recognition and management of complications, the relationship between exercise, food intake, and insulin doses, the significance of diabetes control, the management of T1DM on a daily basis, stress management and other challenges in life. **Mode:** group with parents **Personnel:** medical director, physician, dietician, and psychologist **Duration:** 1 week **Delivery method:** camp-based (face-to-face)	HBA1c levels increased from 7.02 to 7.28 % (p=0.010)	Improved Self-efficacy in diabetes management and QOL

No.	Author / Year / Country	Study design / Duration	Sample	Setting	Intervention	HbA1c outcome	Other outcomes
18	S. Cook *et al.* [33] 2002 USA	Randomized control trial 6 months	53 26 T: 27 C 53% F: 47% M 13 - 18 years	Diabetes clinics/ children children's hospital	**Intervention:** Choices Diabetes Program **Description:** Behavioral intervention- 2-hours six-weekly behavioral sessions included: 1. Making decisions and maintaining a record 2. Making food planning 3. Insulin timing; getting back on track; 5. Decision-making; and 6. Handling the psychological impacts of DM.1. Making choices and keeping records 2. Planning meals 3. Timing insulin 4. Getting back on track 5. Making decisions and 6. Dealing psychologically with the impact of DM. **Mode:** group w/parents **Personnel:** physician consultants, psychologists, and dietician **Duration:** 6 weeks **Delivery method:** face-to-face	Significant reduction on in hba1c after 6 months of intervention from 8.9 to 8.3%, (p<0.01)	– Significant increase in problem problem-solving score from pre-to post-program - No significant differences in knowledge
19	Lehmkuhl HD *et al.* [34] 2010 USA	RCT 3 months	32 18 T: 14 C 71.9%F:28.1%M 9 -17 years	Virtually	**Intervention:** Telehealth Behavior Therapy **Description:** Behavioral intervention- Phone calls (sessions) with the therapist, discussing self-care activities which encourage adaptive self-care (goals for managing diabetes) and identifying potential obstacles to management and education. Discussing self-care activities and reinforcing adaptive self-care (diabetes goals), and identifying potential barriers to management and education. **Mode:** individual with families **Personnel:** research coordinators, assistants, and clinical psychology interns **Duration:** 12 weeks **Delivery method:** phone calls	Significant reduction in hba1c by 0.74 compared to 0.09 in the Waitlist (p = 0.03)	Increased Diabetes self-management profile (DSMP) (p< 0.01)
20	R. Whitemore *et al.* [35] 2010 USA	Multiphase- randomized control trial (pilot phase) 6 months	12 6 T: 6 C 58% F:42%M 13-16 years	Virtually	**Intervention:** Internet Coping Skills Training Program (TEENCOPE) **Description:** Behavioral intervention- TEENCOPE is an intervention Web site consisting of managing diabetes sessions, which include four weekly sessions on glucose control, nutrition, exercise, sick days, and new technology, and five weekly sessions on self-talk, communication skills, social issue skills, stress management, and conflict resolution. Consisted consisting of five weekly sessions on self-talk, communication skills, social problem skills, stress management, and conflict resolution and managing diabetes sessions which are four weekly sessions on glucose Control, nutrition, exercise, sick days, and new technology **Mode:** group with parents **Personnel:** nurses, clinical psychologists, and web- development team (web programmers and designers). **Duration:** 5 weeks **Delivery method:** web-based sessions	No significant reduction in hba1c values between both groups after 6 months of intervention (8% T:7.4% C)	Positive trends in psychosocial outcomes (stress, self-efficacy, and coping), and QOL (acceptability) (p=0.07-0.2)
21	Mulvaney SA *et al.* [36] 2012 USA	Pilot trial 3 months	46 23T:23C 43.5%F:56.5%M 13 - 17 years	Virtually	**Intervention:** tailored diabetes message system for mobile and the web Tailored mobile and web-based diabetes messaging system **Description:** Behavioral intervention- Adolescents were motivated and reminded about diabetes self-care duties via the text messaging systemthe text messaging system was designed to motivate and remind adolescents about diabetes self-care tasks,, they received 10 texts per week, according Aaccording to their individual ly-reported barriers to diabetes self-care, they received 10 text messages per week. **Mode:** individuals **Personnel:** experts in diabetes adherence and clinical care **Duration:** 3 months **Delivery methodmethod:** online-based	No change in the mean hba1c level in the intervention group (8.8%), while the mean level in the control group was significantly higher (9.9%), (p = 0.006)	None

#	Author / Year / Country	Design / Duration	Sample	Setting	Intervention	HbA1c Outcome	Other Outcomes
22	R. Whittemore *et al.* [37] 2012 USA	Multisided-randomized control trial 6 months	320 167 T: 153 C 55% F:45%M 11 – 14 years	Pediatric diabetes clinics	**Intervention:** Internet coping skills training (TEENCOPE) intervention Vs Mvs. Managing Diabetes (MD) program **Description:** Behavioral intervention- comparing TEENCOPE: includes five weekly sessions on conflict resolution, assertive communication, stress reduction, and social skill development includes five weekly sessions on social skills training, cognitive behavior modification, assertive communication, stress reduction, and conflict resolution. VS MD: Internet diabetes educational program, comprised five sessions, each of which featured case studies and problem-solving activities. Consisted consisting of five sessions included case studies and problem-solving exercises **Mode:** group **Personnel:** nurses, psychologists, and phd Ph.D. Candidates **Duration:** 5 weeks **Delivery method:** face-to-face and web-based sessions	No significant differences in hba1c levels (p=0.144)	No significant differences in psychosocial outcomes (QOL, stress, depression, and coping, family conflict)
23	M. Grey *et al.* [38] 2013 USA	Randomized cross-over control trial 18 months	320 167 T: 153 C 55% F: 45% M 11 – 14 years	Virtually	**Intervention:** Internet Psycho-Education Programs **Description:** Behavioral intervention- Comparative efficacy of TEENCOPE This incorporates self-talk, interpersonal communication, social problem-solving skills, stress management, and conflict with managing diabetes which includes self-talk, communication skills, social problem skills, stress management, and conflict, with managing diabetes and Managing Diabetes which focus on decision making for optimal outcomes, both Both programs had 30 minutes-once a week/ five sessions. **Mode:** group with parents **Personnel:** trained research personnel **Duration:** 5 weeks **Delivery method:** web-based sessions	No sig. Difference between the two groups (p = 0.05) - Mean hba1c levels increased slightly in both groups by a mean of 0.12%	Both improved QOL (p= 0.001), with no significant difference between the two groups.
24	G. R. Husted *et al.* [39] 2014 Denmark	Randomized controlled trial 12 months	71 37 T: 34 C 62%F:38%M 13 – 18 years	Pediatrics out-patient's clinic	**Intervention:** gguided self-determination youth (GSD-y) intervention **Description:** Behavioral intervention- life skills training process, facilitates patient-provider empowerment and consists of eight 1-hour sessions with 29 reflection sheetsfacilitates empowerment in the patient-provider relationship, involved involves eight-1-hr sessions consisting of 29 reflection sheets, for adolescents and parents in six steps: Establishing a mutual relationship with distinct "I-you" borders, self-exploration, self-understanding, shared decision-making, action, and feedback (1) establishing a mutual relationship with clear 'I-you' borders, (2) self-exploration, (3) self-understanding, (4) shared decision-making, (5) action, and (6) feedback. **Mode:** group with parents **Personnel:** pediatric diabetes nurses, pediatric physicians, dieticians **Duration:** 8 to 12 months **Delivery method:** face-to-face	No significant reduction in HBA1c values (p=0.65)	No significant differences were observed in glycemic complications (hypoglycemia, hospitalization) and insulin doses/regimens; well-being and competency -Improved autonomy, self-regulation, and parental support
25	M. A. Harris *et al.* [40] 2015 USA	Randomized control trial 7 months	90 46 T: 44 C 55% M:45%F 12 - 19 years	Tertiary diabetes clinic	**Intervention:** Family Systems Therapy -Diabetes (BFST-D) via face-to-face OR Internet video conferencing (Skype) **Description:** The behavioural intervention (BFST-D) had four main parts: 1) problem-solving training, 2) communication training, 3) cognitive restructuring (dispelling strong beliefs), and 4) family therapy approaches, delivered either in-person or virtually. Sessions included modelling, giving directions and feedback, and guiding practise of skills via behavioural assignments. **Mode:** group with caregiver **Personnel:** research assistants, psychologists **Duration:** 12 weeks **Delivery method:** face-to-face and Skype video call	Significant reduction in hba1c (p= 0.01)	Statistically significant improvements in adherence maintained to 3-months follow-up
26	R. Fiallo Scharer *et al.* [41] 2019 USA	Randomized control trial 24 months	214 106 T: 108 C Both Genders (Not specified) 8-16 years	Diabetes clinics	**Intervention:** A family-centered approach **Description:** Behavioral intervention- 1) identify the barriers to family self-management. With a validated survey- Problem Recognition in Illness Self-Management (PRISM) tool 2) tailored self-management resources from the healthcare system for identifying barriers, and 3) alternatives to current behaviours are taken into consideration (social, emotional, or financial) as four group sessions were coordinated with diabetes visits **Mode:** Individuals with families **Personnel:** Trained nurses **Duration:** 9 months **Delivery method:** face-to-face	Significant reduction in hba1c by -0.08 (p<0.05), Large Decline for patients with hba1c >10 (-0.19) (n<0.05).	Increased mean QOL during intervention for Parents (p<0.05)

No.	Study details	Sample	Setting	Intervention	Outcomes
27	A. C. Sarteau *et al.* [42] 2020 USA Randomized control trial 18 months	127 ND 45.9%F: 54.1% M 13 - 16 years	Children's Hospital/Medical Centre and virtually	**Intervention:** The Flexible Lifestyle Empowering Change trial (FLEX) **Description:** Behavioral intervention- combine both strategies (motivational interviewing (MI) & problem-solving skills training (PSST), four 40-to-60-minute introductory coaching sessions - One month apart, there was a (1) evaluation of what worried young people about their T1DM. (2) interacting with youngsters; (3) assigning behavioural homework. Each session where youth goal setting integrated BGM, CGM, and insulin dosing concluded by integrating the parent into the discussion on how they support the objectives identified by the youth. **Mode:** group with parents **Personnel:** dietician, nurse, certified diabetes educator (CDE) **Duration:** 7 months **Delivery method:** face-to-face followed by phone call/text message	Significant reduction in hba1c by 0.4% P= 0.03 No statistically significant difference on days with clinical hypoglycemia
28	E. Bakir *et al.* [43] 2021 Turkey RCT 6 months	50 25 T: 25 C 50%F:50%M 14+/-2 years	Home visits and virtually	**Intervention:** Information–motivation–behavioral skills model **Description:** Behavioral intervention- Consist of a number of phone calls and home visits including information on diet and exercise, motivation applying a good attitude in practicing the information, support, and health alarm, behavioral skills, and behavioral changes for achieving daily goals. **Mode:** group **Personnel:** nurses **Duration:** about 2 months **Delivery method:** face-to-face and phone call	Significant reduction in hba1c levels (p<0.001) And sixth months (p<0.001) Improved knowledge levels (p<0.001), Personal motivation levels (p = 0.001), Social motivation levels (p = 0.004) And Behavioral skills (p<0.001) Of the study group.
29	M. L. Lawson *et al.* [44] 2000 Canada Retrospective cohort study 15 months	28 17T: 11C Both genders (unspecified) 11 - 20 years	Outpatient //hospital	**Intervention:** Intensive Diabetes Management (IDM) with intensive follow-up **Description:** The individualized programeach family received 6 to 8 hours of education, during which time the patients reviewed their meal plan and learned how to adjust their insulin dosage, with incentives when the hba1c target was reached. Compared to group education with routine follow-up , 6-8 hours of education per family, during which the patients reviewed their meal plan, and received insulin dose adjustment algorithm. With incentives when the hba1c target was met, versus group education with standard follow-up (2-hour ssessions). **Mode:** group with families **Personnel:** nurses, dieticians, diabetologists, and research fellow **Duration:** 6 to -8 hours of education over 3 to -4 sessions (not specified) **Delivery method:** face-to-face and phone-call follow-up	Significant reduction by mean -2.5% in T (p<0.0001) Vs -0.9% in C (p=0.05) after 3 months -the The mean hba1c one year later remained significantly lower than at initiation of IDM in the T group (p=0.001) and was not significantly different than that prior to initiation of IDM in the C group (p=0.8). 2 patients of in the T group, had severe hypoglycemic reactions, while no reported cases from the C group.

No.	Study	Sample	Setting	Intervention	HbA1c outcome	Other outcomes
30	V. S. Kumar *et al.* [45] 2004 USA Prospective randomized clinical trial 4 months	39 19 T: 20 C 48.7%F:51.3%M 8-18 years	Virtually	**Intervention:** A Wireless, Portable System to Improve Adherence and Glycemic Control **Description:** A handheld device with diabetes data management software and a wireless modem was given to the game groupthe game group received a handheld device fitted with a wireless modem and diabetes data management software, in addition to a wireless-enabled blood glucose monitor (new technologies) and an integrated motivational game in which participants would guess a blood glucose level, after a collection of three previous readings plus a wireless-enabled BG monitor (new technologies) along with an integrated motivational game in which the participants would guess a BG level following a collection of three earlier readings versus the C group, who received the new technologies only. **Mode:** group with parents **Personnel:** trained research assistants **Duration:**4 weeks **Delivery method** motivational game/virtual	No significant difference (P = 0.06)	Improved diabetes knowledge, frequency of blood glucose monitoring & reduced glycemic complications
31	S. Von Sengbusch *et al.* [46] 2006 Germany Cohort study (pre-/ post- test) 24 months	107 56.1%F:43.9%M 8 - 16 years	Virtually	**Intervention:** Mobile Diabetes Education **Description:** Parents receive 5-day training on insulin function in a group or one-on-one setting, empowering them to handle insulin adjustment5-days parents training in a group or one-to-one setting for 5- days, on insulin function and empowering them to cope with insulin adjustment, sick days, and the challenges in everyday daily life. And 24 mobile-based follow-ups every year. **Mode:** one-to-one or group with families **Personnel:** pediatric nurses and diabetologists **Duration:** 5-day yearly courses **Delivery method:** mobile phone	No significant difference in the overall hba1c Levels **Although** Patients with high hba1c (>8%); showed significant reduction (p<0.01), while patients with low < 6.8% showed a significant increase (P < 0.05) -Both were exposed to DM complications.	No change in the frequency of severe hypoglycemic episodes No change in the number of episodes of severe hypoglycemia -Significant reduction in the number of hospital admissions, -Improved knowledge and pedqol
32	S. J. Channon *et al.* [47] 2007 UK Multi-center randomized controlled trial 12 months	66 38 T: 28 C 28.8%F:71.2%M 14 - 17 years	Diabetes clinicclinic	**Intervention:** A Multicenter, motivational interviews **Description:** The participants received individual, patient patient-driven, motivational interviewing Sessions on DM awareness raising and alternatives to current behaviours were taken into consideration. Sessions on DM DM-related awareness building, Alternatives to the current behaviors were considered (social, emotional, or financial)" Problem-solving, making decisions, setting goals, and lowering therapy resistanceproblem problem-solving, making choices, goal goal-setting, and reduce reducing resistance to therapy **Mode:** Individuals **Personnel:** psychologists, and nurses **Duration:** 12 months **Delivery method:** face-to-face	Significant reduction (9.3 to 8.7% (T): 9 to 9.2%(C), p=0.04) and maintained at 24 months (9.3 to 8.7% (T): 9 to 9.1%(C), (p=0.003)	Significant improvement in QOL p=0.001
33	D. Lafusco *et al.* [48] 2011 Italy Randomized control trial 2 years	396 193 T: 203 C 56% F: 44% M 10 - 18 years	Virtually	**Intervention:** Chat Line as a tool Tool to Improve Coping with DM **Description:** Sessions on a weekly basis for at least two years. Simultaneouslyweekly education chat line sessions for at least 2 years consecutively, lasted lasting 90 min about diabetes management, anxiety about the future, as well as interpersonal and societal interactionsanxiety about the future, and interpersonal and social relationships. **Mode:** group with parents **Personnel:** research assistant, physician, and psychologist **Duration:** weekly sessions with 2-year follow-up **Delivery method:** chat line	No significant difference in hba1c between the two groups (p = 0.056)	Significant improvement of diabetes-specific QOL. - Reduced worries about diabetes -Improved adherence to injection frequency and type of therapy (no statistical significance)

No.	Study	Sample	Setting	Intervention	HbA1c Outcome	Other Outcomes
34	Pinsker JE *et al.* [49] 2011 USA Pilot study 6 months	32 16T:16C Both genders (not specified) <18 years	Virtually	**Intervention:** Pediatric Diabetes Education Portal **Description:** A website where patients and their family could check clinic test results, read educational materials about these results, and ask their diabetes educator questions a website for patients and families that allowed them to review clinic test results, review educational Materials related to these results and post questions to their diabetes educator, Fingerstick, hemoglobin A1c (hba1c) testing, and regular periodic use of a continuous glucose monitoring system (CGMS) with the results displayed posted to the website after each clinic visit. Patients and/or parents were categorised as website users or non-users. Patients and/or parents were classified as users or non-users of the website **Mode:** group with families **Personnel:** diabetes care team with endocrinologist and educators **Duration:** 3-5 days **Delivery method:** online-based	Significant reduction in hba1c among website users (p = 0.03)	Improved patient compliance, Diabetes knowledge (statistically non-significant), and increased monitoring by physicians.
35	D. H. Frøisland *et al.* [50] 2012 Norway Pilot mixed-method study (pre-/post intervention) 3 months	12 58.3%F:41.7%M 13 - 19 years	Virtually	**Intervention:** Visual Learning on Mobile Phones **Description:** Two mobile phone apps: (1) one that is pictures-based diabetic diary to record physical activity and photos of food intake; the phone and glucometer were connected through Bluetooth Two mobile phone applications: (1) an application that contained a picture-based diabetes diary to record physical activity, and photos of food eaten, the phone was communicated with the glucometer by Bluetooth technology to capture blood glucose values, and (2) A short message (SMS) service that is web-based, password-secured, and encrypted Web-based, password-secured and encrypted short message service (SMS) **Mode:** group with parent **Personnel:** researchers and physicians **Duration:** 3 months **Delivery methodmethod:** mobile apps	No significant difference in hba1c (p = 0.38)	-No significant change in diabetes knowledge (P = 0.82) -Higher levels of satisfaction (statistically non-significant -Rising effects in the management of diabetes subjectively.
36	Peña NV *et al.* [51] 2013 Germany RCT (pre-/post intervention) 7 months	13 61.5%F:38.5%M 6 - 10 years	Pediatric Diabetes Unit and virtually	**Intervention:** Impact of Telemedicine Assessment on Glycemic Variability **Description:** The glucose values were measured for 3 months after training sessions on the Accu-Chek (Roche) Smart Pix software, and the results were compared to those from a following 4-month period without telemedical support. Training sessions were held on Accu-Chek (Roche) Smart Pix software, then glucose values were assessed for 3 months; and compared with a subsequent 4-month period without telemedical support **Mode:** group with families **Personnel:** researchers with diabetes specialists **Duration:** 3 months **Delivery methodmethod:** online-based	Significant reduction in mean hba1c levels (p = 0.012)	No significant reduction in mean blood glucose (MBG) and the High Blood Glucose Index (HBGI)
37	B. Bin-Abbas *et al.* [52] 2014 KSA Prospective experimental trial (pre-/post intervention test) 6 months	200 Both genders (unspecified) Mean age= 11 years	Virtually	**Intervention:** mobile Mobile phone messaging service **Description:** Daily informational texts, interactive messages once a week, and multimedia video messages about diabetes care procedures were sent to the kids via their parents the children were provided – through their parents – with daily information messages, with weekly interactive messages, and on request, with multimedia video messages about procedures related to diabetes care, contained basic knowledge on diabetes care, including : pathophysiology, aetiology, diagnosis, and management covered general diabetes care knowledge, including diabetes symptoms, signs, pathophysiology, etiology, diagnosis, management including (insulin therapy, nutrition therapy, and psychotherapy insulin therapy, diet therapy, psychotherapy and diabetes press news and recent information about diabetes). **Mode:** group with parents **Personnel:** pediatricians and research assistants **Duration:** 6 months **Delivery method:** text messaging and phone calls	Sig. Reduction in hba1c P=0.0001	Improved knowledge, Blood glucose monitoring -Decline glycemic complications -Reduced missed insulin dosing to 0%.

#	Study	Design	Participants	Setting	Intervention	HbA1c outcome	Other outcomes
38	B. Kassai *et al.* [53] 2015 France	Parallel-group randomized controlled trial 12 months	77 39 T: 38 C 36% F: 41% M 12 - 17 years	Multi-center	**Intervention:** Pediatrician and nurses counseling **Description** Either the intervention group (three-monthly doctor visits plus a monthly nurse visit and biweekly phone calls) or the control group (three-monthly doctor visits) The content of the intervention included general information about diabetes, how to manage it, and how to minimize diabetes-related complications. **Mode:** group **Personnel:** pediatricians and nurses **Duration:** One year **Delivery method:** face-to-face and phone calls	No significant reduction -0.04% (T) (p=0.61) Versus -0.03% (C) (p=0.54)	No significant differences for diabetes-related adverse effects (except ketoacidosis) which was more frequently in the intervention group compared to the control group
39	S. M. Ng [54] 2015 UK	Cohort study (pre-/ post- test) 5 years	The number and gender of participants were not specified; Age 12-25 years	Virtually	**Intervention:** Technology and social media intervention **Description:** Three digital technology techniques 1) Facebook social media platform for interactive communications that provided diabetic support and education. 2) Twinkle.Net integrated paediatric diabetes electronic management system (which permit monthly audits and more intensive contacts with low controls patients, and 3) Diasend® blood glucose and insulin pump downloading system, which enables quick access to and joint analysis of patients' blood glucose data in a clinic and enables the team to individualize treatment regimens. **Mode:** group with families **Personnel:** pediatric diabetes team **Duration:** 1 years **Delivery method:** social media technology	Significant reduction in hba1c (p<0.05)	Reduced length of stay and hospital admissions - Over 81% felt that the download technology for glucose metres and insulin pumps had benefited them, and 87% believed the technology had improved clinic patient management decisions.
40	M. Joubert *et al.* [55] 2016 France	Prospective multicenter-pilot study (pre-/post- test) 6 months	47 58% F: 42% M 11 - 18 years	Virtually	**Intervention:** Serious Videogame Designed for Flexible Insulin Therapy **Description:** In ''L'Affaire Birman'' the player will start solving diabetes-related - problems (hypoglycemia or hyperglycemia) and adapts insulin dose injection. No additional education was provided to the participants during their participation beyond that which was based on their blood glucose level, degree of physical activity, and carbohydrate intake. **Mode:** group with families **Personnel:** physicians, nurses, dieticians, and expert diabetic patients (academic diabetes care team) **Duration:** about 3 months **Delivery Method:** web-based game sessions	No significant reduction in hba1c but remained stable throughout the study	Improvement in knowledge without changes in therapeutic behavior Significant improvement in insulin titration and carbohydrate (CHO) quantification
41	R. O. La Banca *et al.* [56] 2021 Brazil	Pilot randomized trial 8 - 12 months	20 10 T: 10 C 60% F: 40% M 7 - 12 years	Diabetes clinics	**Intervention:** Therapeutic play intervention (ITP) **Description:** Following a video of children in the intervention group injecting a doll with insulin, a narrative about a T1DM child who self-injects insulin at school was read to the children. Children then videotaped injecting the doll once more, while the control group received standard clinic-based education. **Mode:** group with families **Personnel:** trained nurses with the research team **Duration:** 1 month **Delivery method:** face-to-face	No significant reduction -mean HBA1c was 8.8+/-1.2% T:9.3+/-2.6% C; (p=0.6)	Statistically with significant improvement in injection technique scores 90% of participants reported extreme QOL satisfaction
42	K. Dłużniak-Gołaska *et al.* [57] 2019 Poland	Randomized control trial 6 months	196 98 T: 98 C Both genders (not specified) 8 - 17 years	Hospital - Diabetology Clinic and virtually	**Intervention:** Interactive Nutrition Education **Description:** All participants had poorly controlled type 1 diabetes that was managed with insulin pumps, and they were randomly assigned to one of two groups (E) that also used interactive methods (quiz + multimedia application) or the control group (C), which only used informative methods (lecture). Educational materials about carbohydrate counting, blood glucose response to food, and healthy eating. **Mode:** group with parent **Personnel:** trained dietician **Duration:** 3 months **Delivery method:** face-to-face sessions followed by interactive mobile apps.	Significant reduction in hba1c in Group E By −0.47%, (P<0.01) -The positive effect Was no longer present after 6 months.	Non-significant improvement in clinical outcomes at 6 months follow-up in both groups. -Obesity % increased more in group C than E. -Significant difference was noted in knowledge scoring for "blood glucose response to food"

#	Study	Design / Duration	Sample	Delivery	Intervention	Glycemic Outcome	Other Outcomes
43	E. Döğer *et al.* [58] 2019 Turkey	Cohort study (pre-/post- test) 6 months	82 53% F: 47.6% M 10.89±4 years	Virtually	**Intervention:** Telehealth System **Description:** Patients/parents who called daily, 5–6 times per week, 1-2 times per week, or once every 15 days were classified as frequent callers, while those who called less frequently were classified as infrequent callers. Counselling was conducted via communication networks to discuss the current treatment plan and ask diabetes-related questions (about insulin dose and blood glucose regulation, carbohydrate counting, and appropriate actions to be taken in the case of hyperglycemia and hypoglycemia). **Mode:** Group with families **Personnel:** diabetes team (nurses, dieticians, psychologists, and physicians) **Duration:** 3 months **Delivery method:** Internet and smartphones	Significant reduction in hba1c (p<0.001)	None
44	S. S. Jaser *et al.* [59] 2020 USA	Randomized controlled trial 6 months	120 60 T: 60 C 52.5% F:47.5%M 13 - 17 years	Virtually	**Intervention:** Positive psychology intervention **Description:** Every two weeks, educational materials were mailed to the control group (EDU). Included details like adherence, hba1c, and hypoglycemia. And the intervention group Positive Affect (PA) group, who received reminders (gratitude, self-affirmation, parental affirmation, and modest presents) in addition to the same materials as the EDU group. **Mode:** group with caregivers **Personnel:** trained research assistants **Duration:** 2 months (8 weeks) **Delivery method:** text message or phone call	No significant difference post 3 months (p=0.86), no sig difference after 6 months (p=0.557)	PA intervention significantly improved QOL
45	JE Alfonsi *et al.* [60] 2020 Canada	Randomized control trial 3 months	46 23 T: 23 C Both Genders (not specified) 8 - 17 years	Virtually	**Intervention:** Carbohydrate Counting App Using Image Recognition **Description:** The ispy app, a cutting-edge mobile application that allows food identification through images and is designed to help young people with T1DM count carbohydrates, was provided on participants' mobile devices, and they were asked to complete tasks using it. **Mode:** group **Personnel:** registered dieticians and educators **Duration:** 3 months **Delivery Method:** mobile app	Significant reduction in hba1c Levels (p =0.03)	CHO counting ability/accuracy improved p=0.008, with reduced frequency of counting errors - Positive QOL scores (acceptability and engagement)
46	M. Otis *et al.* [61] 2020 USA	Mixed-phase pilot study 5 months	42 22 phase 1: 20 phase 2 64%F:36% M 5 - 14 years	Virtually	**Intervention:** Mobile Educator Tool/program **Description:** The Mobile Diabetes Educator (MDE) comprises of eight animated, interactive modules with a preadolescent with T1DM who is of uncertain ethnicity. The aetiology of diabetes, controlling blood sugar levels, and suggested diet and exercise regimens are all covered. A tablet with information on diet, glucose tests, glucose responses, and insulin was given to parent-child couples. **Mode:** Group with parents **Personnel:** Children's educational media consultants **Duration:** one hour **Delivery method:** interactive electronic book (mobile)	No significant difference in hba1c (p=0.71)	-No significant changes were observed for the diabetes knowledge, attitudes, and behavioral measures. -No significant changes in diabetes self-management, self-efficacy, and parental communication
47	R. Whittemore *et al.* [62] 2020 USA	Randomized control trial 6 months	162 81 T: 81 C 98% F: 2% M 11 - 16 years	Virtually	**Intervention:** ehealth program **Description:** Participants were randomly assigned to the wait-list control group or the Type 1 Teamwork website. They were given access to the ehealth programme via email, along with instructions on how to access, and were given information on the challenges of adolescence, creating a positive partnership between parents and adolescents, communicating positively with adolescents, gradually assigning them more responsibility, understanding the emotions that parents experience, and the significance of taking care of oneself. Type 1 Teamwork included six interactive sections. **Mode:** group of parents of adolescents **Personnel:** pediatric diabetes endocrinologists **Duration:** 6 months **Delivery Method:** web-based sessions	No significant reduction in hba1c but remained stable throughout the study (p=0.089)	Significantly lower parenting stress (better coping while spending more time in the program)

#	Study	Design	Sample	Setting	Intervention	hba1c outcome	Other outcome
48	V. Pais *et al.* [63] 2021 Canada	Randomized, controlled, parallel-group trial 4 months	50 24 T: 26 C 54%F:46%M 12 - 18 years	The Hospital for Sick Children (sickkids) and virtually	**Intervention:** Counting Carbs to Be in Charge **Description:** Compared the efficiency of teaching carbohydrate counting principles. Started by evaluation of participants' knowledge, followed by either an online session or an in-person session led by a dietician and post-intervention evaluation. **Mode:** group **Personnel:** dieticians **Duration:** about 1 month **Delivery method:** face-to-face and online	Significant reduction in hba1c after 3 months by 1% in both C & T groups (p=0.01)	Improved frequency of CHO Calculation, increasing CHO counting efficiency and knowledge in both methods (no sig. Difference)
49	H. J. Tong *et al.* [64] 2021 China	Quasi-experimental prospective study 9 months	102 52 T: 50C 56.9%F:43.1%M <14 years	Hospital of China Medical University and virtually	**Intervention:** Hospital discharge education plan **Description:** In the hospital, a multidisciplinary team provided diabetes education, skill training, psychological intervention, telephone follow-up, and Wechat intervention. Thematic education for youngsters and their families focused on problem-solving and coping skills, self-management skills, and decision-making abilities. **Mode:** group with families **Personnel:** nurse, nutritionist, endocrinologist, pharmacist, and psychologist **Duration:** 4 months **Delivery method:** face-to-face and phone call follow-up	Significant reduction in hba1c post-intervention (p=0.012)	Discharge readiness and education scores were higher in the intervention group than control group.

RESULTS AND DISCUSSION
Studies Characteristics
The 49 studies included in this review were published between 2000 and 2021. The research setting spans 18 different countries, with most articles (33/49) published after 2011. Furthermore, 12 (24%) studies utilized qualitative designs, while 37 (76%) adopted the mixed-method design. Six quantitative studies were randomized controlled trials (RCT), and four had observational analytical designs (case-control/ cohort studies). Moreover, 36 out of 49 (73.5%) articles compared the outcomes between the participants in the educational interventions and the control group that adhered to their original course of treatment and care. Other research compared the outcomes of different patient education interventions or pre- and post-test studies.

A significant variation was detected in the types of patient education intervention, design, and outcome measures between studies. The studies were classified into three categories based on the duration of the educational intervention, where 24 (49%) studies lasted ≤ 3 months, 15 (30.6%) studies were conducted between three to six months, and 10 (20.4%) education interventions lasted for six to 12 months. Furthermore, 28 out of 49 (57%) studies showed that hba1c levels were substantially decreased over time. Meanwhile, 16 studies that reported a significant decrease in hba1c recorded the measurements between three to six months post-intervention, while only three were measured in ≥ 1 year of intervention.

Sample Population Characteristics
A total of 5874 patients were comprised in this scoping review (**Table 1**), with an age range of 10.3 to 17.3 years. Nonetheless, several studies [31, 32, 38, 39, 49, 53, 59, 63] had a target population consisting of children, adolescents, and young adults between 18 and 25 years old, having type T1DM for at least a year. In addition, 42 out of the 49 studies (85.7%) had an average of 44% male and 56% female participants.

Intervention Characteristics
The patient education interventions vary between studies (objectives, participants, locality, and delivery methods) and are detailed in the supplementary information (**Table 1**). The interventions were conducted physically or virtually, focusing on the patients' (children and adolescents) and caregivers' (patients' families) coping skills and knowledge provided to improve T1DM management, patients' health, and daily life. A total of 17 (34.7%) interventions were held face-to-face, 17 (34.7%) were conducted virtually (via mobile phones, video conferencing, or web-based), and 15 (30.6%) combined both techniques. In addition, 26 (53.1%) interventions were conducted in person at hospitals (clinics or centers), while five (10.2%) were in summer camps.

Among the 46 group-based interventions, 33 (67.3%) included family or support persons, while the other 13 (26.5%) did not. On the other hand, three interventions were conducted individually with patients. Furthermore, 42 (85.7%) interventions were led by health care providers and seven interventions involved researchers and trained research assistants as the main facilitators. Multidisciplinary teams directed another 22 (44.9%) interventions.

Seven (14.3%) interventions were designed as session-based, structured education programs, five (10.2%) were camp-based interventions with training and activities, five (10.2%) involved behavioral and coping skills training, and four (8.2%) were peer-education that consisted of problem sharing and discussion. The remaining interventions were

motivational interviews, game-based and therapeutic play interventions, psychological interventions, dietary interventions with carb calculation training, and an intensive diabetes education program involving frequent blood glycemia monitoring, self-management, and a hospital discharge education plan. Most education interventions included educational materials on T1DM pathophysiology, carbohydrate counting, insulin dose adjustment, diabetic complications management, and sick-day rules.

Study Outcomes

The hba1c level is the primary outcome of this study. Most interventions or 48 (98%) studies reported reduced hba1c levels post-intervention, among which 28 (58%) were statistically significant. Other outcomes include learning, behavioral, psychological, QOL, and health status. Notably, 16 interventions evaluated diabetes-related knowledge as learning outcomes, of which 12 studies (75%) demonstrated improvements and were statistically significant. A total of 23 studies (46.9%) assessed behavioral outcomes, such as dietary practice, self-care, self-management, problem-solving, blood glycemia monitoring, and adherence to insulin, where 22 reported enhancements in at least one of the measured parameters.

Another 10 studies reported improvements in psychological and socio-psychological outcomes, including self-esteem, self-efficacy, coping with T1DM, discharge readiness, motivation, reduced stress, and treatment satisfaction. Meanwhile, 16 out of 49 studies exhibited better QOL, of which five were statistically significant. Improved health status outcomes were indicated by decreased diabetes-related complications (hypo/hyperglycemia) and hospital admissions, which were recorded in eight studies.

Education is a vital process in diabetes management that allows for patient-specific care, improving treatment adherence and prevent-diabetes related complications, thus, leading to optimized management [65]. Lorig and Holman [9] stated that education enables patients to understand their illnesses, hone relevant skills and knowledge to manage challenges, customize treatments, and maintain a good QOL. This study provided the necessary information for the scientific debate about the efficacy of various interventions to improve the welfare of diabetic children and adolescents.

Generally, most educational interventions effectively improved glycemia control and reflected a reduction in hba1c. This finding suggested that education intervention effectively controls T1DM in children and adolescents. Nevertheless, most studies did not explore the key factors, such as the sustainability of glycemia control, despite the level of sustained glycemic control in young patients with type 1 diabetes being the leading cause of chronich and acute complications [66].

It is highly recommended for an educational intervention to be patient-specific, depending on their age, culture, diabetes stage, lifestyle, and maturity to suit the individual needs [67]. For example, more than 15000 participants whose data were retrieved from the T1DM Exchange registry across the United States of America (USA) demonstrated that hba1c levels skyrocketed between ages 13 and 25 and did not stabilize until after 30 [68]. Furthermore, hba1c in this age range has worsened since 2010, charting the highest average of 9.2% among 19-year-old patients [68]. These findings indicated the urgency of optimizing glycemic levels specifically in younger populations.

In the search for the best education intervention, a trend toward significant glycemic improvements were observed in 13 out of 22 (59.1%) studies associated with multidisciplinary interventions by teams of doctors, nurses, dietitian, and psychologists. The collaboration between health care providers with different expertise demonstrated a synergistic effect in managing children and adolescents with T1DM, resulting in significant outcomes and better glycemic control. Wigert *et al.* [69] explained three significant outcomes of an effective multidisciplinary team when caring for children and adolescents with T1DM: 1) building a long-term relationship, 2) integrating knowledge through multidisciplinary teamwork, and 3) ensuring adequate documentation.

Effective communication between patients and health care providers is essential in building a long-term relationship based on trust, shared responsibilities, and ethical considerations. Furthermore, the multidisciplinary team must be able to communicate effectively with one another in disseminating knowledge required by the patients, besides ensuring adequate documentation crucial for patient follow-ups and in maintaining the functioning and stability within the team [69]. Moreover, Likitmaskul *et al.* [20] emphasized the importance of a multidisciplinary team for an effective education program and for helping diabetic children and their families manage their glycemia, arising problems, and long-term self-care.

Most interventions that reported significant improvements in glycemia control measured the glycated hemoglobin between three- and six-months post-intervention. In contrast, few interventions with significant improvements measured the patients' hba1c levels regularly for more than a year. These findings suggested that most effective interventions lack sustainable glycemia control. Regular consultations and follow-ups with T1DM patients for more than a year post-intervention resulted in long-term improvements in hba1c and reduced incidence of severe hypoglycemia [70]. Additionally, post-intervention feedback was reported in several reviewed studies. The participants found the interventions beneficial, reporting better health status reflected by fewer diabetes-related complications (hypoglycemia, hyperglycemia, hospital admissions, and length of stay in hospital) [38, 54, 55, 58, 61, 62]. Intervention evaluation and participants' feedback are vital in evaluating and modifying intervention content, design, and delivery and are valuable for patient targeting [71].

The QOL is a multidimensional concept that measures patients' well-being, and physical, psychological, and social functioning [72]. This concept was selected as an outcome of several education interventions (n = 16) with positive results, where five were statistically significant. Meanwhile, the peers-based intervention studies demonstrated that sharing knowledge, experiences, and management strategies in dealing with T1DM-related challenges allowed the young patients to learn from each other besides promoting awareness about their illness [73].

CONCLUSION

In conclusion, the study findings demonstrated that the outcomes from education interventions were related to intervention duration. Therefore, it is essential to integrate education intervention programs into all diabetic management settings instead of limited duration or teaching at the beginning of the patient's follow-up. In addition, it is recommended that a well-structured multidisciplinary education intervention program should be divided into two phases: 1) comprehensive education intervention phase in which the participants (children or adolescents and their families) are exposed to the general knowledge and management strategies of T1DM, and 2) individualized, patient-centered phase, in which each patient subjective characteristics are considered, and the educational materials are tailored to their individual needs. Both phases are predicted to contribute to effective, sustainable, and potentially cost-effective improvements in glycemia control.

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