

Behavioral Interventions in Pediatric Type 1 Diabetes Management: An Updated Meta-Analysis

Alexandra D. Monzon, PhD,¹ Jeffrey C. Hoover, PhD,² Jessica S. Pierce, PhD,¹ Rachel Wasserman, PhD,³ Shedeline Ulysse, BS,¹ Susana R. Patton, PhD, ABPP, CDCES⁴

abstract

CONTEXT: The last meta-analysis of behavioral interventions regarding pediatric type 1 diabetes (T1D) management was conducted over a decade ago.

OBJECTIVE: This meta-analysis aimed to (1) provide an updated review of adherence-promoting behavioral interventions and their effect on youths' hemoglobin A_{1c} (HbA_{1c}) and (2) evaluate whether multicomponent interventions targeting both direct and indirect processes of T1D management continue to yield greater HbA_{1c} improvements.

DATA SOURCES: We conducted a systematic search in PubMed and Scopus for articles published between April 2009 and February 2025.

STUDY SELECTION: Included studies were randomized controlled trials (RCTs) evaluating behavioral interventions targeting T1D self-management in youth and young adults up to age 25 years.

DATA EXTRACTION: Extracted data included study characteristics, intervention content and duration, and glycemic outcomes for intervention and comparison groups.

RESULTS: Of the 62 RCTs identified, 46 reported sufficient data for quantitative analysis. The pooled effect size demonstrated a small benefit of adherence-promoting interventions on HbA_{1c} ($g = 0.12$). Pilot RCTs showed larger effects ($g = 0.36$) than full RCTs ($g = 0.07$). Multicomponent interventions yielded greater improvements ($g = 0.19$) than direct ($g = 0.08$) or indirect ($g = 0.15$) interventions. Family-focused interventions demonstrated stronger effects ($g = 0.29$) than youth- ($g = 0.05$) or parent-focused ($g = 0.04$) interventions.

LIMITATIONS: Findings are limited to published RCTs.

CONCLUSIONS: Despite significant advancements in diabetes technology over the last decade, behavioral interventions continue to modestly improve HbA_{1c} in youth with T1D. Multicomponent, family-focused strategies appear to be most effective. Findings highlight the need for rigorous trial designs to advance care for youth living with T1D.

ARTICLE SUMMARY: Updated meta-analysis shows behavioral interventions modestly improve HbA_{1c} in youth with T1D, with multicomponent, family-focused approaches outperforming single-component, youth- or parent-focused strategies overall.



¹Center for Healthcare Delivery Science, Nemours Children's Health, Orlando, Florida; ²Accessible Teaching, Learning, and Assessment Systems, University of Kansas, Lawrence, Kansas; ³Department of Pediatric and Adolescent Medicine, Western Michigan University Homer Stryker MD School of Medicine, Kalamazoo, Michigan; and ⁴Center for Healthcare Delivery Science, Nemours Children's Health, Jacksonville, Florida

Address correspondence to: Alexandra D. Monzon, PhD, Center for Healthcare Delivery Science, Nemours Children's Health, 6900 Lake Nona Blvd, 5th Floor, Orlando, FL 32827. alexandra.monzon@nemours.org

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INTRODUCTION

Since 2022, the American Diabetes Association has recommended a hemoglobin A_{1c} (HbA_{1c}) level of less than 7% for most children and adolescents with type 1 diabetes (T1D).¹ At this HbA_{1c} level, youth with T1D have a lower risk of developing diabetes-related complications and a greater likelihood of experiencing the protective effects of metabolic memory.² Data from the Type 1 Diabetes Exchange suggest that less than 20% of youth with T1D in the United States have achieved an HbA_{1c} less than 7% and more than a third have an HbA_{1c} level greater than 9%.³ For youth, diabetes management tasks are challenging due to biological, behavioral, familial, and social factors. Nevertheless, findings from meta-analytic studies indicate a relationship between lower HbA_{1c} levels and greater engagement in T1D management among youth,⁴ underscoring the continued need for behavioral interventions to enhance treatment engagement.

In 2010, Hood and colleagues published a meta-analysis of behavioral interventions designed to enhance T1D treatment engagement and improve HbA_{1c} levels in pediatric T1D patients.⁵ The authors characterized interventions with “adherence-promoting components” as strategies that target either direct behaviors essential to T1D management (eg, increased glucose monitoring) or the indirect psychosocial processes that support effective management (eg, coping skills). Their meta-analysis reported a small pooled effect size ($d = 0.11$) for pre- to post-treatment changes in HbA_{1c} among youth receiving adherence-promoting interventions against comparators.⁵ However, subgroup analyses indicated that multicomponent interventions addressing both direct behaviors and indirect processes were associated with greater HbA_{1c} reductions than direct-only interventions.⁵

The meta-analysis conducted by Hood and colleagues remains foundational, highlighting the ongoing need to develop and disseminate interventions that help youth with T1D achieve a clinically significant reduction in HbA_{1c}. It has been more than a decade since Hood et al published their meta-analysis. During this time, numerous advancements have taken place, including a rise in the availability of T1D devices (eg, continuous glucose monitors [CGMs], automated insulin delivery systems) in youth.⁶ Further, health care delivery has shifted, with increasing adoption of video-based telehealth, mobile health (mHealth), and real-time monitoring data from commercial wearables.⁷ These substantial advances in both T1D management and health care delivery have transformed the context in which behavioral interventions operate, making it unclear whether effect sizes reported more than a decade ago still reflect the realities of contemporary T1D care.

Therefore, the current meta-analysis evaluates whether more recent behavioral interventions designed to increase engagement in T1D management translate into

improvements in metabolic control, that is, HbA_{1c}, a clinically meaningful and universally reported endpoint in T1D research, within the context of modern diabetes care. Although recent systematic reviews and meta-analyses have examined behavioral interventions in pediatric diabetes, these have generally restricted their focus to a single modality,⁸ intervention type,^{9,10} or publication window.^{11,12} In contrast, this study synthesizes more than a decade of randomized trials conducted during an era of widespread CGM use, telehealth, and digital health integration, while systematically examining how intervention targets (direct vs indirect), family involvement, setting, and delivery modality relate to glycemic outcomes. We hypothesize that behavioral interventions will continue to demonstrate at least a small effect on youth's HbA_{1c} and that multicomponent interventions, including strategies targeting both direct and indirect processes, will yield greater improvements in HbA_{1c} than interventions targeting direct behaviors alone. By integrating these features in a single comprehensive meta-analysis, this study clarifies which behavioral intervention strategies continue to add value in contemporary pediatric T1D care and identifies priorities for future intervention development.

RESEARCH DESIGN AND METHODS

We registered the details of the systematic review and meta-analysis on Open Science Framework (<https://osf.io/nkjyx>).¹³ Methods adhere to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.¹⁴ Table S1 in the Supplementary Materials contains the PRISMA checklist.

Search Strategy and Article Identification

To update the meta-analysis conducted by Hood and colleagues,⁵ we searched the same databases (PubMed and Scopus) for studies published between April 2009 and February 2025. We formed the search string and uploaded all identified articles to Covidence (Veritas Health Innovation). Table S2 in the Supplementary Materials provides complete search strings. Like Hood et al, the search strings included components for diagnosis (eg, T1D), treatment engagement (eg, adherence), glycemic outcomes (eg, HbA_{1c}), and population (eg, children, youth). The search strings also included components to reflect changes in behavioral diabetes management, such as digital health interventions (eg, mHealth) that have evolved over the past 16 years.

After identifying articles from the database search, we removed duplicate citations. Study team members further conducted a reference check of recent reviews and meta-analyses.^{8–10,12} A study met inclusion criteria if it (1) was a randomized controlled trial (RCT), (2) included individuals with T1D only, (3) included youth and young adults aged up to 25 years, (4) reported glycemic outcomes, and

(5) examined the effect of a behavioral to improve T1D self-management. In this review, we use the term *youth* to include children, adolescents, and young adults up to age 25 years, reflecting the age range commonly served in pediatric and transitional diabetes care. Table S3 in the Supplementary Materials provides additional information regarding inclusion and exclusion criteria.

Data Extraction and Quality Assessment

Four authors (A.D.M., S.R.P., J.S.P., and R.W.) screened abstracts and extracted data from the identified articles. Two reviewers screened each abstract and collected data from each included article. We recorded year of publication, country, study outcomes, whether the study was a pilot or full RCT, and sample demographics (ie, age, sex, duration of T1D). Because no consensus definition of pilot RCTs exists in this area of research, we adopted a transparent, reproducible, rule-based approach in which a study was coded as a pilot trial only when the authors explicitly labeled it as such. This approach aims to conservatively control for effect size shrinkage (ie, full RCTs often fail to replicate the effect sizes observed in pilot RCTs¹⁵), without introducing bias by classifying studies inconsistently with authors' self-reports of whether their study was a pilot RCT, which reflects their research questions and designs. Additionally, we recorded the delivery modality of the intervention, intervention type, intervention duration, total intervention time, comparator type, time to follow-up, and mean glucose at baseline and follow-up assessments. Table S4 in the Supplementary Materials provides the data extraction codebook and explanation of variables.

For intervention type, we retained the categories of "direct" and "combined," like the meta-analysis conducted by Hood and colleagues. Direct interventions focused exclusively on diabetes self-management behaviors (eg, insulin administration). Combined interventions included both these behaviors and related psychosocial components that support diabetes management (eg, coping). We created a third category of "indirect" interventions for studies targeting psychosocial factors surrounding diabetes management, with minimal or no emphasis on direct T1D behaviors. These interventions addressed indirect influences, such as depressive symptoms, parental anxiety, or family conflict, based on the assumption that improvements in these domains may indirectly enhance engagement with T1D management. Next, we recorded whether interventions were entirely digital (eg, phone apps), whether the main intervention target was to increase self-monitoring of blood glucose (SMBG), and whether the intervention took place during the youth's routine diabetes clinic appointment. Following the meta-analysis conducted by Hood and colleagues, we attempted to calculate the percentage of the intervention that explicitly targeted engagement in diabetes management (ie, adherence

promotion). Unfortunately, we were unable to reliably estimate this variable due to a limited description of several interventions. Lastly, 2 authors (A.D.M., S.U.) assessed the risk of bias in the findings of all included RCTs via the revised Cochrane risk-of-bias tool for randomized trials.¹⁶

Data Synthesis and Statistical Analysis

The synthesis of results for this study included primary and secondary analyses. The primary analysis included a meta-analysis of the pooled effect of behavioral interventions on HbA_{1C} in the target population across all eligible studies; further, the primary analysis included 2 meta-analyses broken out by trial type to compare the effect of the behavioral intervention on HbA_{1C} in full RCTs to the effect in pilot RCTs. The secondary analyses included meta-analyses of the effect of behavioral interventions broken out by covariates (ie, subgroup analyses by intervention type: direct, combined, indirect). Additionally, the secondary analyses included mixed-effects meta-regression using study-level effect sizes, intervention length, and total time of intervention.

Primary Analyses

Eligible studies were included for meta-analysis if sufficient information was reported to calculate an effect size. Effect sizes were calculated using standardized mean differences. In the majority of the included studies, Cohen's *d* effect sizes¹⁷ were calculated using means and SDs; however, reported test statistics (eg, *t*) were used when necessary to calculate Cohen's *d*. The Cohen's *d* effect sizes were converted to Hedges' *g* to produce unbiased effect size estimates even with small sample sizes.¹⁸ Random-effects meta-analysis with inverse variance weighting was used to calculate pooled effect sizes for the effect of intervention on HbA_{1C}.¹⁹ The pooled effect size estimate, *P* value, and 95% CI are presented. The *I*² statistics are presented as a measure of heterogeneity within the included studies. The Egger regression test was used to assess the risk of publication bias.²⁰

Secondary Analyses

The study-level effect sizes calculated for the primary analyses were used for the secondary analyses. The meta-analyses for the secondary analyses also used random-effects meta-analysis, and the same statistics were reported. The secondary analyses examined subgroup meta-analyses broken out by covariates: type of intervention (ie, direct, indirect, combined), digital interventions (ie, yes, no), interventions to increase SMBG (ie, yes, no), interventions during routine diabetes appointments (ie, yes, no), and intervention target (ie, youth, parent, family). These subgroup analyses were designed to identify the effect of behavioral interventions on HbA_{1C} in the target population across the levels of these covariates. These subgroup

analyses were reported for all included studies and full RCTs only. Results are presented as a narrative analysis when 5 or fewer studies were included by providing study-level effect size estimates.

Additionally, the secondary analyses included mixed-effects meta-regression using study-level effect sizes, intervention length, and total time of intervention.¹⁹ The meta-regression analyses used the Hedges' *g* effect sizes with inverse variance weighting. Study-level effect sizes were regressed on intervention length and total intervention time. These meta-regression analyses were designed to provide evidence on whether the length or total duration of the intervention was associated with the effect sizes observed in each study.

RESULTS

Search Results

The initial searches identified a total of 3470 articles; however, 2220 articles were duplicate records, resulting in

1250 abstracts screened (see Figure 1 for the PRISMA flow diagram). We excluded 1155 records during abstract screening, leaving 95 articles for full-text screening. Of these, 33 articles were deemed ineligible, and 62 articles met the inclusion criteria. Due to limited data for calculating an effect size for HbA_{1c}, only 46 articles were included in the quantitative analysis. Intraclass correlation coefficients ranged from 0.84 to 1.00, indicating acceptable to good interrater reliability.

Study Characteristics

Of the 62 studies meeting inclusion criteria for the systematic review, 16 studies specifically stated they were pilot RCTs. Of the 46 full RCTs, 36 reported a power analysis or sample size calculation, indicating intentional, high-quality study design. Across the 62 included studies, 45 adequately described the sample (ie, age, sex, HbA_{1c}, diabetes duration) to better understand who these interventions served. Further, 39 studies recruited samples from North America, 13 studies from Europe, 7 from Asia, 2 from

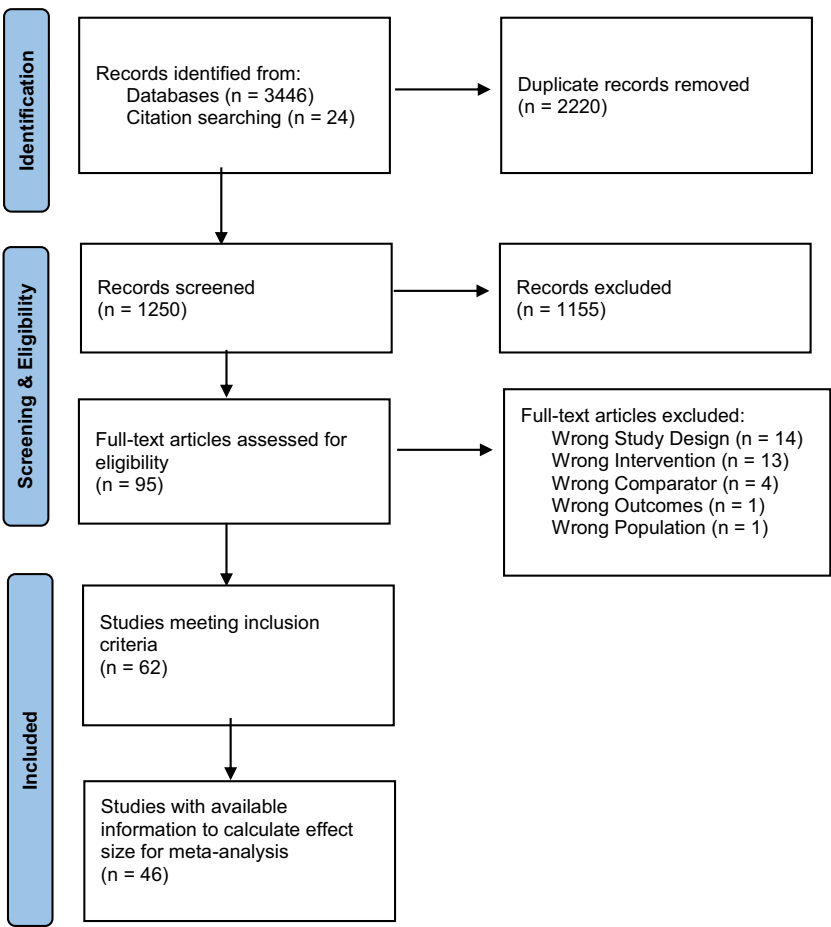


FIGURE 1. PRISMA flow diagram. Abbreviation: PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

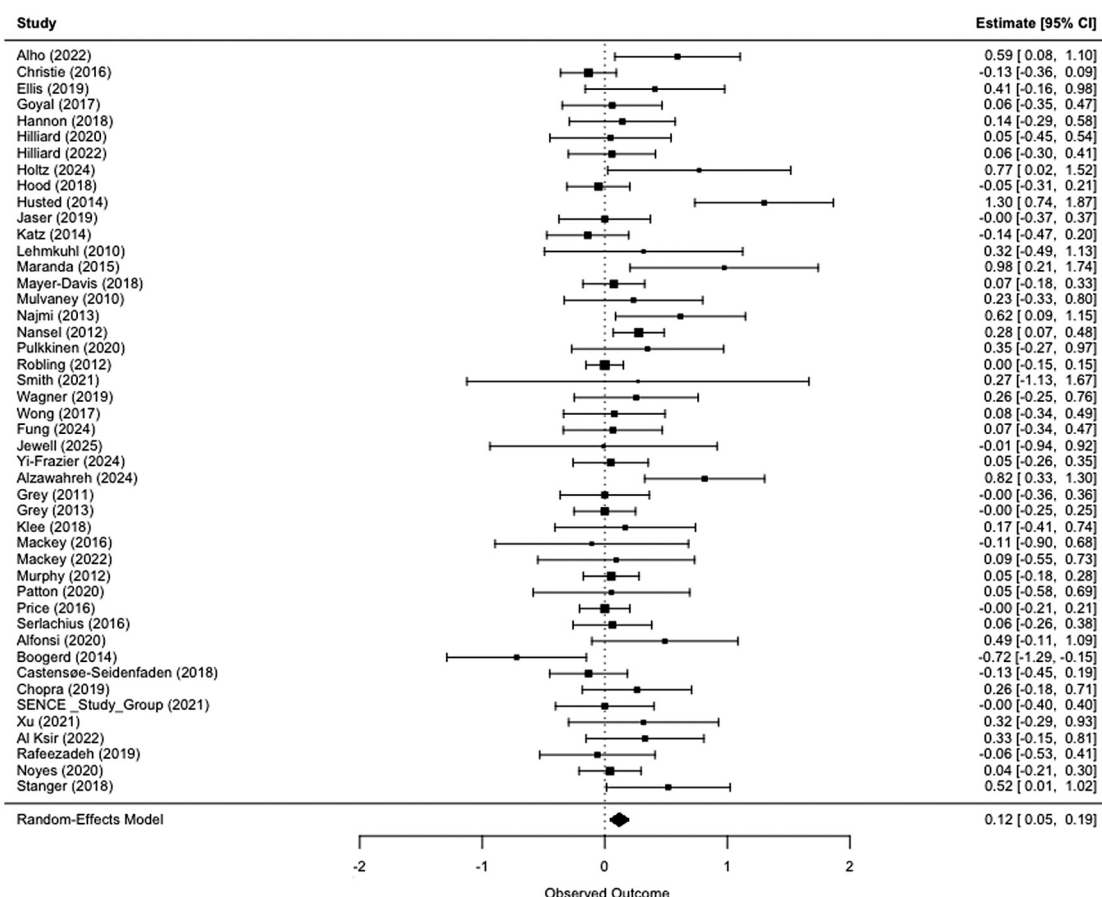


FIGURE 2. Pooled prevalence of all behavioral interventions included in the meta-analysis with individual study effect sizes and 95% CIs. Abbreviation: RE, random effects.

Australia/Oceania, and 1 from Africa. Sample sizes ranged from 8 to 693 participants, with a median sample size of 91 participants. On average, study samples were 52% female, and an average of 25% of participants belonged to minoritized racial and ethnic backgrounds. The average age of study participants across study samples was 13 years, and the average time since T1D diagnosis was 5.7 years. See Table 1 for a summary of the 16 pilot RCTs, Table 2 for a summary of the 46 full RCTs, and the Supplementary Materials for additional study-related variables.

Primary Analyses

Although 62 articles met the inclusion criteria, 16 did not provide sufficient information to calculate an effect size; thus, 46 studies were included for quantitative analysis. The pooled estimate from the random-effects meta-analysis of these 46 studies is 0.12 (95% CI, 0.05–0.19; $I^2 = 33.5\%$). This effect size is similar to the effect size reported in the Hood et al⁵ meta-analysis and demonstrates modest improvement in HbA_{1c} for behavioral intervention groups vs a comparator. See Figure 1 for the pooled prevalence

of all included studies. This pooled estimate includes 13 pilot trials and 33 full RCTs. When examining HbA_{1c} by trial type, the pooled estimate for pilot trials is 0.36 (95% CI, 0.18–0.53; $I^2 = 0.0\%$) and for full RCTs is 0.07 (95% CI, 0.01–0.14; $I^2 = 22.9\%$). Figures S1 and S2 in the Supplementary Materials provide the pooled prevalence of pilot RCTs and full RCTs, respectively. We were unable to assess the pooled estimate for time in range due to the low number of studies that included time in range as an outcome ($n = 4$). Of these, study-level effect size estimates ranged from -0.27 to 0.21 . Lastly, Egger's regression test indicates no significant risk of publication bias for pilot studies ($z = -0.27$, $P = .79$); however, it does indicate significant risk of publication bias for the full RCT studies ($z = 2.86$, $P < .01$). Thus, it appears that full RCTs observing statistically significant effect sizes were more likely to be published.

Secondary Analyses

Of the 46 studies included in the quantitative analysis, the pooled estimate for the 17 “direct” interventions is 0.08

TABLE 1. Summary of Included Pilot Trials (n = 16)

Author, Year, Location	N	Age (years)	Female Sex (%)	Intervention Content	Intervention Type	Intervention Target	Intervention Length	Intervention Sessions (n, Duration)	Control Group
Alfonsi, 2020, Canada ^{a,b}	46	14.0 ± 1.7, 10–17	39%	The iSpy app aimed to support T1D self-management by helping youth estimate carbohydrate content within 10 g of true values across a wide variety of foods. App uses an image recognition algorithm that identifies foods from images to assist youth in counting carbohydrates.	Direct	Child only	3 mo	N/A	Standard care
Alho, 2022, Finland ^b	72	13.4 ± 1.2, 12–16	63%	Acceptance and commitment group therapy to reduce diabetes-related distress and manage difficult thoughts, emotions, and behaviors tied to T1D management.	Combined	Child only	8 wk	5, 90 min sessions	Standard care
Ellis, 2019, USA ^b	50	14.3 ± 2.4, 10–18	62%	Multisystemic therapy adapted for T1D and delivered by community health workers either at home or in the community. Addressed both diabetes-specific barriers and broader family or environmental challenges through case management and tailored behavioral strategies.	Combined	Family	6 mo	20, 60–90 min primary sessions; 16, 30 min follow-up sessions	Standard care
Hilliard, 2020, USA ^{a,b}	80	15.3 ± 1.5, 12–17	59%	Type 1 Doing Well—strengths-based mHealth app for parents of adolescents with T1D that enhanced positive parent-teen interactions around diabetes care by helping parents notice, track, and reinforce their teen's diabetes-related strengths.	Indirect	Parent only	3–4 mo	N/A	Standard care
Holtz, 2024, USA ^{a,b,c}	43	12.4 ± 1.6, 10–15	61%	MyT1DHero—phone app for parents and children to improve effective communication around T1D care. Youth received praise and recognition from parents based on app-generated summaries and messaging tools.	Combined	Family	3 mo	N/A	Standard care
Jaser, 2014, USA ^{b,c}	40	15.2 ± 1.5, 13–17	51%	Parents provided affirmations to adolescents, and adolescents were asked to engage in gratitude and self-affirmation during T1D care.	Indirect	Child only	8 wk	Phone calls every 2 wk for 8 wk	Attention control
Jewell, 2025, USA ^b	16	8.7 ± 2.9, 2–12	62.50%	Occupation-based coaching delivered through telehealth sessions. Goal to help youth understand how diabetes management can integrate into their daily routines and support adaptive habits that align with the family's T1D care plan.	Direct	Family	12 wk	12, 60 min sessions	Standard care
Lehmkuhl, 2010, USA ^b	32	13.7 ± 2.4, 9–17	72%	Phone-based behavioral therapy incorporating principles from Behavioral Family Systems Therapy focused on self-care activities, reinforcing adaptive self-care, identifying barriers to management, and setting education goals.	Combined	Family	12 wk	36, 15–20 min phone calls	Waitlist control
Mackey, 2016, USA ^b	30	4.5 ± 1.7, 1–6	50%	The Young Child–Newly Diagnosed intervention provided developmentally tailored diabetes education, cognitive behavioral strategies to support parents, and parenting strategies for young children with T1D via phone. Parents provided peer support through trained parent partners.	Combined	Parent only	1 mo	5, 60 min phone sessions; 4 phone calls from a peer parent	Education

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TABLE 1. Summary of Included Pilot Trials (n = 16) (Continued)

Author, Year, Location	N	Age (years)	Female Sex (%)	Intervention Content	Intervention Type	Intervention Target	Intervention Length	Intervention Sessions (n, Duration)	Control Group
Mackey, 2022, USA ^b	36	4.7 ± 0.9, 2–5	36%	TOTs program—multicomponent healthy eating and physical activity intervention for parents of young children with T1D delivered via phone, text, and in-person session.	Combined	Parent only	12 wk	5, 40–50 min phone sessions; 1, 90 min in-person session	Standard care
Malik, 2024, USA	39	16.1 ± 1.9, 12–18	46.20%	Two treatment groups: (1) gain frame—earning financial incentives for meeting goals; (2) loss frame—receiving an initial balance that was reduced if goals were unmet. Youth selected one daily T1D self-management behavior to be incentivized.	Direct	Child only	36 wk	N/A	Standard care
Maranda, 2015, USA ^c	28	14.2 ± 1.9, 10–17	46%	Caring for a pet fish. Families were encouraged to pair fish care with T1D self-management tasks to improve twice-daily glucose monitoring.	Indirect	Child only	3 mo	N/A	Standard care
Patton, 2020, USA ^b	43	4.4 ± 1.4, 1–6	41%	REDCHIP intervention is a telehealth group intervention to help parents reduce their fear of hypoglycemia. Parents learned cognitive behavioral and behavioral parenting strategies that improved day-to-day T1D management.	Indirect	Parent only	10 wk	10, 30–60 min sessions	Waitlist control
Smith, 2021, USA ^{a,b}	8	17.0 ± 1.5, 15–24	50%	Web-based CGM training and education that included goal setting, expectation setting, and discussion boards. Goal to improve CGM adherence, reduce hassles, and increase self-efficacy.	Direct	Child only	6 wk	N/A	Standard care
Stanger, 2018, USA ^{a,b,c}	61	15.1 ± 1.5, 13–17	43%	WebRX—web-based intervention that included incentives for adolescents and parents, motivational and cognitive behavioral therapy, working memory training, and training in contingency contracting. Goal to help youth achieve 5 glucose checks per day, develop stronger problem-solving and self-regulation skills, and maintain behaviors over time.	Combined	Family	25 wk	15, 20 min sessions + working memory tasks and weekly coaching calls	Standard care
Zhang, 2018, USA ^c	48	14.7 ± 1.3, 13–17	52%	Personalized text messaging intervention to promote positive affect. Youth received humor or inspirational content 2–3 times/week. Caregivers were also sent reminders to give positive messages.	Indirect	Family	8 wk	N/A	Education

Abbreviations: mHealth, mobile health; N/A, not applicable; REDCHIP, Reducing Emotional Distress for Childhood Hypoglycemia in Parents; T1D, type 1 diabetes; TOTs, Type One Training.

Age data are mean ± SD and range.

^a Indicates a digital intervention delivered via a website or phone app.

^b Indicates a study was included in the quantitative analysis.

^c Indicates an intervention aimed at increasing self-monitoring of blood glucose.

TABLE 2. Summary of Included RCTs (n = 46)									
Author, Year, Location	N	Age (Years)	Female Sex (%)	Intervention Content	Intervention Type	Intervention Target	Intervention Length	Intervention Sessions (n, Duration)	Control Group
Al Ksir, 2022, Tunisia ^{a,b,c}	66	15.2 ± 1.7, 13–18	50%	Motivational interviewing-based intervention focused on supporting T1D-specific self-management skills. Adolescents worked with the nurse to set short-term, personalized goals related to diabetes routines and independent self-care.	Combined	Child only	6 mo	1, 20 min session; 4, 10 min phone calls	Standard care
Alzawahreh, 2024, Jordan ^{a,c}	68	14.2 ± 1.5, 12–18	50%	The family-centered empowerment model consisted of education sessions on diet, exercise, glucose monitoring, and insulin administration; cognitive behavioral group therapy; goal-setting workshops; and parenting skills.	Combined	Family	6 mo	N/A	Standard care
Booġerd, 2014, the Netherlands ^{b,c,d}	62	15.2 ± 2.0, 11–21	65%	Website “Sugarsquare” that includes a message board with professionals, review of personal data, chat with other users, online bulletin board, and a link to the Carelink.	Direct	Child only	9 mo	N/A	Standard care
Castensøe-Seidenfaden, 2018, Denmark ^{b,c,d}	151	17.6 ± 2.6, 14–22	54%	mHealth app “Young with Diabetes” includes connection to a health care physician, information about the diabetes department, chat room with peers, information on how to count carbohydrates, and information for parents about how to support their teen.	Direct	Child only	12 mo	N/A	Standard care
Chopra, 2019, India ^{b,c}	83	13.7 ± 5.0, 2–25	46%	Phone calls from a diabetes nurse educator every 2 weeks discussing blood glucose readings over the last week with insulin adjustments if needed and education on self-management.	Direct	Child only	6 mo	10–15 min phone calls every 2 wk	Standard care
Christie, 2016, England ^{b,c}	362	13.2 ± 2.1, 8–16	55%	The CASCADE structured education program involved family group therapy to build youth confidence in T1D skills. Sessions incorporated motivational interviewing and solution-focused brief therapy.	Combined	Family	4 mo	4 sessions	Standard care
Ellis, 2012, USA ^b	146	14.2 ± 2.3, 10–18	56%	Multisystemic therapy—an intensive, home and community-based family intervention targeting risk factors across multiple systems involving consultation with school and diabetes care teams. Therapists accompanied teens to medical appointments and helped integrate diabetes care across family, school, and community systems.	Direct	Family	6 mo	Variable for each family. Mean number of sessions = 45.7 (18.6)	Attention control
Fiallo-Scharer, 2019, USA ^{a,b}	214	8–16	49%	Tailored self-management resources to a family's self-identified barriers delivered across family group sessions coordinated with diabetes visits. Youth participated in discussions, activities, and problem-solving tailored to their identified barrier.	Combined	Family	9 mo	4, 75 min sessions	Standard care
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TABLE 2. Summary of Included RCTs (n = 46) (Continued)

Author, Year, Location	N	Age (Years)	Female Sex (%)	Intervention Content	Intervention Type	Intervention Target	Intervention Length	Intervention Sessions (n, Duration)	Control Group
Fung, 2024, Canada ^{b,c}	102	11.9 ± 2.2, 8–14	52%	Telephone coaching intervention for parents to identify challenges with their child's self-management, set goals to support their child, and develop strategies to achieve these goals.	Indirect	Parent only	6 mo	N/A	Standard care
Goyal, 2017, Canada ^{b,c,d,e}	92	14.0 ± 1.6, 11–16	55%	Phone app "Bant" that includes wireless blood glucose reading transfer, out-of-range blood glucose trend alerts, coaching around out-of-range glucose levels, and a point-based incentive system.	Direct	Child only	12 mo	N/A	Standard care
Grey, 2011, USA ^c	129	8.0 ± 2.9, 1–12	57%	Coping skills group training for parents of youth with T1D that addressed communication, social problem-solving, cognitive restructuring, stress management, and conflict resolution. Sessions used interactive role-play, discussion, and practice, guided by a trained therapist or psychologist.	Indirect	Parent only	3 mo	6, 90 min sessions	Education
Grey, 2013, USA ^{b,c,d}	320	12.3 ± 1.1, 11–14	55%	Internet coping skills training program (TEENCOPE) that included social skills training, cognitive behavior modification, assertive communication, stress reduction, and conflict resolution. Content used a graphic-novel storyline featuring characters navigating diabetes-related social challenges.	Indirect	Child only	5 wk	N/A	Education
Guo, 2020, China ^b	102	13.6 ± 3.1, 8–20	56%	Coping skills training camp that included goal setting, communication, social problem-solving, conflict management, stress management, and positive self-talk, adapted for youth in China.	Indirect	Child only	5–6 mo	2-day camp with 7, 60–90 min group sessions + 5 monthly phone calls	Standard care
Hannon, 2018, USA ^{b,c,e}	128	14.6 ± 1.7, 12–18	49%	Combination of family-centered goal setting with motivational interviewing and health information technology-enhanced SMBG (ie, real-time alerts for glucose checks)	Direct	Family	6 mo	2, 30 min sessions + text messages	2 control groups of component parts
Hilliard, 2022, USA ^{b,c}	157	4.5 ± 1.6, 1–6	55%	Stepped-care aimed to allocate more intensive intervention to families with more difficulty (ie, parent depressive symptoms or elevated HbA _{1c}): step 1—parent coaching; step 2—five telephone sessions with a master's level interventionist; step 3—consultations with a diabetes educator and psychologist.	Combined	Parent only	9 mo	Varies based on step	Standard care
Holmes, 2014, USA ^{a,b}	226	12.9 ± 1.2, 11–14	54%	Family teamwork coping program promoted effective family interactions and practiced coping skills with diabetes care. Activities involved discussion, role-play, practicing teamwork strategies, and identifying T1D-related challenges.	Combined	Family	1 y	4, 30–45 min sessions + phone calls	Education

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Author, Year, Location	N	Age (Years)	Female Sex (%)	Intervention Content	Intervention Type	Intervention Target	Intervention Length	Intervention Sessions (n, Duration)	Control Group
Hood, 2018, USA ^c	264	15.7 ± 1.1, 14–18	60%	STePS Program is cognitive behavioral and social problem-solving skills group. The program also involves coping skills such as relaxation techniques and seeking social support. Aimed to reduce depressive symptoms by teaching teens to challenge negative thoughts, improve decision-making and coping, and enhance resilience.	Indirect	Child only	4.5 mo	9, 90–120 min sessions	Education
Husted, 2014, Denmark ^{a,b,c}	71	14.8 ± 1.4, 13–18	61%	Guided self-determination intervention sheets in which youth and parents completed reflection sheets to explore individual and shared difficulties with T1D.	Indirect	Family	8–12 mo	8, 60 min sessions	Standard care
Ibrahim, 2021, France ^{b,d}	92	14.8 (median), 12–21	62%	Daily text message reminders at self-selected times to prompt insulin injections throughout the day.	Direct	Child only	6 mo	N/A	Standard care
Jaser, 2019, USA ^{b,c,e}	120	14.8 ± 1.4, 13–17	53%	Positive psychology—received educational materials in addition to small gifts and text messages or phone calls to express gratitude and self-affirmation. Parents also provided affirmations. Aimed to make T1D management less emotionally burdensome and more intrinsically motivating by linking it to positive emotions.	Indirect	Child only	8 wk	N/A	Education
Katz, 2014, USA ^c	153	12.9 ± 2.3, 8–16	56	Two intervention groups: (1) monthly outreach from the care ambassador via phone or email, (2) monthly outreach plus psychoeducational intervention around family management of diabetes.	Combined	Family	2 y	30 min session during quarterly diabetes visit	Standard care
Kaushal, 2022, USA ^b	165	15.7 ± 2.1, 12–18	47%	Daily text message about preselected self-care behavior with financial incentives.	Direct	Child only	6 mo	N/A	Standard care
Klee, 2018, Switzerland ^{b,c,d}	55	13.6 ± 2.4, 10–18	44%	mHealth app “Webdia” that contains a bolus calculator, a list of nutrients and carbohydrate content for meals, and data review of last meal entries. Teens could share all logged data in real time with caregivers and clinicians.	Direct	Child only	3 mo	N/A	Standard care
Lertbannaphong, 2021, Thailand ^e	39	14.1 ± 2.5, 0–18	46%	Diabetes self-management education (ie, diabetes knowledge, SMBG, exercise, hypo/hyperglycemia management, insulin action, sick-day management, diabetes complications, and nutrition) plus motivational interviewing group sessions to increase intrinsic motivation, strengthen problem-solving skills, and improve readiness for behavior change.	Combined	Child only	6 mo	2, 45–60 min motivational interviewing sessions, 2, 60–90 min diabetes self-management education sessions, and 4 phone calls	Education

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TABLE 2. Summary of Included RCTs (n = 46) (Continued)

Author, Year, Location	N	Age (Years)	Female Sex (%)	Intervention Content	Intervention Type	Intervention Target	Intervention Length	Intervention Sessions (n, Duration)	Control Group
Mayer-Davis, 2018, USA ^{b,c,e}	258	14.9 ± 1.1, 13–16	38%	FLEX used a combination of motivational interviewing and problem-solving skills training to help adolescents resolve ambivalence, increase intrinsic motivation, and build actionable strategies to improve behaviors such as SMBG, insulin dosing, diet, and physical activity.	Combined	Family	18 mo	4, 40–60 min sessions and either additional monthly 15–20 min phone calls or 3–4, 40–60 min sessions	Standard care
McGill, 2020, USA ^{a,e}	301	15.0 ± 1.3, 13–17	51%	TW intervention focused on blood glucose monitoring and insulin bolus dosing through problem-solving sessions. Adolescents also received text message reminders to check glucose levels. Sessions used motivational interviewing, interactive questions, and tablets for guided exercises.	Direct	Child only	12 mo	5 sessions	Standard care
Mulvaney, 2010, USA ^{a,d}	72	15.1 ± 1.4, 13–17	44%	YourWay—an internet-based self-management intervention, which enhances problem-solving barriers to self-management with social opportunities to engage with others on the website. The website delivered 6 multimedia stories portraying common psychosocial barriers to T1D management.	Indirect	Child only	11 wk	N/A	Standard care
Murphy, 2012, UK ^c	305	13.2 ± 2.0, 11–16	52%	Family-centered group education session on conventional diabetes self-management and family communication training. Teens learned practical skills to problem-solve daily diabetes tasks, adjust insulin confidently, and share diabetes responsibilities with their families.	Combined	Family	6 mo	6, 90 min sessions	Standard care
Najmi, 2013, Iran ^c	120	14.9 ± 1.8, 12–18	42%	A combination of cognitive behavioral group therapy for adolescents' approach to enhance T1D self-efficacy and communication skills group training for parents. Sessions included cognitive behavioral strategies such as identifying unhelpful thoughts, strengthening coping skills, improving problem-solving, enhancing motivation, and increasing confidence in managing T1D tasks.	Combined	Family	8 wk	8, 90 min sessions	Standard care
Nansel, 2012, USA ^{a,b,c}	390	12.5 ± 1.8, 9–14	51%	"WE-CAN manage diabetes" intervention was designed to help families improve diabetes management by facilitating problem-solving skills, communication skills, and appropriate responsibility sharing.	Direct	Family	21 mo	7, 30 min sessions	Standard care
Nansel, 2015, USA ^b	136	12.8 ± 2.6, 8–16	52%	Family-based behavioral intervention integrating motivational interviewing, active learning, and applied problem-solving to increase healthy eating. Youth attended 6 core nutrition sessions with interactive activities and a goal to increase 2 target food groups each visit.	Combined	Family	15 mo	6 core sessions and 3 booster sessions	Standard care

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TABLE 2. Summary of Included RCTs (n = 46) (Continued)

Author, Year, Location	N	Age (Years)	Female Sex (%)	Intervention Content	Intervention Type	Intervention Target	Intervention Length	Intervention Sessions (n, Duration)	Control Group
Newton, 2009, New Zealand ^b	78	14.4 ± 2.4, 11–18	53%	Adolescents wore an open pedometer for 12 wk, with a goal of at least 10 000 steps/d. Motivational text messages were sent to remind them to wear the pedometer and stay active.	Direct	Child only	12 wk	N/A	Standard care
Noyes, 2020, UK ^{b,c}	337	12.5 ± 3.1, 6–18	54%	Youth received the EPIC self-management kit, a standardized but flexible diabetes education package designed to support daily management. Kits included booklets, magazines, leaflets, CDs, website links, and diaries for insulin injections or pump therapy.	Combined	Child only	6 mo	N/A	Standard care
Obarcanin, 2015, Germany and Bosnia-Herzegovina ^b	68	14.7, 12–18	57%	Pharmacists assessed drug-related needs and identified problems. Pharmacists developed care plans with problem-solving and individualized goals.	Direct	Child only	6 mo	6, 60–90 min sessions + phone calls	Standard care
Price, 2016, UK ^{b,c}	396	13.8 ± 1.5, 11–16	55%	KICK-OFF is a 5 d group education course that focuses on carbohydrate counting and insulin administration.	Direct	Child only	5 d	5 d course	Standard care
Pulkkinen, 2020, Finland ^{a,b,c,e}	47	14.6 ± 0.8, 12–15	46%	Physicians used motivational interviewing principles in standard educational care with a focus on improving glucose and insulin administration.	Direct	Child only	12 mo	N/A	Standard care
Rafeezadeh, 2019, Iran ^{b,c,d}	68	10.2 ± 1.3, 8–12	43%	An educational interactive video game that provided short educational clips on a special self-care topic, and the child could play the game and make choices based on the educational clip. Gameplay offered positive and negative feedback based on choices, with points, gold stars, and stage progression, reinforcing correct self-care behaviors.	Direct	Child only	12 wk	N/A	Standard care
Robling, 2012, UK ^{a,b,c}	693	10.6 ± 2.8, 4–15	51%	Training program for provider to engage in more constructive conversations about behavior change. Training emphasized shared setting of agendas and a guiding communication style.	Direct	Child only	12 mo	N/A	Standard care
SENCE Study Group, 2021, USA ^{b,c}	143	5.7 ± 1.8, 2–7	50%	CGM with family behavioral intervention that involved standardized CGM training and sessions that addressed family attitudes and behaviors that can be barriers to CGM use.	Combined	Family	6 mo	5, 30 min sessions	Standard care
Serlachius, 2016, Australia ^{a,b,c}	156	14.3 ± 1.1, 13–16	54%	Best of Coping is a CBT-based group therapy program that uses a combination of coping skills training, problem-solving approaches, and cognitive restructuring. Sessions covered coping strategies, goal setting, positive/negative self-talk, problem-solving, and conflict resolution.	Indirect	Child only	5 wk	5, 2 hr sessions	Standard care

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Author, Year, Location	N	Age (Years)	Female Sex (%)	Intervention Content	Intervention Type	Intervention Target	Intervention Length	Intervention Sessions (n, Duration)	Control Group
Wagner, 2019, USA ^{b,c,e}	60	15.6 ± 2.3, 12–19	40%	Monetary reinforcement for self-monitoring blood glucose–related behaviors. Clinicians also provided monthly feedback on glucose patterns.	Direct	Child only	24 wk	Text messages + 6 telephone calls	Standard care
Whittemore, 2012, USA ^{b,d}	320	12.3 ± 1.1, 11–14	55%	Internet coping skills training program (TEENCOPE) that included social skills training, cognitive behavior modification, assertive communication, stress reduction, and conflict resolution. Content was presented through a graphic-novel format with diverse characters modeling real-life diabetes-related social challenges and coping strategies.	Indirect	Child only	N/A	N/A	Education
Whittemore, 2016, USA ^d	124	12.1 ± 1.1, 11–14	63%	TeensConnect is an internet coping skills training program that combines TEENCOPE, a coping skills training program, with Managing Diabetes, a diabetes educational program.	Indirect	Child only	4 wk	N/A	Attention control website
Wong, 2017, USA ^{b,c,e}	90	16.3 ± 1.9, 14–20	58%	Daily financial incentives for glucose monitoring goals. Adolescents received daily feedback messages (email or text) indicating whether they met SMBG goals and their updated virtual balance.	Direct	Child only	3 mo	N/A	Standard care
Xu, 2021, China ^{b,c,d}	80	13.2 ± 1.7, 10–19	48%	CGM and subscription to a WeChat Official Account named “KongTangTianDi,” which disseminates scientific diabetes-related information. A nurse also analyzed, evaluated, and reviewed CGM data.	Direct	Child only	6 mo	N/A	Standard care
Yi-Frazier, 2024, USA ^{b,c}	172	15.7 ± 1.6, 13–18	56%	PRISM intervention targets 4 resilience resources: stress management, goal setting, cognitive reframing, and meaning making.	Indirect	Child only	6 mo	2, 45–90 min sessions + 1, 30 min summary	Standard care
Abbreviations: CGM, continuous glucose monitoring; FLEX, Flexible Lifestyle Empowering Change; mHealth, mobile health; KICK-OFF, Kids in Control of Food; N/A, not applicable; PRISM, Promoting Resilience in Stress Management; RCT, randomized controlled trial; SMBG, self-monitoring of blood glucose; T1D, type 1 diabetes; TW, Teenwork.									
Age data are means ± SD and range.									
^a Indicates an intervention delivered at participant’s endocrinology appointment.									
^b Indicates a study that reported their power analysis.									
^c Indicates a study was included in the quantitative analysis.									
^d Indicates a digital intervention delivered solely via a website, automated text message, or phone app.									
^e Indicates an intervention aimed at increasing SMBG.									

(95% CI, -0.02 to 0.18; $I^2 = 18.0\%$), for the 12 “indirect” interventions is 0.15 (95% CI, -0.03 to 0.33; $I^2 = 59.1\%$), and for the 17 “combined” interventions is 0.19 (95% CI, 0.04–0.33; $I^2 = 51.6\%$). The pooled estimate for the 14 digital interventions is 0.09 (95% CI, -0.06 to 0.24; $I^2 = 25.7\%$), and for the 32 nondigital interventions is 0.13 (95% CI, 0.05–0.22; $I^2 = 40.1\%$). The pooled estimate of the 10 interventions aimed to increase SMBG is 0.18 (95% CI, 0.04–0.32; $I^2 = 0.0\%$) and for the 36 studies that did not include SMBG as a primary intervention target is 0.10 (95% CI, 0.02–0.19; $I^2 = 41.5\%$). The pooled estimate for the 7 interventions that took place at diabetes appointments is 0.38 (95% CI, 0.03–0.72; $I^2 = 87.4\%$) and for the 39 interventions that took place in other settings is 0.06 (95% CI, 0.00–0.12; $I^2 = 0.0\%$). The pooled estimate for the 24 studies where youth were the primary intervention participants is 0.05 (95% CI, -0.02 to 0.12; $I^2 = 0.0\%$), for the 7 studies where the parent or caregiver was the primary intervention participant is 0.04 (95% CI -0.14 to 0.22; $I^2 = 0.0\%$), and for the 15 studies where the parent/child dyad or family unit was the intervention participant is 0.29 (95% CI, 0.09–0.49; $I^2 = 74.3\%$). In addition, we did not observe a significant relationship between the effect size of the intervention and the intervention length ($R^2 = 0.0$) or total time of the intervention ($R^2 = 0.0$). Lastly, we evaluated the moderating role of age, duration of T1D, sex, and ethnicity in the effect of each intervention on HbA_{1c}; however, none of these relationships were statistically significant.

Given the difference observed between the pooled estimate for the pilot and full RCTs, we replicated the secondary analysis, excluding the pilot RCTs. Only including full RCTs, the pooled estimate for “direct” interventions is 0.07 (95% CI -0.04 to 0.17; $I^2 = 20.0\%$), for “indirect” interventions is 0.12 (95% CI, -0.07 to 0.32; $I^2 = 63.8\%$), and for “combined” interventions is 0.10 (95% CI, -0.04 to 0.25; $I^2 = 50.3\%$). The pooled estimate for digital interventions is -0.01 (95% CI, -0.15 to 0.13; $I^2 = 0.0\%$) and for nondigital interventions is 0.10 (95% CI, 0.02–0.19; $I^2 = 37.3\%$). The pooled estimate for interventions aimed to increase SMBG is 0.10 (95% CI, -0.05 to 0.25; $I^2 = 0.0\%$) and for those that did not include SMBG as a primary intervention target is 0.08 (95% CI, -0.01 to 0.17; $I^2 = 48.6\%$). The pooled estimate for interventions that took place at the youth’s routine diabetes appointment is 0.38 (95% CI, 0.03–0.72; $I^2 = 87.4\%$) and for those that took place in other settings is 0.02 (95% CI, -0.04 to 0.09; $I^2 = 0.0\%$). Lastly, the pooled estimate for youth-focused interventions is 0.02 (95% CI, -0.05 to 0.10; $I^2 = 0.0\%$) and for family-focused interventions is 0.25 (95% CI, 0.00–0.51; $I^2 = 84.2\%$). We were unable to assess the pooled estimate for parent-focused interventions among full RCTs due to the low number of studies testing these interventions. In the Supplementary Materials, Table S5 provides all results

for the primary and secondary analyses, and Table S6 provides the risk-of-bias assessment.

CONCLUSIONS

The current meta-analysis extends prior work by providing the most comprehensive evaluation to date of behavioral interventions targeting treatment engagement and glycemic outcomes in youth with T1D in the modern era of diabetes technology. By synthesizing RCTs published after the seminal Hood et al⁵ meta-analysis, this review demonstrates that adherence-promoting behavioral interventions continue to confer modest improvements in HbA_{1c} despite significant advances in diabetes devices and care delivery models. Further, consistent with our hypotheses, interventions that combined strategies targeting both direct T1D self-management behaviors and indirect psychosocial processes were associated with greater improvements in HbA_{1c} compared to interventions targeting direct behaviors or indirect processes alone. These results support the continued value of multicomponent interventions and underscore the complex nature of T1D management.

Notably, pilot RCTs demonstrated larger effects on HbA_{1c} than full RCTs. However, this finding should be interpreted with caution for several reasons. First, we categorized studies based on the authors’ descriptions of the trial, which may vary in clarity or consistency, as there is often disagreement among researchers about what constitutes a pilot trial.²¹ Also, we did not independently evaluate whether the “full RCTs” were indeed adequately powered. Second, as Freedland²¹ outlines, positive findings of small pilot studies often fail to replicate in larger RCTs. Moreover, the median sample size in the pilot RCTs was 42, compared to 129 in the full RCTs. Smaller samples yield less precise estimates due to greater variability and reduced power to detect true effects. As a result, findings from pilot studies may be less reliable and may not generalize well to broader populations. Thus, it is important to interpret this finding with caution and refrain from suggesting clinical implications based on the positive effects of pilot studies alone.

Interestingly, subgroup analyses revealed several noteworthy findings. First, we found that interventions delivered during routine diabetes clinical visits demonstrated greater efficacy than those conducted in other settings. Families and individuals may be more responsive to diabetes-focused interventions within the context of their routine diabetes medical appointments, possibly due to established trust with the medical team that extends to behavioral interventions conducted in the same setting or families being already primed to discuss diabetes management in this setting. It is also possible that the perceived benefits of clinic-embedded interventions reflect fewer structural barriers among families who regularly attend diabetes visits (eg, transportation reliability, work-schedule flexibility),

as socioeconomic factors can influence both the ability to attend clinic appointments and readiness to participate in behavioral interventions. Still, these findings suggest the structured setting of routine clinical visits may provide an opportunity to enhance engagement and seamlessly integrate intervention content into time-limited clinical trials.

Second, interventions involving both youth and their families, together, yielded stronger effects than those targeting youth or parents alone, potentially underscoring the central role of families in supporting diabetes management during childhood and adolescence. Moreover, this finding aligns with a robust body of literature emphasizing the importance of collaboration between parents and their children in diabetes care, where shared responsibility, emotional support, and consistent communication within the family unit are associated with improved health and family outcomes.²² Involving both youth and caregivers in behavioral interventions may facilitate problem-solving around diabetes-related challenges and foster parent-child communication patterns that reinforce positive behavioral change. There are also important developmental considerations when determining shared responsibility for daily T1D self-care, including how to gradually transition toward autonomous self-management. Considering these factors, future interventions should continue to target parents and youth, when appropriate and as needed, and include content to promote youth independence in a developmentally appropriate manner.

Third, interventions that focused specifically on increasing the frequency of SMBG demonstrated a small, yet significant, effect on glycemic outcomes. Although SMBG remains a part of new-onset diabetes education, its relevance as a daily self-care behavior is fading with the widespread adoption of CGMs. Future interventions should consider how to translate effective components of SMBG-focused strategies, such as habit formation, goal setting, and data interpretation, into approaches that align with CGM technology. Finally, we calculated pooled effect sizes for digital and mHealth interventions for youth with T1D. Interestingly, when we included full RCT and pilot studies, the pooled effect sizes for digital and nondigital formats were comparable, with nondigital interventions showing a slightly greater impact. This finding suggests that digital platforms may be slightly less effective than traditional in-person approaches. However, when only full RCTs were included in the analysis, nondigital interventions appeared to have a greater impact on HbA_{1C} than digital interventions. The potential for digital interventions to enhance reach, scalability, and cost-efficiency is particularly relevant in settings with limited access to behavioral health providers. Nevertheless, these results highlight a need for more nuanced evaluations of and greater optimization of digital delivery formats. Future research should explore factors

such as accessibility across diverse populations, sustained engagement with digital tools, the degree of individual tailoring, and long-term clinical outcomes. As the digital health landscape continues to evolve, with increasing integration of wearables, real-time data feedback, and artificial intelligence (AI)-driven personalization, understanding how to optimize these technologies to support behavioral change remains a critical area for investigation in pediatric diabetes.

Our meta-analysis underscores several gaps in current literature and directions for future research. First, few interventions explicitly targeted time in range as an outcome, despite its increasing relevance in clinical practice and its potential to meaningfully capture glycemic variability. Second, although interest in individualized intervention strategies is increasing, few studies used adaptive, just-in-time, or tiered delivery approaches that tailor behavioral support to youth and/or parents. The growing availability of digital health tools, including CGMs and other wearable devices, mobile apps, and AI, coupled with innovations in real-time data capture (eg, ecological momentary assessment), offers new opportunities to develop scalable, personalized behavioral interventions. Finally, there remains a need for more transparent reporting of intervention components, dosing, and engagement metrics to facilitate more consistent comparisons across studies and provide stronger implementation guidance.

Despite the many strengths of this updated meta-analysis, the current study has some limitations. First, we only examined the effects of these interventions on HbA_{1C}. In general, pediatric diabetes trials use HbA_{1C} as their primary or only measure of glycemia, but this practice may ignore other important health and psychosocial outcomes (eg, time in range, acute complications, diabetes distress). Second, we only included data from published studies in our meta-analysis. Other clinical trials of behavioral interventions in pediatric diabetes may have recently been completed but are not yet published. Third, we restricted the inclusion criteria to studies published after April 2009 to capture publications following the Hood et al meta-analysis.⁵ Although this approach excluded some earlier interventions that demonstrated efficacy, those interventions were delivered within a markedly different diabetes care context and may not generalize to the behavioral and technological demands youth with T1D experience today. Finally, as previously mentioned, we did not independently verify that full RCTs were indeed adequately powered to detect differences in HbA_{1C} outcomes. Thus, it is possible we inadvertently included some pilot studies in our sample of full-scale RCTs.

In conclusion, daily T1D treatment is effortful and relentless and requires consistent engagement in T1D self-care activities by youth living with T1D and their families. Despite substantial progress in diabetes technology over

the past decade, behavioral interventions for youth with T1D have yielded only modest improvements in HbA_{1C}, underscoring the importance of evaluating and refining these approaches to optimize their efficacy. Our findings reinforce the importance of combining direct behavioral and indirect psychosocial strategies, targeting family systems, and carefully interpreting pilot data that were designed to test feasibility and acceptability rather than intervention efficacy. To accelerate progress toward optimal diabetes management for all youth, future work must prioritize rigorous trial designs and innovative delivery models, in addition to standardizing reporting of trial results and including more clinically relevant endpoints (eg, time in range).

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Health, Florida, who worked with the authors to develop and implement the search strategy in addition to obtaining articles for the systematic review and meta-analysis. The authors also thank Stacy Nozime, who helped with the risk-of-bias coding.

ABBREVIATIONS

AI: artificial intelligence
 CGM: continuous glucose monitor
 HbA_{1C}: hemoglobin A_{1C}
 mHealth: mobile health
 PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
 RCT: randomized controlled trial
 SMBG: self-monitoring of blood glucose
 T1D: type 1 diabetes

AD Monzon designed the study protocol, performed screening, quality assessment, data collection, and data synthesis, contributed to the interpretation of data in the manuscript, drafted the initial manuscript, and critically reviewed and revised the manuscript. JC Hoover performed the quantitative analysis, drafted the initial manuscript, and critically reviewed and revised the manuscript. JS Pierce, SR Patton, and R Wasserman assisted in designing the study protocol, performed screening, quality assessment, data collection, and data synthesis, contributed to the interpretation of data in the manuscript, drafted the initial manuscript, and critically reviewed and revised the manuscript. S Ulysse performed screening, quality assessment, data collection, and data synthesis and critically reviewed and revised the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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