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School Performance of Children and Adolescents With Type 1 Diabetes: A Systematic Review

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ABSTRACT

Introduction: Type 1 diabetes (T1D) may negatively impact cognitive function in children and adolescents, but data regarding its impact on academic performance remains inconsistent.

Aim: To systematically review the evidence on academic performance assessed by school grades in youth with T1D and its association with glycemic control.

Methods: PubMed, Scopus, Web of Science, and Google Scholar were searched for studies evaluating academic achievement through school grades in children and adolescents with T1D and assessing its association with glycemic control. Risk of bias was evaluated using the Joanna Briggs Institute critical appraisal tool.

Results: Sixteen studies involving 26,794 children and adolescents with T1D met the inclusion criteria. Thirteen studies were rated as having a low risk of bias. Of 11 studies comparing school grades of children with T1D to that of peers or national norms, five reported lower performance in youth with T1D, five reported no significant differences, and one found reduced performance in primary but not secondary school. Among 10 studies examining glycemic control, eight reported that higher HbA1c levels were significantly associated with lower school grades.

Conclusion: Academic performance based on school grades in youth with T1D shows mixed results; however, poor glycemic control is consistently associated with reduced academic achievement. These findings underscore the importance of optimal diabetes management and highlight the need for longitudinal research to clarify causal relationships and inform interventions.

1 | Introduction

Type 1 diabetes (T1D) is characterized by the destruction of pancreatic beta cells, usually of autoimmune origin, leading to complete insulin deficiency and hyperglycemia [1, 2]. Although the etiology of T1D is not yet fully understood, it is suggested that the combination of genetic predisposition and environmental factors, such as viral infections, plays a central role, with possible contributions from toxins and dietary components [1]. Despite the significant advancements in treatment and management, the disease constitutes a considerable challenge from the individual and public health perspectives [3].

T1D can develop at any age, with a notably higher global incidence during early adolescence [2]. There has been a consistent increase in the prevalence of the disease across various geographical regions over the last decades [4, 5]. In addition to its epidemiological impact, T1D may negatively affect the psychosocial [6] and economic [7] well-being of patients, and poses a substantial economic burden on healthcare systems [4]. There is also a growing concern regarding the cognitive impact of the disease [8]. Findings from studies using structural and functional magnetic resonance imaging [9–11] and neuropsychological [12–15] tests support that T1D negatively affects cognitive function in children and adults. Structural and functional imaging studies reveal that brain abnormalities occur even at early stages following diagnosis [16]. The mechanisms underlying cognitive impairment in T1D are not fully understood, but the contribution of vascular complications and metabolic abnormalities are acknowledged to play a role [17]. It is also not possible to rule out the impact of psychological distress on cognitive impairment, given that individuals with T1D may experience distress more frequently than the general population [18, 19], and that the association between psychological distress and cognitive function observed in other clinical settings [20].

Despite the evidence suggesting that T1D may negatively impact cognitive function in children and adolescents, studies on their academic achievement have produced mixed results. Therefore, this review aims to compare academic performance assessed by school grades between children and adolescents with T1D and their peers without the condition and to explore the relationship between glycemic control and academic achievement.

2 | Materials and Methods

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Supporting Information: Appendix A) [21]. The protocol was registered in PROSPERO (CRD42024602495).

2.1 | Eligibility Criteria

We included studies investigating academic performance in children and adolescents with T1D and addressing the association between glycemic control and academic performance. We excluded reviews, case reports, case series, personal opinions, book chapters, and conference abstracts.

Academic performance was the primary outcome of interest. To ensure conceptual precision and support meaningful comparison across studies, we operationalized academic performance using two clearly defined and widely validated domains: (i) standardized academic achievement, encompassing performance on nationally, regionally, or institutionally standardized assessments in core academic subjects (e.g., mathematics, reading/language, and science). For each study, we documented the specific assessment instruments used, their scaling procedures, and the metrics through which achievement was reported, and (ii) course-based academic performance: this domain includes indicators of sustained academic achievement derived from official school records. Eligible measures comprised course grades, cumulative or term grade point averages, and subject-specific examinations embedded within the regular curriculum. To maintain conceptual coherence, we restricted this category to summative or curriculum-aligned indicators and excluded short-duration tasks, experimental performance measures, or outcomes lacking established grading criteria.

For all included studies, we extracted detailed information on outcome definitions, measurement instruments, scoring procedures, and reporting formats.

2.2 | Search Strategy

PubMed, Scopus, and Web of Science were searched from their inception to August 7, 2025, as detailed in Supporting Information: Appendix B. Gray literature search was performed on Google Scholar, and the first 100 results were screened. A reference management system [22] was used to collect the references and select the studies.

2.3 | Study Selection

Two reviewers (Lorena Oliveira Alves and Bruna Teles Soares Beserra) independently screened the articles based on their titles and abstracts to select eligible studies. Then, the same reviewers independently applied the inclusion criteria to the full-text version of selected studies. A third reviewer (Angélica Amorim Amato) was consulted in case of disagreement between the first and second reviewers.

2.4 | Data Collection

The following information was collected using a standardized form: study characteristics (authors, year of publication, country, and type of study), population characteristics (sample size, age at T1D diagnosis and at the time of the study, and glycemic control), outcomes, and main findings.

For consistency, study designs were assigned based on the methodological framework of the data informing our outcome of interest rather than the overall study structure. In studies that included both cross-sectional and longitudinal assessments, when only the cross-sectional component contributed academic performance data, they were categorized as case-control or cross-sectional for the purposes of this review, despite containing longitudinal elements for other outcomes.

2.5 | Risk of Bias in Individual Studies

Risk of bias was assessed by using the Joanna Briggs Institute critical appraisal checklist for analytical cross-sectional studies (Supporting Information: Appendix C), cohort studies (Supporting Information: Appendix D), and case-control studies (Supporting Information: Appendix E) [23], by two independent reviewers (Lorena Oliveira Alves and Bruna Teles Soares Beserra). Any disagreement was resolved by discussion with a third reviewer (Angélica Amorim Amato). Studies were considered as having a “high risk of bias” when the study reached 49% or less of the score “yes,” as having a “moderate risk of bias” when the study reached 50%–69% of the score “yes,” and as having a “low risk of bias” when the study reached more than 70% of the score “yes.”

2.6 | Description of the Results

Due to variations in the tools used to assess academic performance by school grades across studies, we could not combine the findings from individual studies into a meta-analysis. Therefore, we summarized data by describing results from each study in a table format (structured summary method) and by describing the effect estimates from each study based on the direction of the effect (vote counting based on the direction of effect method). To explore potential sources of heterogeneity, we categorized the included studies according to the type of academic performance assessment used, the age group of participants, the glycemic control thresholds applied, and the year of publication.

3 | Results

3.1 | Study Selection

A total of 4535 references were retrieved, and after duplicate removal and title and abstract screening, 44 studies were eligible for full-text analysis. Sixteen studies were included in the systematic review (Figure 1), and 28 studies were excluded (Supporting Information: Appendix F).

3.2 | Study Characteristics

Seven studies were conducted in America [24–30], five in Europe [31–35], two in Oceania [36, 37], one in Asia [38], and one in Africa [39]. All were published in English between 1985 and 2023. Ten studies had a cross-sectional design [24, 25, 27, 28, 31, 33–35, 37, 39], four studies had a cohort design [26, 30, 32, 36], and two were case-control studies [29, 38] (Table 1). The detailed description of the design of the included studies is presented in Supporting Information: Appendix G.

The sample size of individual studies ranged from 33 to 13,294 children and adolescents with T1D, and 29 to 2,454,862 children and adolescents without T1D. Nine studies reported mean HbA1c levels from study participants with T1D, which ranged from 7.6% to 12.9%. Eight studies presented mean time since diagnosis, which ranged from 4 to 7.5 years. In studies addressing the association between glycemic control and academic performance ($n = 10$), all assessed HbA1c levels and one additionally assessed peripheral blood glucose levels.

Eight studies assessed academic performance by school grades, seven used data from national assessment programs, and one used another validated tool to examine academic performance. Moreover, assessment of academic performance comprised a variety of subjects. In studies using school grades as the outcome, all included mathematics and language. National assessment programs also included mathematics and language.

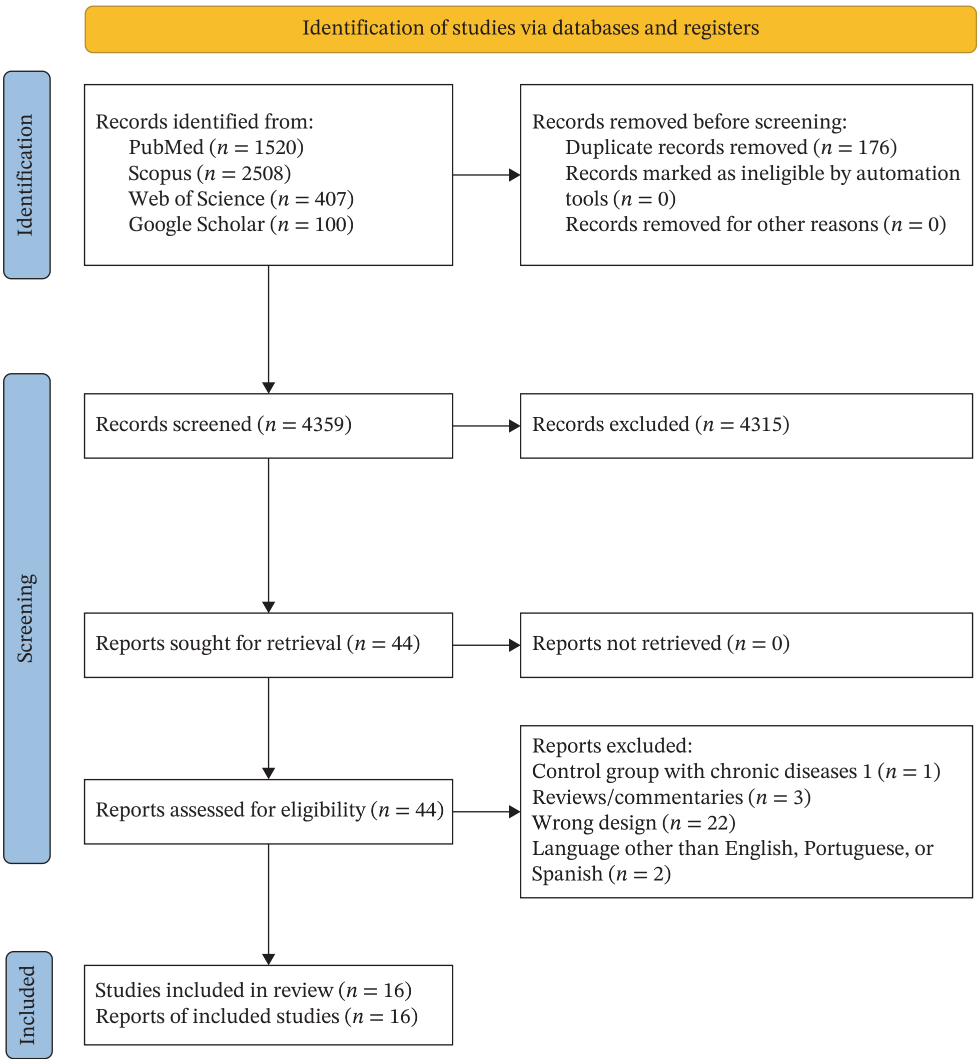

FIGURE 1 | Literature search and study selection process.

TABLE 1 | Characteristics of the included studies examining the association between type 1 diabetes and academic performance ($n = 16$).

Author (reference), country, study design	Sample characteristics	Glucose assessment[a]	Academic performance assessment, areas	Adjustment factors/covariates	Main conclusion
Ryan et al. [29][b] US Case-control	T1D $N = 33$ (15.4 ± 1.7 years) Time since diagnosis: 7.5 ± 1.9 years HbA1c: 12.7%–12.9% ± 1.6%–2.4% Controls $N = 29$ (15.5 ± 1.9 years) Source: diabetes clinic at the Children's Hospital of Pittsburgh	—	Wide range achievement test (reading, spelling, and arithmetic)	—	Children with T1D exhibited lower scores in reading, spelling, and arithmetic compared with children without T1D
McCarthy et al. [26] US Retrospective cohort	T1D $N = 243$ (14.8 ± 3.2 years) Time since diagnosis: 7.1 ± 3.9 years HbA1c: NR Controls Siblings $N = 110$ (14.6 ± 3.2 years) Classmates $N = 219$ (age NR) Current and previous achievement scores Source: public schools	HbA1c	ITBS/ITED Math, reading, and core total (a composite score of reading, language, and math) Reported in standard scores (mean of 100 and SD of 15)	—	Children with T1D exhibited higher core total and math standard scores than their siblings, and higher reading standard scores than their classmates Children with T1D exhibited similar reading and language standard scores compared with their siblings, and similar core total, language, and math standard scores compared with their classmates Children with T1D did not present a decrease in standard scores from grade 3 to grade 8 compared with siblings or classmates Children with higher HbA1c presented similar reading, math, and core total scores compared with their classmates and siblings
McCarthy et al. [25] US Cross-sectional	T1D $N = 244$ (14.8 ± 3.2 years) Time since diagnosis: 7.1 ± 3.9 years HbA1c: NR Source: public schools	HbA1c (mean value for current year)	ITBS/ITED Math, reading, and core total (a composite score of reading, language, and math) GPA Reported in standard scores (mean of 100 and SD of 15)	—	Children with T1D and higher HbA1c exhibited lower scores in reading ITBS/ITED), core total ITBS/ITED), and GPA but similar scores in math (ITBS/ITED) compared with children with T1D and lower HbA1c levels
Dahlquist and Källén [31] Sweeden Cross-sectional	T1D $N = 5159$ (16 years) Time since diagnosis: NR HbA1c: NR Comparator: general population	—	National standard achievement tests (math, English, and Swedish), numerical marks (1988–1997) or alphabetical marks (1998–2003)	Year of birth, maternal age, parity, maternal education	Children with T1D exhibited lower scores than children without T1D

(Continues)

TABLE 1 | (Continued)

Author (reference), country, study design	Sample characteristics	Glucose assessment[a]	Academic performance assessment, areas	Adjustment factors/covariates	Main conclusion
	$N = 1{,}330{,}968$ (16 years) Source: public schools				
Persson et al. [32] Sweeden Cohort	16 years (compulsory school) T1D: $n = 2392$ Controls: $n = 9563$ 19 years (upper secondary school) T1D: $n = 713$ Controls: $n = 3365$ Age at diagnosis <4 years: 10% 5–9 years: 38% 10–15 years: 53% HbA1c: NR Source: public schools	—	School grades (Swedish, English, and math)	Sex, year of grade, socioeconomic background, country of birth of the parents (and mean final grade from compulsory school for upper secondary school)	Children with T1D exhibited lower school grades than children without T1D
Meo et al. [38] Saudi Arabia Case-control	T1D $N = 36$ (17.02 ± 0.53 years) Time since diagnosis: 6.11 ± 0.65 years HbA1c: 8.37% ± 0.21% Controls $N = 36$ (17.85 ± 0.41 years) Source: public school	—	Academic grades (English, math, physics, chemistry, biology, and humanities)	—	Children with T1D exhibited lower academic grades compared with children without T1D
Potts et al. [27] US Cross-sectional	T1D $N = 39$ (12.5 ± 2.73 years) Time since diagnosis: 48.05 ± 41.08 months HbA1c: 8.39% ± 1.63% Source: public schools	HbA1c Average from 2 peripheral blood glucose measurements taken before and after neuropsychological tests (peripheral blood glucose)	Self-reported grades in math, science, and English (A = 5, B = 4, C = 3, D = 2, E = F, grades averaged)	Depression (child depression inventory) and perception of difficulty with academic performance (neuropsychological tests)	Glucose levels assessed by peripheral blood glucose but not HbA1c were negatively associated with school grades in children with T1D, but the association was not seen after controlling for perception of difficulty with academic performance
Cooper et al. [36] Australia Cohort	T1D $N = 666$ (7–14 years) Time since diagnosis: NR HbA1c: 7.6%–8.2% ± 0.9%–1.2% Controls $N = 3260$ (7–14 years) Source: public and private school	HbA1c (mean values during 2 years prior to NAPLAN)	NAPLAN (numeracy, reading, writing, spelling, and grammar and punctuation) Years 3, 5, 7, and 9	Calendar year (where applicable), sex, age, and treatment regimen, carers' education, and school attendance – subset of students attending public schools	Children with T1D exhibited similar scores compared with children without T1D, and scores did not change over time in children with T1D HbA1c levels were negatively associated with lower scores in children with T1D
Román et al. [28] Chile Cross-sectional	T1D $N = 66$ (13.4 ± 2.9 years) Time since diagnosis: 5.3 ± 3.2 years HbA1c: 8.6% ± 1.9%	HbA1c	Annual grades (annual grade point average and average of each subject, ranging from 1 to 7)	—	Children with T1D in primary education exhibited lower school grades than the general population Children in T1D in secondary

(Continues)

TABLE 1 | (Continued)

Author (reference), country, study design	Sample characteristics	Glucose assessment[a]	Academic performance assessment, areas	Adjustment factors/covariates	Main conclusion
	No T1D $N = 105{,}032$ (data from the Ministry of Education) Source: public, private, and chartered schools				education exhibited similar school grades compared with the general population HbA1c levels were not associated with school grades in children with T1D
Winnick et al. [30] US Cohort	T1D $N = 252$ (12.49 ± 1.53 years) Source: NR	HbA1c	Grade point average (every 6 months for 2.5 years, mother's report)	Sex, age, T1D duration, insulin delivery method, intelligence quotient	Higher levels of HbA1c limited subsequent increases in grade point average
Lansing et al. [24] US Cross-sectional	T1D $N = 172$ (12.9 ± 1.39 years) Time since diagnosis: 4.66 ± 3.6 years HbA1c: 8.3% ± 1.6% Source: NR	HbA1c	Grade point average (mothers' reports)	Age, time since diagnosis, intelligence quotient, family income, family structure, self-control (brief self-control scale), self-efficacy (self-efficacy for diabetes management scale), Mom acceptance (acceptance subscale of the mother–father–peer scale), peer relation (extreme peer orientation scale), adherence (self-care inventory)	HbA1c levels were negatively associated with school grades in children with T1D
Skipper et al. [33] Denmark Cross-sectional	Total $N = 631{,}620$ (10.31 ± 2.42 years) T1D $N = 2031$ Time since diagnosis: 4.5 ± 3.3 years HbA1c: 7.9% ± 1.1% No T1D $N = 629{,}589$ Source: public and private schools	HbA1c	Standardized test score (math and reading), range 1–100	Grade, topic, year, and socioeconomic status	Children with T1D exhibited similar scores compared with children without T1D HbA1c levels were negatively associated with academic scores
Ahmed et al. [39] Sudan Cross-sectional	T1D $N = 122$ (13.2 ± 2.81 years) Time since diagnosis: >1 years HbA1c: 11.2% ± 2.7% Source: NR	HbA1c	Academic scores obtained from schools (0%–100%)	—	HbA1c levels were negatively associated with academic scores
French et al. [34] Wales Cross-sectional	T1D $N = 1212$ (15–16 years) Time since diagnosis: NR HbA1c: NR No T1D $N = 263{,}426$ (15–16 years) Source: public schools	HbA1c	High stakes testing at the end of compulsory school for the GCSE (key stage 4, for ages 15–16 years) Total grade points score for each subject, with values standardized to a mean of zero and SD of 1	Sex, academic year, household deprivation, and special educational needs	Children with T1D exhibited similar grades compared with children without T1D HbA1c levels were negatively associated with academic scores

(Continues)

TABLE 1 | (Continued)

Author (reference), country, study design	Sample characteristics	Glucose assessment[a]	Academic performance assessment, areas	Adjustment factors/covariates	Main conclusion
Mitchell et al. [37] Australia Cross-sectional	T1D $N = 833$ (grade 3), 673 (grade 5), 516 (grade 7), 324 (grade 9), 843 (grade 10), 775 (grade 11), 682 (grade 12) Time since diagnosis: NR HbA1c: NR Comparator group: no diabetes $N = 833$ (grade 3), 673 (grade 5), 516 (grade 7), 324 (grade 9), 843 (grade 10), 775 (grade 11), 682 (grade 12) Source: public, Catholic, and independent schools	—	NAPLAN (numeracy and reading) Grades 3, 5, 7, and 9	Sex, NAPLAN grade, LBOTE, socioeconomic status, parental education and occupation, school sector (government, Catholic, independent), geographic location	Children with T1D exhibited similar scores compared with children without T1D
Liu et al. [35] Sweden Cross-sectional	Total $N = 2,454,862$ T1D $N = 13,294$ (15–16 years) Time since diagnosis: Mean age at diagnosis: 9.1 ± 4.1 years Age at assessment: 15–16 years HbA1c: NR No T1D $N = 2,441,568$ (15–16 years) Source: NR	—	Grade point average at completion of compulsory school, ages 15–16 years Swedish, English, mathematics; 13 additional subjects during the final academic year	Sex, birth cohort, parental highest education level, and other childhood onset somatic conditions	Children with T1D exhibited lower scores compared with children without T1D

Note: GCSE, General Certificate of Secondary Education Exam; WJ-III ACH, Woodcock Johnson Tests of Achievement-Third edition.
Abbreviations: FSIQ, full-scale intelligence quotient; GPA, grade point average; ITBS, Iowa Tests of Basic Skills (grades 3–8); ITED, Iowa Tests of Educational Development (grades 9–12); LBOTE, language background other than English; NAPLAN, National Assessment Program—literacy and numeracy; NMS, national minimal standard; NR, not reported; T1D, type 1 diabetes.
[a]For studies addressing the association between glucose control and academic performance in children with T1D.
[b]The multiple regression analysis reported in the study examined predictors of academic performance within the T1D group only and was not used for between-group comparisons; therefore, no covariate adjustment was applied to the comparison between children with and without T1D.

3.3 | School Performance of Children and Adolescents With T1D

Eleven studies, employing heterogeneous methodological designs, investigated academic performance of children with T1D either through direct comparison with matched control groups or by leveraging national educational databases (Tables 1 and 2, Supporting Information: Appendix H). Five studies reported that children with T1D exhibited lower academic performance when compared with those without T1D, being either controls [29, 32, 35, 38] or the general national population [31]. In contrast, five studies found that academic performance was similar, or even higher in some areas, when comparing children and adolescents with and without T1D, being the latter either controls [26, 36, 37] or the national general population [33, 34]. One study reported that academic performance was lower in children with T1D attending primary education compared with controls, whereas it was similar to that of the controls in secondary education [28].

When examining academic performance across different school subjects, most studies reported lower or similar grades across domains for children and adolescents with T1D compared with their peers. An exception was study by McCarthy et al. [26], which found higher performance in specific subjects: children with T1D scored higher in mathematics compared with their siblings and higher in reading compared with classmates. The remaining studies did not observe differences between domains, reporting generally comparable performance across subjects.

TABLE 2 | Summary of findings from studies examining the association between type 1 diabetes and academic performance, stratified by key study characteristics ($n = 11$).

	Academic achievement		
Study characteristic	**Higher**	**Similar**	**Lower**
Type of assessment			
School grades ($n = 4$)[a]	—	1	4
Standardized achievement tests or national exams ($n = 7$)[b]	1	5	2
Educational stage			
Primary education ($n = 3$)[c]	—	2	1
Secondary education ($n = 11$)[b]	1	6	5
High school	—	—	—
Year of publication			
Before 2000 ($n = 1$)	—	—	1
Between 2000 and 2010 ($n = 2$)[b]	1	1	1
Between 2010 and 2020 ($n = 5$)[a]	—	3	3
After 2020 ($n = 3$)	—	2	1
Number of participants with type 1 diabetes			
<100 ($n = 3$)[a]	—	1	3
100–1000 ($n = 2$)[b]	—	2	1
>1000 ($n = 6$)	—	3	3

[a]One study reported either similar or lower academic performance depending on the age group assessed [28].
[b]One study reported either higher or similar performance depending on the subject evaluated [26].
[c]Three studies included participants across both primary and secondary education levels [28, 33, 37].

We observed that studies assessing academic achievement using teacher-assigned school grades more often reported lower performance in children and adolescents with T1D compared with their peers without T1D, whereas studies using standardized national examinations tended to find similar performance between groups (Table 2). In contrast, no consistent pattern emerged when studies were grouped by educational stage (primary versus secondary education; Table 2). We also noted that studies with larger sample sizes more frequently reported comparable academic achievement between children and adolescents with and without T1D (Table 2). Finally, grouping studies by publication year did not reveal any systematic differences in findings (Table 2).

3.4 | Association Between Glycemic Control and School Performance in Children With T1D

Ten studies using diverse methodological approaches evaluated the association between glycemic control and academic performance in children with T1D, assessing HbA1c [24–28, 30, 33, 34, 36, 39] and peripheral glucose levels [27] (Tables 1 and 3, Supporting Information: Appendix I). Eight reported that poorer glycemic control was associated with lower scores in school grades or on other tools to assess academic achievement [24, 25, 27, 30, 33, 34, 36, 39].

Most studies examining the association between HbA1c levels and academic achievement using linear models reported a negative correlation, indicating that higher HbA1c levels were associated with lower test scores (Table 3). Studies using categorical

TABLE 3 | Summary of findings from studies examining the association between HbA1c levels in type 1 diabetes and academic performance, by statistical model ($n = 11$).

	Academic achievement (higher vs. lower HbA1c)		
Type of statistical model	**Higher**	**Similar**	**Lower**
Linear models for the association between A1c and academic achievement ($n = 4$)	—	1	3
Categorical models for the association between A1c and academic achievement ($n = 6$)			
HbA1c >10 vs. 8–10 vs. <8% ($n = 2$)[a]	—	2	1
HbA1c >7.5 vs. <7.5% ($n = 2$)[b]	—	1	1
HbA1c >8.6 vs. <8.6% ($n = 1$)[b]	—	—	1
HbA1c >9.5 vs. <9.5% ($n = 1$)	—	—	1
HbA1c quintile (1st quintile < 7.9, 5th quintile > 10.1, $n = 1$)	—	—	1

[a]One study found higher or similar results, according to the subject [25].
[b]One study compared academic achievement in two different ways (HbA1c > vs. <7.5 and > vs. <8.6).

models were more heterogeneous in how they defined HbA1c groups; however, the majority similarly found that higher HbA1c levels were linked to poorer academic achievement (Table 3).

3.5 | Risk of Bias Within Studies

Among the 10 included cross-sectional studies, all but one [39] were considered to have a low risk of bias (Supporting Information: Appendix C). All but one [36] of the four cohort included studies were considered to have a low risk of bias (Supporting Information: Appendix D), and both case-control included studies were considered to have a low risk of bias (Supporting Information: Appendix E).

4 | Discussion

This systematic review of observational studies indicates no consistent evidence that children and adolescents with T1D exhibit differences in academic performance assessed by school grades or national assessment programs compared with their peers without T1D. However, most studies addressing the association between glycemic control in T1D found that children with poorer control exhibited lower academic performance than those with better control. Additionally, the review highlights the paucity of knowledge regarding academic performance in children and adolescents with T1D, as only 16 studies have been conducted on this topic over the past 40 years.

We found previous meta-analyses addressing the impact of T1D during childhood, adolescence, and adulthood on cognitive function assessed by neuropsychological tests. Brands et al. [12] synthesized data from 35 studies involving individuals aged over 18 years with T1D who underwent neuropsychological tests in euglycemia. They found that those with T1D exhibited reduced intelligence, speed of information processing, psychomotor efficiency, visual and sustained attention, cognitive flexibility, and visual perception compared to subjects without T1D. Tonoli et al. [15] conducted a meta-analysis of studies investigating cognitive function in children and adults with T1D. They reported that children exhibited poorer performance on executive function, full intelligence quotient, and motor speed.

Despite evidence indicating that T1D during childhood and adolescence can negatively impact cognitive performance, its effects on academic performance remain poorly understood. A previous systematic review summarized findings from two studies that evaluated high-stakes testing at the end of compulsory education, reporting that adolescents with T1D had lower average grades compared to their peers without the condition [40]. However, no other review to date examined the literature on academic performance of children and adolescents with T1D at different ages or explored its relationship with glycemic control. Therefore, we aimed to comprehensively review the literature to determine whether school performance among children and adolescents with T1D differs from that of their non-diabetic peers.

Notably, there was a paucity of data addressing this issue, with only 11 studies published since 1985 comparing academic performance in children with T1D and controls, and with mixed results. Moreover, due to the methodological heterogeneity regarding the assessment of academic performance, we could not pool their findings in a meta-analysis. Therefore, current evidence is insufficient to determine whether academic achievement is affected in children and adolescents with T1D. Therefore, it is currently unclear whether the abnormalities observed in neuropsychological tests in this age range [15] are accompanied by unfavorable changes in academic performance. The inconsistency between studies addressing neuropsychological function and academic performance may also raise the questions of whether school exams are reliable as the sole measure of academic performance and whether differences in the pedagogical assessment tools used by the respective countries may have had any impact on the results.

The reasons for the discrepancies in the findings from the included studies are not fully understood since we could not pool data into a meta-analysis and conduct subgroup analysis to examine whether the type of academic achievement assessment (school tests or national standardized exams), age/educational stage, year of the study, factors related to T1D, sample size, and socioeconomic status could have explained the varied results. However, we examined some of these factors qualitatively.

Two noteworthy patterns emerged when examining sources of heterogeneity across studies. First, the type of academic assessment appeared to influence the consistency of findings. Studies that evaluated school performance using national standardized examinations generally reported comparable academic outcomes between children and adolescents with T1D and their peers without T1D. Standardized exams are less vulnerable to teacher-related variability, grading subjectivity, and school-level differences, which may partly explain the greater uniformity of results in this subgroup. In contrast, studies relying on teacher-assigned school grades more frequently indicated lower performance in children and adolescents with T1D, suggesting that contextual factors such as classroom practices, grading criteria, and subjective evaluation may interact with the challenges of living with T1D and contribute to divergent findings. Collectively, these findings underscore the need for consistent and objective assessment methods and highlight the importance of considering contextual and methodological differences when interpreting academic performance in youth with T1D.

Second, the educational stage did not reveal a consistent pattern across studies. Although some evidence—such as that from Román et al. [28]—indicated that younger children in primary school may experience lower academic performance, this trend was not consistently observed across the broader set of included studies. The mixed findings suggest that developmental stage alone may not fully account for differences in academic achievement. Instead, the interplay of age-related cognitive demands, self-management responsibilities, school-level support, and glycemic variability may influence academic outcomes in more complex ways than a simple primary-versus-secondary distinction can capture.

We also examined whether publication year explained variability in the findings. Although no definitive pattern emerged, we noted a general trend: studies published before 2014 tended to report lower academic performance in children and adolescents with T1D compared with their peers without T1D, whereas studies published after 2014 more commonly reported similar performance between groups. This observation makes it reasonable to speculate whether the recent advances in T1D management could have favorably impacted academic achievement, given their positive impact on quality of life [41] and psychological distress [42]. Although the effects of psychosocial factors on academic achievement have not been addressed in children and adolescents with T1D, there is previous evidence supporting that psychological distress adversely affects academic outcomes in various settings [43].

The studies comparing academic performance in children and adolescents with and without T1D varied considerably concerning sample size. Despite the possibility that smaller studies conducted in nonrandom sample of subjects could have led to different conclusions compared with studies involving a broader and random sample, we observed that even when comparing only smaller studies or larger studies the findings were still inconsistent, with both smaller and larger studies indicating that children and adolescents with T1D have lower or similar performance when compared with their peers without the disease. Since the studies also varied regarding the covariates that could influence academic performance, such as socioeconomic status and parental education, we also examined whether the adjustment of data or the lack of adjustment could explain the inconsistent results between studies, but when comparing only studies in which data were adjusted, and studies in which data were not adjusted we still observed mixed results.

Despite the inconsistent evidence regarding the association between T1D and academic performance assessed by school grades in children and adolescents, we found that poorer glycemic control was associated with lower academic achievement in children and adolescents with T1D in most studies. This suggests the subtle but significant effects of poor glycemic control on academic achievement and is consistent with the evidence indicating the negative association between poor metabolic control and cognitive function. In a recent meta-analysis, Hua et al. [14] synthesized the findings from six cross-sectional studies comprising 351 subjects with T1D and a mean age ranging from 11 to 34 years. They found that poorer glycemic control assessed by HbA1c was associated with poorer performance in full-scale intellectual quotient, although not in memory, attention, and verbal intellectual quotient.

While no definite conclusions may be drawn due to the observational design of the included studies, the evidence supporting the negative effect of glycemic control on cognitive function suggests that the association with academic performance is biologically plausible. Findings from previous studies indicate that the mechanisms underlying cognitive dysfunction in T1D are diverse and include the direct effects of chronic hyperglycemia and hypoglycemia, in addition to microvascular dysfunction, as has been thoroughly reviewed elsewhere [17]. Interestingly, it was recently shown that insulin deprivation for less than 6 h induced metabolic derangements that were accompanied by significant adverse changes in brain bioenergetics and microstructure, in addition to acute impairment in fine motor speed, attention, and short-term memory in adolescents and young adults with T1D, pointing to the direct influence of transient and subtle insulin deficiency and metabolic alterations on cortical function [44]. Importantly, the later alterations are frequently seen early in the course of T1D, in the absence of vascular complications. Data from a zebrafish model demonstrated the negative effects of acute hyperglycemia on cognitive function, suggesting a causal and direct role for hyperglycemia in cognitive impairment [45].

An additional relevant consideration regarding the association between glycemic control and academic achievement was raised by Skipper et al. [33]. The authors conducted a population-based retrospective cohort in Denmark with 631,620 children and adolescents, of which 2031 had T1D, and found that school grades were not different between those with and without T1D. However, among those with T1D, HbA1c levels were negatively correlated with grades after adjustment for socioeconomic factors. In addition to raising the negative impact of poor glycemic control on cognitive function, the authors argued that parents of children with T1D directed more resources toward them, which would positively affect both metabolic control and school grades, or that good academic attainment and better glycemic control were confounded by cognitive and noncognitive skills [33].

Future studies on academic performance in children and adolescents with T1D should address the impact of blood glucose levels and fluctuations at the time of academic assessment, in addition to overall glucose control measured by HbA1c and peripheral blood glucose levels. Knight and Perfect [46] assessed 67 children and adolescents with T1D and found that higher glucose levels during 6 days before neurobehavioral evaluation were associated with poorer reading fluency and writing fluency performance. Additionally, more time spent with hypoglycemia within the 12 h before academic evaluation was associated with worse reading, fluency, calculation, and spelling performance. In agreement with this, Potts et al. [27] found that peripheral blood glucose levels taken before and after academic assessment, but not HbA1c levels, were negatively associated with scores.

This review has several limitations. First, we could not pool data from individual studies due to significant heterogeneity regarding the method to assess and report academic performance. However, it is critical to point out that this methodological diversity simultaneously reflects the inherent complexity of measuring academic performance and the specificities of the national contexts in which they were conducted. Assessing academic performance is an intrinsically multifaceted process, encompassing dimensions such as knowledge, skills, socioeconomic influences, and pedagogical practices. This complexity suggests that future studies should adopt varied methods to comprehensively capture academic achievement.

In view of the methodological heterogeneity of included studies, we could also not examine whether there were differences between children and adolescents with T1D and their peers in specific domains, such as mathematics or language, or whether factors such as age, time since T1D diagnosis, access to healthcare and advances in the management of T1D, and socioeconomic status affected academic performance. Moreover, most included studies were conducted in high-income countries; hence, the findings are not readily generalizable to other settings. This is particularly important in developing countries due to the inequities in access to advances in T1D management [47].

5 | Conclusions

The current systematic review of observational studies does not support a consistent difference in academic performance assessed by school grades or national assessment programs between children and adolescents with and without T1D. Nevertheless, it suggests that poorer glycemic control is associated with lower academic achievement. While there is a growing body of evidence from clinical studies indicating cognitive impairment [15] and functional brain imaging abnormalities [17] in children and adolescents with T1D, the mixed findings on academic achievement as indicated in the current review suggest that some children with T1D may experience challenges in academic performance, while others do not. Therefore, to fully elucidate the impact of T1D on academic achievement, future studies should focus on overcoming the limitations of current studies. Thus, this type of research should incorporate random population-based samples, greater geographical diversity, and address different characteristics of children and adolescents with T1D, such as age, time since T1D diagnosis, glycemic control, family support, psychological well-being, access to healthcare and advances in diabetes management, and socioeconomic factors that may affect academic performance. Additionally, comprehensive assessments of academic performance should be conducted, and findings should be reported in standardized formats to enable meaningful comparisons across different studies.

Author Contributions

Lorena Oliveira Alves conceptualized and designed the study, designed tha data collection instruments, collected data, drafted the initial manuscript, and critically reviewed the manuscript. Bruna Teles Soares Beserra collected data, carried out initial analysis, drafted the initial manuscript, and critically reviewed the manuscript. Luiz Claudio Gonçalves de Castro coordinated and supervised data collection, and critically reviewed and revised the manuscript for important intellectual content. Angélica Amorim Amato conceptualized and designed the study, coordinated and supervised data collection, and critically reviewed the manuscript.

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Disclosure

All the authors have approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available in the supporting information of this article.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. (*Supporting Information*)

Appendix A. Preferred reporting items for systematic reviews and meta-analyses checklist. Appendix B. Search strategies with appropriate keywords and MeSH terms. Appendix C. Risk of bias summary, assessed by Joanna Briggs Institute critical appraisal checklist for analytical cross-sectional studies: author's judgments for each included study. Appendix D. Risk of bias summary, assessed by Joanna Briggs Institute critical appraisal checklist for cohort studies: author's judgments for each included study. Appendix E: risk of bias summary, assessed by Joanna Briggs Institute critical appraisal checklist for case-control studies: author's judgments for each included study. Appendix F. Excluded articles and reasons for exclusion for the review question ($n = 28$). Appendix G. Detailed results from individual studies addressing the effect of type 1 diabetes in academic performance ($n = 11$). Appendix H. Detailed results from individual studies addressing the effect of glycemic control in academic performance of children with type 1 diabetes ($n = 10$).