

LORENA OLIVEIRA ALVES

DESEMPENHO ESCOLAR DE CRIANÇAS COM DIABETES MELLITUS TIPO 1: UMA
REVISÃO SISTEMÁTICA

SCHOOL PERFORMANCE OF CHILDREN WITH TYPE 1 DIABETES MELLITUS:
A SYSTEMATIC REVIEW

BRASÍLIA, 2025

UNIVERSIDADE DE BRASÍLIA
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ABSTRACT

Introduction: Type 1 diabetes mellitus (T1D) is one of the most prevalent chronic diseases in childhood, characterized by the destruction of the pancreatic β -cells, usually by an autoimmune process, that results in significant or complete deficiency in insulin production. While T1D is often associated with biological and metabolic challenges, its impact extends further, affecting psychosocial and cognitive aspects, including the academic performance of children and adolescents. Previous studies suggest that inadequate glycemic control, as well as episodes of hypoglycemia and hyperglycemia, may negatively interfere with cognitive functions such as attention, memory, and executive functions, in addition to impairing school performance. However, research findings on this relationship remain inconsistent due to methodological and population heterogeneity. **Aims:** This systematic review aims to examine school performance in children and adolescents with type 1 diabetes (T1D) and its association with glycemic control through a systematic review. **Methods:** We searched PubMed, Scopus, Web of Science, and Google Scholar from inception to February 2025, for studies addressing school performance of children and adolescents with T1D assessed by school grades or validated tools to evaluate academic achievement, and studies investigating the association between school performance and glycemic control. Risk of bias was assessed using the Joanna Briggs Institute tool. The systematic review was registered in PROSPERO (CRD42024602495). **Results:** Sixteen studies comprising 26,794 children and adolescents with T1D were included, of which nine had a cross-sectional design. Most (13/16) were considered to have a low risk of bias. Eleven studies compared school achievement of children and adolescents with T1D to that of a control group or of the country's general population, of which five reported similar achievement and five reported lower achievement of children with T1D compared with children without T1D. One study reported that academic performance was lower in primary but similar in secondary school. Ten studies addressed the association between school achievement and glycemic control assessed by glycated hemoglobin (HbA1c) or peripheral glucose levels, of which eight reported that higher HbA1c levels were associated with lower academic performance. **Conclusion:** This systematic review does not support that there are differences in school performance between children and adolescents with T1D and their peers without T1D. However, it underscores that inadequate glycemic control may adversely affect academic outcomes. Additionally, the review points to a notable lack of research focused on school performance in T1D, emphasizing the need for future studies to explore this critical area comprehensively. Addressing this gap will be crucial for understanding the full impact of T1D on educational attainment and developing effective interventions to support affected children and adolescents.

Key words: type 1 diabetes, academic performance, school performance, glycemic control.

RESUMO

Introdução: O diabetes mellitus tipo 1 (DM1) é uma das doenças crônicas mais prevalentes na infância, caracterizado por destruição das células β pancreáticas, geralmente por uma reação autoimune, que resulta em deficiência significativa ou completa na produção de insulina. Embora o DM1 seja frequentemente associado a desafios biológicos e metabólicos, seu impacto vai além, afetando também aspectos psicossociais e cognitivos, incluindo o desempenho acadêmico de crianças e adolescentes. Estudos prévios sugerem que o controle glicêmico inadequado, bem como episódios de hipoglicemia e hiperglicemia, pode interferir negativamente nas funções cognitivas, como atenção, memória e funções executivas, além de impactar o desempenho escolar. Apesar disso, os resultados de pesquisas sobre essa relação permanecem inconsistentes, devido à heterogeneidade metodológica e populacional.

Objetivo: Esta revisão sistemática teve como objetivo investigar o desempenho escolar de crianças e adolescentes com DM1 e sua associação com o controle glicêmico por meio de uma revisão sistemática.

Métodos: Foram utilizadas as bases de dados PubMed, Scopus, Web of Science e Google Scholar desde sua implementação até fevereiro de 2025, para identificar estudos que avaliaram o desempenho escolar de crianças e adolescentes com DM1 com base em notas escolares ou ferramentas validadas para medir o desempenho acadêmico, além de estudos que investigaram a associação entre desempenho escolar e controle glicêmico. O risco de viés foi avaliado por meio da ferramenta do Instituto Joanna Briggs. A revisão sistemática foi registrada no PROSPERO (CRD42024602495).

Resultados: Foram incluídos 16 estudos, envolvendo 26.794 crianças e adolescentes com DM1, dos quais nove apresentavam um desenho transversal. A maioria (13/16) foi considerada com baixo risco de viés. Onze estudos compararam o desempenho acadêmico de crianças e adolescentes com DM1 com um grupo controle ou com a população geral do país, dos quais cinco relataram desempenho semelhante e cinco indicaram desempenho inferior em crianças com DM1 em comparação com aquelas sem a doença. Um estudo relatou que o desempenho acadêmico foi inferior no ensino fundamental, mas semelhante no ensino médio. Dez estudos investigaram a associação entre desempenho acadêmico e controle glicêmico, avaliado por hemoglobina glicada (HbA1c) ou níveis de glicose periférica, dos quais oito relataram que níveis mais altos de HbA1c estavam associados a um pior desempenho acadêmico.

Conclusão: Esta revisão sistemática não sustenta que existam diferenças no desempenho escolar entre crianças e adolescentes com T1D e seus pares sem T1D. No entanto, destaca que um controle glicêmico inadequado pode afetar negativamente os resultados acadêmicos. Além disso, a revisão aponta uma notável falta de pesquisas focadas no desempenho escolar de indivíduos com T1D, enfatizando a necessidade de estudos futuros que explorem essa questão de forma abrangente. Preencher essa lacuna será essencial para compreender o impacto total do T1D na trajetória educacional e para desenvolver intervenções eficazes que apoiem crianças e adolescentes afetados.

Palavras-chave: diabetes mellitus tipo 1, desempenho acadêmico, desempenho escolar, controle glicêmico.

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LIST OF ABBREVIATIONS AND ACRONYMS

FSIQ: full-scale Intelligence Quofficient

GPA: Grade Point Average

IDF: International Diabetes Federation

ITBS: Iowa Tests of Basic Skills

ITED: Iowa Tests of Educational Development

JB: Joanna Briggs Institute

LBOTE: language background other than English

NAPLAN: National Assessment Program - Literacy and Numeracy

NMS: national minimal standard

NR: not reported

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

PROSPERO: International Prospective Register of Sistematic Reviews

SACA: South and Central America

T1D: Type 1 diabetes

WJ-III ACH: Woodcock Johnson Tests of Achievement – Third edition

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PREFACE

This dissertation aims to compare school performance between children with T1D and their peers without the condition and to explore the relationship between glycemic control and academic achievement. The relevance of this topic is evidenced by the rising incidence of type 1 diabetes and the need to better understand how this condition affects the educational and cognitive development of affected young individuals. Given the increasing use of new technologies in diabetes management, understanding how these resources influence academic performance is crucial to ensuring more effective educational support.

The structure of this dissertation is organized to provide a detailed and in-depth analysis of the proposed topic. The Introduction section addresses the characteristics and the implications of type 1 diabetes on the daily lives of children and adolescents, with an emphasis on academic performance. This section also includes the research objectives.

In the Methods section, the inclusion and exclusion criteria, defined using the PECOS strategy, are outlined to ensure that the selected studies were rigorous and relevant to the systematic review's objective. The methodology used for data collection and analysis is described, with a focus on the systematic review. This section discusses the criteria for selecting articles, the processes for evaluating the methodological quality of the included studies, and the strategies adopted for data analysis.

In Chapter 1, the research results are presented, offering a detailed analysis of the variables that influence the academic performance of students with T1D. The implications of these results for educational practices and clinical management of type 1 diabetes are discussed, along with the relationship between glycemic control and academic performance. Chapter 1 also presents the discussion of the findings, delving deeper into the interpretation of the results. It analyzes the possible mechanisms that explain how type 1 diabetes interferes with cognitive functions and learning, with an emphasis on the implications for educational support. The critical analysis also addresses the limitations of the reviewed studies and suggests new approaches that can be explored in future research to optimize the clinical and educational management of students with the disease. Final Consideration session presents a summary of the main findings and their implications. Recommendations for more inclusive and tailored educational practices are presented, along with suggestions for future research on the topic. This session reinforces the importance of a multidisciplinary approach involving collaboration between healthcare professionals and educators to improve the quality of life and academic performance of students with type 1 diabetes.

Through this dissertation, the goal is to contribute to a better understanding of the challenges faced by children and adolescents with T1D in the school context, highlighting the importance of effective disease management and pedagogical strategies that foster a more inclusive learning environment, enabling these students to achieve their academic potential.

1. INTRODUCTION

Type 1 diabetes (T1D) accounts for 5 to 10% of all cases of diabetes, and is characterized by an autoimmune destruction of pancreatic beta cells, usually by autoimmune mechanisms, leading to complete insulin deficiency and hyperglycemia (1). 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 (2).

Type 1 diabetes (T1D) can develop at any age. Population studies indicate that the predominant age of onset ranges from 10 to 14 years, while in Finland, the peak incidence occurs between 5 and 9 years. Furthermore, in some countries, a decreasing trend in the peak age of incidence has been observed in recent years. There has been a consistent increase in the prevalence of the disease across various geographical regions over the last decades (3). T1D was estimated to affect 1.5 million individuals aged under 20 years in 2021, and its prevalence is projected to increase by 60 to 107% in 2040 across all age groups (4). In addition to its epidemiological impact, T1D may negatively affect the psychosocial (5) and economic (6) well-being of patients, and poses a substantial economic burden on healthcare systems (3).

In addition to the traditional vascular complications of T1D, there is a growing concern regarding the cognitive impact of the disease (7). Findings from studies using structural and functional magnetic resonance imaging (8-10) and neuropsychological (11-14) tests support that T1D negatively affects cognitive function in children and adults. Notably, structural and functional imaging studies reveal that brain abnormalities occur even at early stages following diagnosis (15). 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 (16). 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 (17, 18), and that the association between psychological distress and cognitive function observed in other clinical settings (19).

Despite the evidence suggesting that T1D may negatively impact cognitive function in children and adolescents, studies on school performance in children with T1D have produced mixed results. To date, no systematic review published in the PubMed, Scopus, Web of Science, and Google Scholar databases has comprehensively examined this issue. Therefore, this review aims to compare school performance between children with T1D and their peers without the condition and to explore the relationship between glycemic control and academic

achievement.

2. METHODS

2.1. Protocol and registration

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (20). The protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) database under the registration number CRD42024602495.

2.2. Eligibility criteria

The PECOS (Population, Exposure, Comparison, Outcomes, Study type) acronym was used to create the review question. To address whether school performance was different between children and adolescents with T1D and children and adolescents without T1D, P was ‘individuals aged under 18 years’, E was ‘type 1 diabetes’, C was ‘individuals without type 1 diabetes’, O was ‘academic performance assessed by school grades or other validated tools’, and S was ‘observational studies’. To address the association between school performance and glycemic control, P was ‘individuals aged under 18 years with T1D’, E was ‘poor glycemic control assessed by fasting glucose, glycated hemoglobin or continuous glucose monitoring’, C was ‘better glycemic control assessed by fasting glucose, glycated hemoglobin or continuous glucose monitoring’, O was ‘academic performance assessed by school grades or other validated tools’, and S was ‘observational studies’.

Therefore, we included studies investigating school performance in children and adolescents with T1D, assessed by school grades or other validated tools, such as national exams or tests of achievement. Studies addressing the association between glycemic control and school performance were also included. We excluded studies that reported school grades for children and adolescents with T1D but did not compare them to those of children and adolescents without the disease and did not assess the association between glycemic control and school performance. We also excluded studies involving only neuropsychological tests but not school grades or national exams to assess school performance, reviews, case reports, case series, personal opinions, book chapters, and conference abstracts.

2.3. Search strategy

PubMed, Scopus, and Web of Science were searched from inception to February 2, 2025, for studies published in English, Spanish, or Portuguese. Additionally, grey literature was performed on Google Scholar, and manual searches were performed on the reference lists

of included articles. The search strategy included descriptors related to T1D, children, school performance, and glycemic control, as detailed in Appendix A. A reference management system (21) was used to collect the references and select the studies.

2.4. Study selection

A two-phase process was applied to select studies. In the first phase, two reviewers (L.O.A. and B.S.T.B) independently screened the articles based on their titles and abstracts to select eligible studies. In the second phase, the same reviewers independently applied the inclusion criteria to the full-text version of selected studies. A third reviewer (A.A.A.) was consulted in case of disagreement between the first and second reviewers. Finally, one reviewer thoroughly examined the reference lists of all the included articles.

2.5. Data collection

For all included studies, the following information was collected using a standardized form: study characteristics (authors, year of publication, country, type of study), population characteristics (sample size, age, glycemic control), outcomes, and main findings. The outcome of interest was school performance assessed by school grades, score on national exams, or tests of academic achievement.

2.6. 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 (Appendix B), Cohort Studies (Appendix C), and Case-Control Studies (Appendix D) (22), by two independent reviewers (L.O.A. and B.S.T.B). Any disagreement was resolved by discussion with a third reviewer (A.A.A.). 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.’

2.7. Description of the results

Due to differences among studies concerning the tool used to assess school performance, we could not pool findings from individual studies in 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).

CHAPTER 1

3. Results

3.1. Study selection

A total of 4,117 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, and 28 studies were excluded (Figure 1). The reasons for exclusion are detailed in Appendix E.

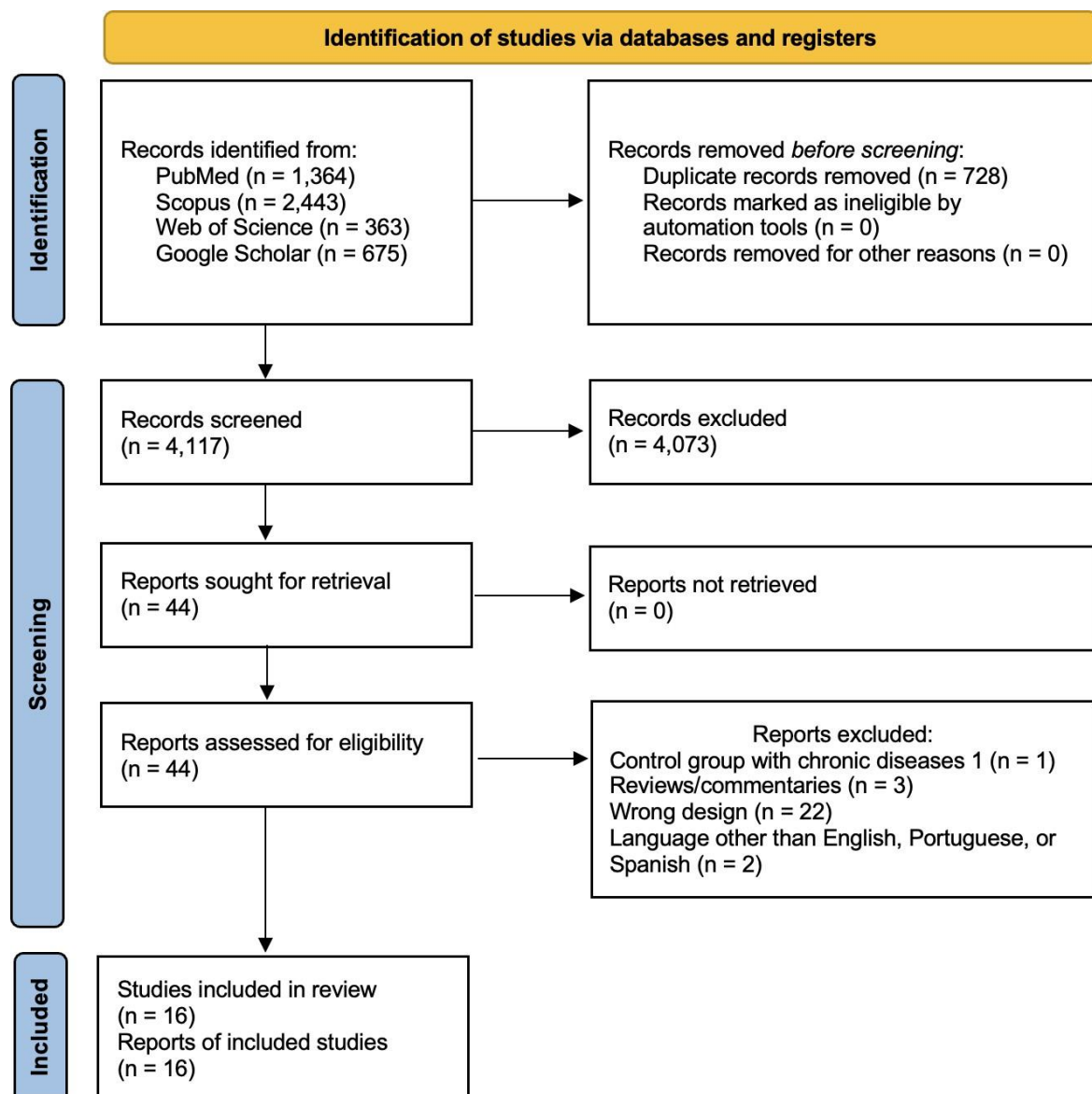


Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses Flow Diagram of Search Results and Reasons for Exclusion of Studies.

3.2. Study characteristics

Seven studies were conducted in America (23-29), five in Europe (30-34), two in Oceania (35, 36), one in Asia (37), and one in Africa (38). All included studies were published in English between 1985 and 2023. Nine studies had a cross-sectional design (23, 24, 26, 27, 30, 32-34, 38), five studies had a cohort design (25, 29, 31, 35, 36), and two were case-control studies (28, 37). A summary of their descriptive characteristics is presented in Table 1.

The included studies comprised a total of 26,794 children and adolescents with T1D. The sample size from 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 type since diagnosis, which ranged from 4 to 7.5 years. In the studies addressing the association between glycemic control and school performance ($n = 10$), all assessed HbA1c levels and one additionally assessed peripheral blood glucose levels.

Eight studies assessed school performance by school grades, seven used data from national assessment programs, and one used another validated tool to examine academic performance. Moreover, assessment of school 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.

Table 1. Characteristics of the included studies examining the association between diabetes and academic performance (n = 16).

Author (year), country, study design	Sample characteristics	Glucose assessment ¹	Academic performance assessment, areas	Adjustment factors/covariates	Main conclusion
Ryan et al., 1985 US Case-control	T1D N = 33 (15.4 ± 1.7 y) Time since diagnosis: 7.5 ± 1.9 y HbA1c: 12.7-12.9 ± 1.6-2.4 % Controls N = 29 (15.5 ± 1.9 y) Source: NR	-	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., 2002 US Retrospective cohort	T1D N = 243 (14.8 ± 3.2 y) Time since diagnosis: 7.1 ± 3.9 y HbA1c: NR Controls Siblings N = 110 (14.6 ± 3.2 y) 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., 2003 US Cross-sectional	T1D N = 244 (14.8 ± 3.2 y) Time since diagnosis: 7.1 ± 3.9 y 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
Dalquist et al. 2007 Sweeden Cross-sectional	T1D N = 5,159 (16 y) Time since diagnosis: NR HbA1c: NR Comparator: general population N = 1,330,968 (16 y) Source: public schools	-	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
Persson et al., 2013 Sweeden Cohort	16 y (compulsory school) T1D: n = 2,392 Controls: n = 9,563 19 y (upper secondary school) T1D: n = 713 Controls: n = 3,365 Age at diagnosis < 4 y: 10 % 5-9 y: 38 %	-	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

	10-15 y: 53 % HbA1c: NR Source: public schools				
Meo et al., 2013 Saudi Arabia Case-control	T1D N = 36 (17.02 ± 0.53 y) Time since diagnosis: 6.11 ± 0.65 y HbA1c: 8.37 ± 0.21 % Controls N = 36 (17.85 ± 0.41 y) 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., 2015 US Cross-sectional	T1D N = 39 (12.5 ± 2.73 y) Time since diagnosis: 48.05 ± 41.08 mo 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., 2016 Australia Cohort	T1D N = 666 (7-14 y) Time since diagnosis: NR HbA1c: 7.6 to 8.2 ± 0.9 to 1.2 % Controls N = 3,260 (7-14 y) Source: public and private school	HbA1c (mean values during 2y 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
Lansing et al., 2018 US	T1D N = 172 (12.9 ± 1.39 y)	HbA1c	Grade point average (mothers' reports)	Age, time since diagnosis, intelligence	HbA1c levels were negatively associated

Cross-sectional	Time since diagnosis: 4.66 ± 3.6 y HbA1c: 8.3 ± 1.6 % Source: NR			quoefficient, 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)	with school grades in children with T1D
Román et al., 2017 Chile Cross-sectional	T1D N = 66 (13.4 ± 2.9 y) Time since diagnosis: 5.3 ± 3.2 y HbA1c: 8.6 ± 1.9 % No T1D N = 105,032 (data from the Ministry of Education) Source: public, private and chartered schools	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 education exhibited similar school grades compared with the general population HbA1c levels were not associated with school grades in children with T1D
Winnic et al., 2017 US Cohort	T1D N = 252 (12.49 ± 1.53 y)	HbA1c	Grade Point Average (every six months for 2.5 y, mother's report)	Sex, age, T1D duration, insulin delivery method, intelligence quotient	Higher levels of HbA1c limited subsequent increases in grade point average
Skipper et al., 2019 Denmark Cross-sectional	Total N = 631,620 (10.31 ± 2.42 y) T1D N = 2,031 Time since diagnosis:	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

	4.5 ± 3.3 y HbA1c: 7.9 ± 1.1% No T1D N = 629,589 Source: public and private schools				
Ahmed et al., 2021 Sudan Cross-sectional	T1D N = 122 (13.2 ± 2.81 y) Time since diagnosis: > 1 y 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., 2022 Wales Cross-sectional	T1D N = 1,212 (15-16 y) Time since diagnosis: NR HbA1c: NR No T1D N = 263,426 (15-16 y) Source: public schools	HbA1c	High stakes testing at the end of compulsory school for the GCSE (Key Stage 4, for ages 15-16 y) 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
Mitchell et al., 2022 Australia Case-comparison cohort	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	-	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

	(grade 10), 775 (grade 11), 682 (grade 12) Source: public, Catholic, and independent schools				
Liu et al., 2023 Sweden Cross-sectional	Total N = 2,454,862 (15-16 y) T1D N = 13,294 (15-16 y) Time since diagnosis: Mean age at diagnosis: 9.1 ± 4.1 y HbA1c: NR No T1D N = 2,441,568 (15-16 y) Source: NR	-	Grade point average at completion of compulsory school, ages 15-16 y) 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

¹ For studies addressing the association between glucose control and academic performance in children with T1D.

FSIQ: full-scale Intelligence Quotient; GCSE: General Certificate of Secondary Education Exam; 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; WJ-III ACH: Woodcock Johnson Tests of Achievement – Third edition.

3.3. School performance in children with type 1 diabetes

Eleven studies investigated school performance in children with T1D compared with controls or with data from national databases. Five studies reported that children with T1D ($n = 20,914$) exhibited lower school performance when compared with those without T1D ($n = 3,795,458$), being either controls (28, 31, 34, 37) or the general national population (30). In contrast, five studies found that school performance was similar when comparing children with T1D ($n = 4,985$) with children without T1D ($n = 657,437$), being either controls (25, 35, 36) or the national general population (32, 33). One study reported that school 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 (27). Their detailed results are presented in Appendix F.

Ryan et al. (1985) conducted a study with 33 adolescents with T1D and 29 controls aged 12 to 18 to investigate the impact of diabetes on academic and neuropsychological performance. School performance was assessed using the Wide Range Achievement Test, including subtests in Reading, Spelling, and Arithmetic. Additionally, visuomotor skills were assessed using the Trail Making Test, the Digit Symbol Substitution Test, and the Grooved Pegboard Test. The results indicated that adolescents with T1D performed significantly worse on academic tasks, and exhibited slower performance on visuomotor tasks. In addition, they also presented higher rates of school absenteeism, although there was no difference between adolescents with T1D and controls regarding self-esteem or general intelligence (28).

McCarthy et al. (2002) prospectively assessed 243 children with T1D and 239 controls (either siblings or classmates without T1D) using the Iowa Tests of Basic Skills and Iowa Tests of Educational Development (ITBS/ITED), which comprise Reading, Language, and Mathematics, in addition to a composite score of the three subjects. They found that children with T1D had higher Mathematics and core total scores than their siblings, and higher Reading scores than their classmates. They performed similarly to siblings in Reading and Language, and similarly to classmates in Math and Language. Moreover, children with T1D did not present a decrease in school performance through grades 3 to 8 compared with their siblings and classmates (25).

Dalquist et al. (2007) assessed the National Standard Achievement Test scores at the end of compulsory education in Sweden. They compared data from 5,159 children with T1D with data from the general population, comprising 1,330,968 children, and found that those with T1D exhibited lower scores than those without it (30).

Persson et al. (2013) assessed school grades from 2,392 adolescents with T1D and

9,563 controls at the end of compulsory education (age 16 years). They found that those with T1D had a poorer performance after adjusting for sex, socioeconomic background, and country of birth of parents. The authors also assessed 713 adolescents with T1D and 3,365 controls at the end of upper secondary school (age 19 years) and also reported lower school grades in those with T1D compared with controls. Additionally, the study revealed that individuals with T1D were less likely to complete secondary education and be gainfully employed at the age of 29 (31).

Meo et al. (2013) assessed school grades in English, Mathematics, Physics, Chemistry, Biology, and Humanities from 36 adolescents with T1D and 36 age-matched controls and found that those with T1D exhibited poorer performance than controls (37). Cooper et al. (2016) investigated the Australian National Assessment Program scores, comprising numeracy and literacy, from 666 children and adolescents with T1D and 2,320 controls in grades 3, 5, 7, and 9. They found no differences in academic performance between children and adolescents with T1D compared with controls, and this finding did not change over progression from grades 3 to 9 (35).

Román et al. (2017) examined the annual school grades of 66 children and adolescents with T1D and data from the Ministry of Education, including school grades of 105,032 age-matched children and adolescents from the general population. They reported that school grades from those with T1D were lower in primary education but similar in secondary education compared with the general population (27).

Skipper et al. (2019) cross-sectionally assessed the school performance of 631,620 children and adolescents, of which 2,031 had the diagnosis of T1D, by using the standardized test score comprising Mathematics and Reading. They reported that scores were similar between children and adolescents with T1D and controls after adjusting for school grade, subject, year, and socioeconomic status (32).

Mitchell et al. (2022) prospectively assessed children with T1D and controls from grade 3 to grade 12, using the Australian National Assessment Program, comprising Numeracy and Reading, and found that those with T1D had similar performance when compared with controls (36).

French et al. (2022) examined the scores on national exams to assess academic achievement in Wales in 1,212 adolescents with T1 and reported they were similar to those of their peers ($n = 263,426$) without T1D (33). More recently, Liu et al. (2023) compared school grades between adolescents with ($n = 13,294$) and without ($n = 2,441,568$) adolescents at the end of compulsory school and reported that those with T1D performed worse than their peers

without T1D especially those with psychiatric disorders. (34).

3.4. Association between glycemic control and school performance in children with type 1 diabetes

Ten studies examined the association between glycemic control and academic performance in children with T1D, assessing HbA1c (23-27, 29, 32, 33, 35, 38) and peripheral glucose levels (26). Eight reported that poorer glycemic control was associated with lower scores in school grades or on other tools to assess academic achievement (23, 24, 26, 29, 32, 33, 35, 38). Their detailed results are presented in Appendix G.

McCarthy et al. (2002) conducted a study with 243 children and adolescents with T1D, using the ITBS/ITED, comprising Reading, Language, and Mathematics, and a composite score of the three subjects (core total), in addition to the grade point average determined by school grades. The authors found that those with increased Hb1c levels exhibited similar scores compared to controls (siblings or classmates) (25). In a second study, the same group examined 244 children and adolescents with T1D, using the same tool to assess academic performance, and reported that those with higher HbA1c levels had lower scores in Reading, core total, and grade point average than those with lower levels. However, they also reported the small group of children and adolescents in the study with tight metabolic control and hospitalizations due to hypoglycemia exhibited low scores on the ITBS/ITED (24).

Potts et al. (2015) assessed 39 children and adolescents with T1D by self-reported Mathematics, Science, and English grades. They found that poorer glycemic control, determined by peripheral blood glucose but not by HbA1c, was associated with lower school grades. However, the association was not seen after adjusting for the perception of difficulty with academic performance by neuropsychological tests (26).

Cooper et al. (2016) investigated the association between HbA1c levels and academic performance in 666 children and adolescents with T1D assessed by a national exam comprising Mathematics and Language. They found that higher HbA1c levels were negatively associated with lower scores on the exam (35).

Lansing et al. (2016) examined 172 children and adolescents with T1D and found that higher HbA1c levels were associated with lower school grades, even after adjusting for age, time since the diagnosis of T1D, intelligence quotient, family income, family structure, self-control, self-efficacy, Mother's acceptance, peer relation, and self-care (23). Román et al. (2017) investigated 66 children and adolescents with T1D and found that HbA1c levels were not associated with annual school grades (27). Winnick et al. (2017) prospectively examined

the school grades of 252 children and adolescents with T1D and reported that higher HbA1c levels were associated with limited subsequent increases in grades (29).

Ahmed et al. (2021) investigated the association between HbA1c levels and school grades in 122 children and adolescents with T1D and found that higher HbA1c levels were associated with lower grades (38). French et al. (2022) found that, despite similar school performance when compared with their peers, adolescents with T1D and higher HbA1c levels exhibited worse performance than those with lower levels (33).

3.5. Risk of bias within studies

Among the nine included cross-sectional studies, all but one (38) were considered to have a low risk of bias (Appendix B). All but one (36) of the five included studies were considered to have a low risk of bias (Appendix C), and both case-control included studies were considered to have a low risk of bias (Appendix D).

4. Discussion

This systematic review of observational studies indicates no consistent evidence that children and adolescents exhibit differences in academic performance 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 school performance in children 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. Still, no systematic review and meta-analysis investigated academic performance by examining school grades or national exams of educational achievement. Brands et al. (2005) 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 (11). Tonoli et al. (2014) 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. Conversely, adults performed

worse on full, verbal, and performance intelligence quotient, memory, spatial memory, motor speed, and part of the executive function (14).

Due to the findings from previous meta-analyses of studies addressing cognitive function in T1D, we sought to examine the literature for evidence regarding whether school performance in children with the disease differed from that of their peers without T1D. Notably, there was a paucity of data addressing this issue, with only nine studies published since 1985 comparing school performance in children with T1D and controls, and with mixed results. Moreover, due to the methodological heterogeneity regarding the assessment of school performance, we could not pool their findings in a meta-analysis. Therefore, current evidence is insufficient to determine whether school performance is affected in children and adolescents with T1D, and it is currently unclear whether the abnormalities observed in neuropsychological tests in this age range (14) are accompanied by unfavorable changes in school performance. The inconsistency between studies addressing neuropsychological function and school performance may also raise the question of whether school exams are reliable as the sole measure of academic performance.

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 age/stage of development, 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.

Interestingly, we observed that most studies reporting lower school performance in children and adolescents with T1D compared with their peers without T1D were published before 2014, and most studies reporting similar performance were published after that. This observation makes it reasonable to speculate whether the recent advances in T1D management could have favorably impacted school performance, given their positive impact on quality of life (39) and psychological distress (40). Although the effects of psychosocial factors on school performance have not been specifically addressed in children and adolescents with T1D, there is previous evidence supporting that psychological distress adversely affects academic performance in various settings (41).

Moreover, the studies comparing school performance in children and adolescents with and without T1D varied considerably concerning sample size, ranging from studies including 33 to 13,294 children with the disease. 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 school performance to adjust data, 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 school performance in children, this systematic review indicated that most studies examining the association between glycemic control and school performance found that poorer control was associated with lower academic achievement in children and adolescents with T1D. 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. (2024) synthesized the findings from six cross-sectional studies comprising 351 subjects with a mean age ranging from 11 to 34 years and 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 (13).

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 school 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 (16). Interestingly, it was recently shown that insulin deprivation for less than six hours 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 metabolic alterations on cortical function (42). Importantly, the later alterations are frequently seen early in the course of T1D, in the absence of vascular complications. Data from animal models recapitulate the negative effects of acute hyperglycemia on cognitive function, suggesting a causal and direct role for hyperglycemia in cognitive impairment (43).

An additional relevant consideration regarding the association between glycemic control and school performance was raised by Skipper et al. (2019), whose study was included in this systematic review. The authors conducted a population-based retrospective cohort in Denmark with 631,620 children and adolescents, of which 2,031 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 school performance and better glycemic control were confounded by cognitive and noncognitive skills (32).

Moreover, a critical issue that should be addressed in future studies examining school performance in children and adolescents with T1D is the impact of blood glucose levels and fluctuations at the time of assessment of school performance, besides overall glucose control assessed by HbA1c levels and peripheral blood glucose levels. Knight et al. (2019) assessed 67 children and adolescents with T1D for the association between glucose levels in continuous glucose monitoring for six days before and during a neurobehavioral evaluation comprising Mathematics and Language. The authors found that higher glucose levels during evaluation were associated with poorer reading fluency and writing fluency performance, and that more time spent hypoglycemic within the 12 hours before evaluation was associated with worse reading, fluency, calculation, and spelling performance (44). In agreement with this, one of the included studies found that peripheral blood glucose levels taken before and after academic assessment but not HbA1c levels were negatively associated with scores, although the association was not seen after controlling for perception of difficulty with academic performance (26).

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 school 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 school performance more broadly.

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 school 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 (45).

In conclusion, the current systematic review of observational studies does not support a consistent difference in school performance between children and adolescents with and without T1D. However, it suggests that poorer glycemic control is associated with lower academic achievement. While the growing body of evidence from clinical studies indicating cognitive impairment (14) and functional brain imaging abnormalities (16) in children and adolescents with T1D compared with those without T1D, the mixed findings in the included studies suggest that some children with T1D may experience challenges in school performance, while others not. Therefore, to fully elucidate the impact of T1D on school performance, future studies should focus on overcoming the limitations of current studies. Thus, research should include 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. Moreover, it would be ideal to comprehensively assess school performance and report the findings in standardized ways to enable a reasonable comparison between different studies.

5. Final considerations

The findings of this systematic review demonstrate that despite the insufficient evidence that children and adolescents with T1D perform differently from their peers without T1D in school, poor glycemic control adversely impacts their academic performance. Evidence highlights that proper glycemic control plays a central role in mitigating the cognitive and academic impairments associated with T1D. The use of advanced technologies for disease management, such as continuous glucose monitors and insulin pumps, has also proven to be an effective strategy for enhancing academic performance, underscoring the importance of technological interventions in promoting the educational well-being of this population.

These findings emphasize the need for interdisciplinary approaches that integrate clinical, educational, and psychosocial efforts to support children and adolescents with T1D. Understanding the challenges faced by these individuals in the school environment and providing tailored educational support are essential to reducing the barriers posed by the condition and ensuring they can reach their full academic potential.

Despite its contributions, this review has limitations related to the methodological heterogeneity of the studies analyzed, the risk of bias, and the limited representativeness of certain populations. These factors highlight the need for future studies employing more robust designs, with greater control of confounding variables and more diverse samples, to deepen the understanding of the relationship between T1D, glycemic control, and academic performance.

Ultimately, this dissertation contributes to advancing knowledge by synthesizing evidence on the impacts of T1D on educational outcomes, providing a foundation for the development of health and education policies that promote effective disease management and adequate educational support. It is hoped that joint efforts among healthcare professionals, educators, and families will reduce the impacts of T1D on the educational trajectories of children and adolescents, fostering greater equity and opportunities for this group.

6. References

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APPENDICES

Database (search date)	Search
PubMed (August 24, 2024; updated on February 02, 2025) N: 1,364	#1: “Diabetes Mellitus, Type 1” OR “Diabetes Mellitus, Insulin Dependent” OR “Insulin-Dependent Diabetes Mellitus” OR “Type 1 Diabetes Mellitus” OR “Diabetes Mellitus, Juvenile Onset” OR “Diabetes, Juvenile-Onset” OR “Juvenile Onset Diabetes” OR “Juvenile-Onset Diabetes Mellitus” OR “Diabetes Mellitus, Sudden Onset” OR “Sudden-Onset Diabetes Mellitus” OR “Insulin Dependent Diabetes Mellitus 1” OR “Diabetes Mellitus, Type I” OR “Type 1 Diabetes” OR “Diabetes, Type 1” OR “Diabetes Mellitus, Juvenile-Onset” OR “Juvenile-Onset Diabetes” OR “Diabetes Mellitus, Insulin-Dependent” OR “IDDM” OR “Insulin-Dependent Diabetes Mellitus 1” OR “Diabetes Mellitus, Sudden-Onset” OR “Ketosis-Prone Diabetes Mellitus” OR “Autoimmune Diabetes” OR “Diabetes, Autoimmune” OR “Diabetes Mellitus, Brittle” OR “Brittle Diabetes Mellitus” #2: “Educational Status” OR “Academic Performance” OR “School performance” OR “Academic Achievement” OR “Measurement, Educational” OR “Measurements, Educational” OR “Educational Measurements” OR “Learning” OR “School Grades” #3: #1 AND #2
Scopus (August 24, 2024; updated on February 02, 2025) N = 2,443	TITLE-ABS-KEY (“Diabetes Mellitus, Type 1”) AND TITLE-ABS-KEY (“Academic Performance” OR "School performance" OR "Academic Achievement" OR "Learning" OR "School Grades")
Web of Science (August 24, 2024; updated on February 02, 2025) N = 363	TS=(“Diabetes Mellitus, Type 1” OR “Diabetes Mellitus, Insulin Dependent” OR “Insulin-Dependent Diabetes Mellitus” OR “Type 1 Diabetes Mellitus” OR “Diabetes Mellitus, Juvenile Onset” OR “Diabetes, Juvenile-Onset” OR “Juvenile Onset Diabetes” OR “Juvenile-Onset Diabetes Mellitus” OR “Diabetes Mellitus, Sudden Onset” OR “Sudden-Onset Diabetes Mellitus” OR “Insulin Dependent Diabetes Mellitus 1” OR “Diabetes Mellitus, Type I” OR “Type 1 Diabetes” OR “Diabetes, Type 1” OR “Diabetes Mellitus, Juvenile-Onset” OR “Juvenile-Onset Diabetes” OR “Diabetes Mellitus, Insulin-Dependent” OR “IDDM” OR “Insulin-Dependent Diabetes Mellitus 1” OR “Diabetes Mellitus, Sudden-Onset” OR “Ketosis-Prone Diabetes Mellitus” OR “Autoimmune Diabetes” OR “Diabetes, Autoimmune” OR “Diabetes Mellitus, Brittle” OR “Brittle Diabetes Mellitus”)) AND TS=(“Educational Status” OR “Academic Performance” OR “School performance” OR “Academic Achievement” OR “Measurement, Educational” OR “Measurements, Educational” OR “Educational Measurements” OR “Learning” OR “School Grades”)
Google Scholar (August 24, 2024) Results: 675	“Diabetes Mellitus, Type 1” AND (“Educational Status” OR “Academic Performance” OR “School performance” OR “Academic Achievement” OR “Measurement, Educational” OR “Measurements, Educational” OR “Educational Measurements” OR “Learning” OR “School Grades”)

Appendix A. Search strategies with appropriated keywords and MeSH terms.

Appendix B. Risk of bias summary, assessed by Joanna Briggs Institute Critical Appraisal Checklist for analytical cross-sectional studies: author's judgments for each included study.

Authors, year	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Total	Risk of bias
McCarthy et al. (2003)	N	Y	Y	Y	Y	Y	Y	Y	87,5%	Low
Dahlquist et al. (2007)	Y	Y	Y	Y	Y	Y	Y	Y	100%	Low
Potts et al. (2015)	Y	Y	Y	Y	Y	Y	Y	Y	100%	Low
Lansing et al. (2016)	Y	Y	Y	Y	Y	Y	Y	Y	100%	Low
Román et al. (2017)	Y	Y	Y	Y	Y	N	Y	Y	87,5%	Low
Skipper et al. (2019)	Y	Y	Y	Y	Y	Y	Y	Y	100%	Low
Ahmed et al. (2021)	Y	Y	Y	Y	U	N	Y	N	62,5%	Moderate
French et al. (2022)	Y	Y	Y	Y	Y	Y	Y	Y	100%	Low
Liu et al. (2023)	Y	Y	Y	Y	Y	Y	Y	Y	100%	Low

Legend: Y= Yes; N= No; U = unclear.

Q1 - Were the criteria for inclusion in the sample clearly defined?

Q2 - Were the study subjects and the setting described in detail?

Q3 - Was the exposure measured in a valid and reliable way?

Q4 - Were objective, standard criteria used for measurement of the condition?

Q5 - Were confounding factors identified?

Q6 - Were strategies to deal with confounding factors stated?

Q7 - Were the outcomes measured in a valid and reliable way?

Q8 - Was appropriate statistical analysis used?

Total= ΣY /Applicable Items (the Not Applicable (NA) items were excluded from the sum).

Risk of bias was categorized as high when the study reaches up to 49% score 'yes', moderate when the study reached 50% to 69% score 'yes', and low when the study reached more than 70% score 'yes'.

Appendix C. Risk of bias summary, assessed by Joanna Briggs Institute Critical Appraisal Checklist for Cohort Studies: author's judgments for each included study.

Authors, year	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Total	Risk of bias
McCarthy et al. (2002)	Y	Y	Y	Y	N	Y	Y	Y	U	N	Y	72,7%	Low
Persson et al. (2013)	Y	Y	Y	Y	Y	Y	Y	Y	Y	NA	Y	100%	Low
Cooper et al. (2016)	Y	Y	Y	Y	Y	NA	Y	N	U	N	Y	72,7%	Low
Winnick et al. (2017)	Y	Y	Y	Y	Y	NA	Y	Y	Y	Y	Y	100%	Low
Mitchell et al. (2022)	Y	U	N	Y	Y	U	Y	U	N	N	Y	45,4%	High

Legend: Y= Yes; N= No; U = unclear; NA: not applicable.

Q1 - Were the two groups similar and recruited from the same population?

Q2 - Were the exposures measured similarly to assign people to both exposed and unexposed groups?

Q3 - Was the exposure measured in a valid and reliable way?

Q4 - Were confounding factors identified?

Q5 - Were strategies to deal with confounding factors stated?

Q6 - Were the groups/participants free of the outcome at the start of the study (or at the moment of exposure)?

Q7 - Were the outcomes measured in a valid and reliable way?

Q8 - Was the follow up time reported and sufficient to be long enough for outcomes to occur?

Q9 - Was follow up complete, and if not, were the reasons to loss to follow up described and explored?

Q10 - Were strategies to address incomplete follow up utilized?

Q11 - Was appropriate statistical analysis used?

Total= ΣY /Applicable Items (the Not Applicable (NA) items were excluded from the sum).

Risk of bias was categorized as high when the study reaches up to 49% score 'yes', moderate when the study reached 50% to 69% score 'yes', and low when the study reached more than 70% score 'yes'.

Appendix D. Risk of bias summary, assessed by Joanna Briggs Institute Critical Appraisal Checklist for Case-Control Studies: author's judgments for each included study.

Authors, year	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total	Risk of bias
Ryan et al. (1985)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%	Low
Meo et al. (2013)	Y	Y	Y	Y	Y	Y	Y	Y	U	Y	90%	Low

Legend: Y= Yes; N= No; U = nuclear; NA: not applicable.

Q1 - Were the groups comparable other than the presence of disease in cases or the absence of disease in controls?

Q2 - Were cases and controls matched appropriately?

Q3 - Were the same criteria used for identification of cases and controls?

Q4 - Was exposure measured in a standard, valid and reliable way?

Q5 - Was exposure measured in the same way for cases and controls?

Q6 - Were confounding factors identified?

Q7 - Were strategies to deal with confounding factors stated?

Q8 - Were outcomes assessed in a standard, valid and reliable way for cases and controls?

Q9 - Was the exposure period of interest long enough to be meaningful?

Q10 - Was appropriate statistical analysis used?

Total= $\Sigma Y / \text{Applicable Items}$ (the Not Applicable (NA) items were excluded from the sum).

Risk of bias was categorized as high when the study reaches up to 49% score 'yes', moderate when the study reached 50% to 69% score 'yes', and low when the study reached more than 70% score 'yes'.

Appendix E. articles and reasons for exclusion for the review question (n = 28).

Authors	Reason for exclusion
McGavin et al. (1940) [1]	2
Fowler et al. (1985) [2]	2
Rovet et al. (1988) [3]	2
Kovacs et al. (1992) [4]	1
Davis et al. (1996) [5]	2
Hagen et al., 1990 [6]	2
Brands et al. (2005) [7]	2
Daley et. al (2006) [8]	2
Gaudieri et al. (2008) [9]	2
Parent et al. (2009) [10]	2
Blasetti et al. (2011) [11]	2
McCrimmon et al. (2012) [12]	2
Szémán et al. (2012) [13]	3
Joner et al. (2013) [14]	4
Moheet et al. (2015) [15]	2
Cato et al. (2016) [16]	2
Ryan et al. (2016) [17]	2
Li et al. (2017) [18]	3
Pourabbasi et al. (2017) [19]	2
Van et al. (2018) [20]	2
Oakley et al. (2018) [21]	4
Knight et al. (2019) [22]	2
Šuput et al. (2020) [23]	2
Abdullah et al. (2020) [24]	2
Puspasari et al. (2021) [25]	4
Chen et al. (2021) [26]	2
Bowden et al. (2023) [27]	2
Oleiwi et al. (2025) [28]	2

1. Control group with other chronic diseases.
2. Wrong design (assessment of memory, attention, and cognitive dysfunction; no assessment of school grades; no separate data for children with T1D; no comparison between children and adolescents with or without T1D for studies not examining the association between glycemic control and school performance).
3. Language other than English, Portuguese or Spanish.
4. Reviews or commentaries.

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Appendix F. Detailed results from individual studies addressing the effect of type 1 diabetes in academic performance (n = 11).

Author (year), country, study design	Sample size	Results
Ryan et al., 1985 US Case-control	T1D N = 33 (15.4 ± 1.7 y) Controls N = 29 (15.5 ± 1.9 y)	Univariate analysis Wide Range Achievement Test Reading T1D: 114.9 ± 10.4 Controls: 121.0 ± 8.1 P = 0.012 Spelling T1D: 106.3 ± 11.2 Controls: 112.5 ± 8.2 P = 0.016 Arithmetic T1D: 96.8 ± 13.7 Controls: 103.0 ± 11.7 P = 0.061
McCarthy et al., 2002 US Retrospective cohort	T1D N = 243 Controls Siblings N = 110 Classmates N = 219	T1D vs siblings Reading: 111.2 ± 13.4 vs 108.8 ± 14.3 p >0.05 Math: 115.0 ± 13.7 vs 111.1 vs 14.5 p <0.02 Core total: 113.9 ± 14.0 vs 110.5 ± 14.0 p <0.04 T1D vs classmates Reading: 108.9 ± 14.5 vs 106.8 ± 13.1 p <0.04 Math: 111.4 ± 15.3 vs 109.5 vs 14.4 p >0.05 Core total: 110.0 ± 15.6 vs 108.6 ± 13.8 p >0.05 Academic performance in T1D over time (hiearchical linear model): no difference between children with T1D and their siblings or classmates (data reported in figure)
Dalquist et al. 2007 Sweeden Cross-sectional	T1D N = 5,159 Controls N = 1,330,968	T1D vs all children Numerical marks All subjects T1D: 3.15 ± 0.01 Population: 3.23 ± 0.01 p <0.001 OR (95%CI), T1D vs all children Numerical marks Math Passed: reference Not passed: 1.15 (1.05-1.26) Passed with distinction: 1.05 (0.97-1.14) English Passed: reference

		Not passed: 1.08 (0.98-1.19) Passed with distinction: 0.90 (0.83-0.97) Swedish Passed: reference Not passed: 1.11 (1.01-1.22) Passed with distinction: 0.93 (0.85-1.01) Alphabetical marks Math Passed: reference Not passed: 1.56 (1.30-1.86) Passed with distinction: 0.98 (0.88-1.08) English Passed: reference Not passed: 1.40 (1.15-1.70) Passed with distinction: 0.88 (0.80-0.97) Swedish Passed: reference Not passed: 1.47 (1.19-1.83) Passed with distinction: 0.99 (0.83-1.12) Adjusted for year of birth, maternal age, parity, maternal education
Persson et al., 2013 Sweeden Cohort	16 y (compulsory school) T1D: n = 2,392 Controls: n = 9,563 19 y (upper secondary school) T1D: n = 713 Controls: n = 3,365	Linear regression (β coefficient, 95% CI) Compulsory school: -0.07 (-0.10 to -0.04) p < 0.001 Upper secondary school, theoretical programmes: -0.07 (-0.11 to -0.03) p = 0.001 Upper secondary school, vocational programme: -0.02 (-0.06 to +0.01) p = 0.181 Adjusted for sex, year of grade, socioeconomic background, country of birth of the parents (and mean final grade from compulsory school for upper secondary school)
Meo et al., 2013 Saudi Arabia Case-control	T1D N = 36 Controls N = 36	T1D: 86.58 $\pm$ 1.48 Controls: 90.62 $\pm$ 1.36 p = 0.002
Cooper et al., 2016 Australia Cohort	T1D N = 666 Controls N = 3,260	Cross-sectional Linear mixed effect model (β coefficient, 95% CI) Year 3 Numeracy: 0.02 (-0.17 to 0.22) Reading: 0.05 (-0.15 to 0.25) Spelling: 0.03 (-0.16 to 0.21) Grammar/punctuation: 0.05 (-0.16 to 0.26) Narrative writing: 0.13 (-0.10 to 0.35) Persuasive writing: -0.12 (-0.47 to 0.22) Year 5 Numeracy: 0.14 (-0.02 to 0.29) Reading: -0.01 (-0.17 to 0.15) Spelling: 0.00 (-0.16 to 0.16)

		Grammar/punctuation: 0.01 (-0.17 to 0.18) Narrative writing: 0.06 (-0.11 to 0.23) Persuasive writing: 0.28 (-0.10 to 0.67) Year 7 Numeracy: 0.14 (-0.01 to 0.28) Reading: 0.13 (-0.02 to 0.27) Spelling: -0.01 (-0.15 to 0.13) Grammar/punctuation: 0.08 (-0.09 to 0.25) Narrative writing: -0.09 (-0.25 to 0.07) Persuasive writing: 0.36 (0.07 to 0.65) Year 9 Numeracy: 0.10 (-0.04 to 0.24) Reading: 0.08 (-0.08 to 0.24) Spelling: 0.10 (-0.06 to 0.27) Grammar/punctuation: 0.07 (-0.09 to 0.24) Narrative writing: 0.06 (-0.16 to 0.28) Persuasive writing: 0.31 (-0.01 to 0.62) Adjusted for calendar year (where applicable), sex, age, carers education, and school attendance – subset of students attending public schools. Longitudinal Linear mixed effect model (β coefficient, 95% CI) Years 3-5 Numeracy: 0.06 (-0.14 to 0.25) Reading: -0.08 (-0.27 to 0.11) Spelling: -0.05 (-0.18 to 0.09) Grammar a punctuation: -0.03 (-0.27 to 0.20) Narrative writing: 0.11 (-0.14 to 0.36) Years 5-7 Numeracy: 0.04 (-0.08 to 0.16) Reading: -0.002 (-0.12 to 0.11) Spelling: 0.02 (-0.07 to 0.10) Grammar a punctuation: 0.01 (-0.14 to 0.16) Narrative writing: 0.03 (-0.14 to 0.20) Years 7-9 Numeracy: 0.02 (-0.09 to 0.13) Reading: 0.04 (-0.08 to 0.15) Spelling: 0.08 (-0.01 to 0.17) Grammar a punctuation: 0.02 (-0.13 to 0.17) Narrative writing: -0.02 (-0.21 to 0.16) Adjusted for age and sex
Lansing et al., 2016 US		Regression analysis for the association between GPA and A1c (β coefficient, 95% CI): -0.25 (-1.18 to -0.24), $p < 0.05$ Covariates: 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)

Skipper et al., 2019 Denmark Cross-sectional	T1D N = 2031 No diabetes N = 629,589	T1D: 56.56 ± No diabetes: 56.11 ± Mean difference: 0.45 (95%CI -0.31 to 1.22) Linear regression model (estimated difference, 95% CI): 0.45 (-0.58 to 1.49) Adjusted for grade, topic, year, and socioeconomic status
French et al., 2022 Wales Cross-sectional	T1D N = 1,212 Time since diagnosis: NR HbA1c: NR No T1D N = 263,426	High stakes testing at the end of compulsory school for the GCSE (Key Stage 4, for ages 15-16 y) Difference between children with and without T1D: 0.001 standard deviation, 95% CI -0.047 to 0.049, p > 0.05.
Mitchell et al., 2022 Australia Case-comparison cohort	T1D N = 833 (grade 3), 673 (grade 5), 516 (grade 7), 324 (grade 9), 843 (grade 10), 775 (grade 11), 682 (grade 12) No diabetes N = 833 (grade 3), 673 (grade 5), 516 (grade 7), 324 (grade 9), 843 (grade 10), 775 (grade 11), 682 (grade 12)	Frequency of NAPLAN assessment below NMS Numeracy (%) Grade 3 T1D: 3.8 Comparison: 4.0 Grade 5 T1D: 2.7 Comparison: 4.0 Grade 7 T1D: 3.1 Comparison: 3.3 Grade 9 T1D: 2.2 Comparison: 0.9 Chi-square test: p >0.05 Reading (%) Grade 3 T1D: 3.4 Comparison: 3.8 Grade 5 T1D: 5.1 Comparison: 5.9 Grade 7 T1D: 3.5 Comparison: 3.3 Grade 9 T1D: 3.1 Comparison: 4.6 Chi-square test: p >0.05 Association between T1D and NAPLAN assessment below NMS (Relative risk, 95%CI) Numeracy: 0.96 (0.70 to 1.31) Reading: 0.91 (0.69 to 1.20) Adjusted for gender, NAPLAN grade, LBOTE, socioeconomic status, parental education and occupation, school sector (government, Catholic,

		independent) Association between T1D and not completing high school (Relative risk, 95%CI) Year 10: 1.29 (0.68 to 2.42) Year 11: 1.31 (1.02 to 1.69) Year 12: 1.31 (1.04 to 1.65) Adjusted for gender, socioeconomic status, parental education, geographic location, LBOTE
Liu et al., 2023 Sweden Cross-sectional	Total N = 2,454,862 T1D N = 13,294 Time since diagnosis: Mean age at diagnosis: 9.1 ± 4.1 y Age at assessment: 15-16 y HbA1c: NR No T1D N = 2,441,568 Source: NR	All courses Grade point average T1D: 12.7 ± 3.6 No T1D: 13.0 ± 3.6 Linear regression (β coefficient, 95% CI) General population comparison model T1D: -0.13 (-0.20 to -0.06) No T1D: 1 (reference) Sibling population comparison model T1D: -0.19 (-0.28 to -0.09) No T1D: 1 (reference) Core school courses (Swedish, English, and Mathematics) Grade point average T1D: 12.9 ± 3.6 No T1D: 13.1 ± 3.5 Linear regression (β coefficient, 95% CI) General population comparison model T1D: -0.26 (-0.33 to -0.18) No T1D: 1 (reference) Sibling population comparison model T1D: -0.19 (-0.28 to -0.09) No T1D: 1 (reference)

Appendix G. Detailed results from individual studies addressing the effect of glycemic control in academic performance of children with type 1 diabetes (n = 10).

Author (year), country, study design	Sample characteristics	Results
McCarthy et al., 2002 US Case-control	T1D N = 243 Controls Siblings N = 110 Classmates N = 219	T1D vs siblings Reading: A1c < 8%: 115.4 ± 14.8 vs 109.9 ± 13.4 p >0.05 A1c 8-10%: 111.5 ± 12.8 vs 110.0 ± 14.3 p >0.05 A1c > 10% 107.4 ± 13.6 vs 104.6 ± 15.3 p >0.05 Math: A1c < 8%: 121.8 ± 10.1 vs 116.9 ± 11.7 p >0.05 A1c 8-10%: 113.7 ± 14.0 vs 109.7 ± 14.3 p >0.05 A1c > 10% 109.4 ± 14.7 vs 108.4 ± 15.5 p >0.05 Core total: A1c < 8%: 119.5 ± 12.0 vs 112.0 ± 13.0 p >0.05 A1c 8-10%: 114.1 ± 13.1 vs 111.7 ± 15.1 p >0.05 A1c > 10% 108.8 ± 14.5 vs 105.9 ± 15.3 p >0.05 T1D vs classmates Reading: A1c < 8%: 112.1 ± 17.6 vs 110.0 ± 14.6 p >0.05 A1c 8-10%: 110.5 ± 13.2 vs 107.4 ± 12.3 p <0.02 A1c > 10% 105.9 ± 13.1 vs 104.9 ± 14.2 p >0.05 Math: A1c < 8%: 114.4 ± 15.1 vs 112.3 ± 13.9 p >0.05 A1c 8-10%: 111.3 ± 14.8 vs 109.7 ± 13.9 p >0.05 A1c > 10% 109.1 ± 16.3 vs 106.9 ± 15.0 p >0.05 Core total: A1c < 8%: 113.4 ± 16.7 vs 111.4 ± 15.0 p >0.05 A1c 8-10%: 111.1 ± 13.8 vs 109.5 ± 13.2 p >0.05 A1c > 10% 106.7 ± 15.5 vs 105.5 ± 14.7

		p >0.05
McCarthy et al., 2003 US Cross-sectional	T1D N = 244	Mean ITBS/ITED score according to A1c Reading A1c < 8%: 112.1 ± 16.1 A1c 8-10%: 110.1 ± 12.0 A1c > 10%: 105.7 ± 12.9 P <0.05 Math A1c < 8%: 113.1 ± 14.5 A1c 8-10%: 111.8 ± 13.3 A1c > 10%: 109.1 ± 15.9 P >0.05 Core total A1c < 8%: 113.1 ± 15.2 A1c 8-10%: 111.0 ± 12.7 A1c > 10%: 106.7 ± 15.5 P <0.05 GPA A1c < 8%: 3.1 ± 0.7 A1c 8-10%: 3.1 ± 0.7 A1c > 10%: 2.8 ± 0.8 P <0.05 Bivariage correlation between core total score and A1c: -0.21, p <0.05
Potts et al., 2015 US Cross-sectional	N = 39	Correlation between glucose and academic performance A1c: r = -0.26, p >0.05 Peripheral blood glucose: r = -0.37, p <0.05 Multiple linear regression for academic performance (standardized β coefficient) Peripheral blood glucose: -0.37, p <0.05 Predictors in the model: peripheral blood glucose, depression (child depression inventory) and perception of difficulty with academic performance (neuropsychological tests) Multiple linear regression for peripheral blood glucose (standardized β coefficient) Academic performance: -0.18, p >0.05 Predictors in the model: perception of difficulty with academic performance (neuropsychological tests), academic performance, depression (child depression inventory)
Cooper et al., 2016 Australia Cohort	T1D N = 666 Controls N = 3,260	Cross-sectional Linear mixed effect model (β coefficient, 95% CI) Year 3 Numeracy: 0.02 (-0.17 to 0.22) Reading: 0.05 (-0.15 to 0.25) Spelling: 0.03 (-0.16 to 0.21) Grammar/punctutation: 0.05 (-0.16 to 0.26) Narrative writing: 0.13 (-0.10 to 0.35) Persuasive writing: -0.12 (-0.47 to 0.22)

		Year 5 Numeracy: 0.14 (-0.02 to 0.29) Reading: -0.01 (-0.17 to 0.15) Spelling: 0.00 (-0.16 to 0.16) Grammar/punctuation: 0.01 (-0.17 to 0.18) Narrative writing: 0.06 (-0.11 to 0.23) Persuasive writing: 0.28 (-0.10 to 0.67) Year 7 Numeracy: 0.14 (-0.01 to 0.28) Reading: 0.13 (-0.02 to 0.27) Spelling: -0.01 (-0.15 to 0.13) Grammar/punctuation: 0.08 (-0.09 to 0.25) Narrative writing: -0.09 (-0.25 to 0.07) Persuasive writing: 0.36 (0.07 to 0.65) Year 9 Numeracy: 0.10 (-0.04 to 0.24) Reading: 0.08 (-0.08 to 0.24) Spelling: 0.10 (-0.06 to 0.27) Grammar/punctuation: 0.07 (-0.09 to 0.24) Narrative writing: 0.06 (-0.16 to 0.28) Persuasive writing: 0.31 (-0.01 to 0.62) Adjusted for calendar year (where applicable), sex, age, and treatment regimen, carers' education, and school attendance – subset of students attending public schools.
Lansing et al., 2016 US Cross-sectional	N = 172	Correlation between GPA and A1c R spearman: -0.48, $p < 0.01$ Regression analysis for the association between GPA and A1c (β coefficient, 95% CI): -0.25 (-1.18 to -0.24), $p < 0.05$ Covariates: 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)
Román et al., 2017 Chile Cross-sectional	N = 66 Comparator: general population (n = 105,032 students, data from the Ministry of Education)	Annual grade point average < 7.5 %: 5.6 ± 0.8 A1c ≥ 7.5 %: 5.6 ± 0.6 $p > 0.05$ Math < 7.5 %: 5.3 ± 1.2 A1c ≥ 7.5 %: 5.1 ± 1.0 $p > 0.05$ Language < 7.5 %: 5.0 ± 0.9 A1c ≥ 7.5 %: 5.3 ± 0.7 $p > 0.05$ History < 7.5 %: 5.2 ± 1.1 A1c ≥ 7.5 %: 5.2 ± 0.8 $p > 0.05$ Technology

		< 7.5 %: 6.0 ± 0.8 $A1c \geq 7.5$ %: 6.1 ± 0.8 $p > 0.05$ Arts < 7.5 %: 6.2 ± 0.7 $A1c \geq 7.5$ %: 6.1 ± 0.8 $p > 0.05$ Physical education < 7.5 %: 6.3 ± 0.8 $A1c \geq 7.5$ %: 6.3 ± 0.7 $p > 0.05$ Biology < 7.5 %: 5.5 ± 1.0 $A1c \geq 7.5$ %: 5.2 ± 0.8 $p > 0.05$ English < 7.5 %: 5.0 ± 1.1 $A1c \geq 7.5$ %: 5.4 ± 0.9 $p > 0.05$ Linear regression analysis Annual grade point average and A1c: $r = -0.37$, $p > 0.05$
Winnick	Winnic et al., 2017 US Cohort	Higher levels of HbA1c predicted lower subsequent increases in grade point average Coupling term = -0.035, standard error = 0.012, degrees of freedom = 540.774, $t = -2.894$, $p = 0.004$, 95% CI -0.058 to -0.011
Skipper et al., 2019 Denmark Cross-sectional	T1D N = 2031 No diabetes N = 629,589	Linear regression model (mean score difference vs children without T1D, 95% CI): $A1c > 7.5$ %: -1.06 (-2.37 to 0.25) $A1c \leq 7.5$ %: 2.29 (0.83 to 3.75) $A1c > 8.6$ %: -2.47 (-4.50 to -0.45) $A1c \leq 8.6$ %: 1.2 (0.06 to 2.34) Adjusted for grade, topic, year, and socioeconomic status (sex, immigration status, birth order, number of siblings, living with both parents, maternal/paternal education, maternal/paternal income, maternal/paternal diabetes status, zip code)
Ahmed et al., 2021 Sudan Cross-sectional	N = 122	Academic score category according to A1c 0-49% $A1c < 9.5$ %: 2.2 % $A1c > 9.5$ %: 15.6 % 50-59% $A1c < 9.5$ %: 8.9 % $A1c > 9.5$ %: 18.2 % 60-69% $A1c < 9.5$ %: 26.7 % $A1c > 9.5$ %: 31.2 % 70-79% $A1c < 9.5$ %: 22.2 % $A1c > 9.5$ %: 23.4 % 80-100% $A1c < 9.5$ %: 40.0 % $A1c > 9.5$ %: 11.7 % Chi-square test: $p = 0.002$

French et al., 2022 Wales Cross-sectional	T1D N = 1,212 Time since diagnosis: NR HbA1c: NR No T1D N = 263,426	High stakes testing at the end of compulsory school for the GCSE (Key Stage 4, for ages 15-16 y) Children in the lowest HbA1c quintile ($5\% \leq \text{HbA1c} < 7.9\%$): 0.267 standard deviation, 95% CI 0.160 to 0.374, $p < 0.001$ Children in the highest HbA1c quintile ($10.1\% \leq \text{HbA1c} < 14.0\%$): -0.395 standard deviation, 95% CI -0.504 to -0.287, $p < 0.001$
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Appendix H. Preferred Reporting Items for Systematic Review and Meta-Analysis checklist.

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	School Performance of Children and Adolescents with Type 1 Diabetes Mellitus: A Systematic Review	1
ABSTRACT			
Abstract	2	Aims: This systematic review aims to examine school performance in children and adolescents with type 1 diabetes (T1D) and its association with glycemic control through a systematic review. Methods: We searched PubMed, Scopus, Web of Science, and Google Scholar from inception to February 2025, for studies addressing school performance of children and adolescents with T1D assessed by school grades or validated tools to evaluate academic achievement, and studies investigating the association between school performance and glycemic control. Risk of bias was assessed using the Joanna Briggs Institute tool. The systematic review was registered in PROSPERO (CRD42024602495). Results: Sixteen studies comprising 26,794 children and adolescents with T1D were included, of which nine had a cross-sectional design. Most (13/16) were considered to have a low risk of bias. Eleven studies compared school achievement of children and adolescents with T1D to that of a control group or of the country's general population, of which five reported similar achievement and five reported lower achievement of children with T1D compared with children without T1D. One study reported that academic performance was lower in primary but similar in secondary school. Ten studies addressed the association between school achievement and glycemic control assessed by glycated hemoglobin (HbA1c) or peripheral glucose levels, of which eight reported that higher HbA1c levels were associated with lower academic performance. Conclusion: This systematic review does not support that there are differences in school performance between children and adolescents with T1D and their peers without T1D. However, it underscores that inadequate glycemic control may adversely affect academic outcomes. Additionally, the review points to a notable lack of research focused on school performance in T1D, emphasizing the need for future studies to explore this critical area comprehensively. Addressing this gap will be crucial for understanding the full impact of T1D on educational attainment and developing effective interventions to support affected children and adolescents. Key words: type 1 diabetes, academic performance, school performance, glycemic control.	5
INTRODUCTION			
Rationale	3	Type 1 diabetes accounts for 5 to 10% of all cases of diabetes, and is characterized by an autoimmune destruction of pancreatic beta cells leading to complete insulin deficiency and hyperglycemia. Although the etiology of T1D is not yet fully understood, it is suggested that the combination of genetic predisposition	13

Section and Topic	Item #	Checklist item	Location where item is reported
		and environmental factors, such as viral infections, plays a central role, with possible contributions from toxins and dietary components. Despite the significant advancements in treatment and management, the disease constitutes a considerable challenge from the individual and public health perspectives. T1D potentially develops at any age, although the incidence peaks in puberty and early adulthood. There has been a consistent increase in the prevalence of the disease across various geographical regions over the last decades. T1D was estimated to affect 1.5 million individuals aged under 20 years in 2021, and its prevalence is projected to increase by 60 to 107% in 2040 across all age groups. In addition to its epidemiological impact, T1D may negatively affect the psychosocial and economic well-being of patients, and poses a substantial economic burden on healthcare systems. In addition to the traditional vascular complications of T1D, there is a growing concern regarding the cognitive impact of the disease. Findings from studies using structural and functional magnetic resonance imaging and neuropsychological tests support that T1D negatively affects cognitive function in children and adults. Notably, structural and functional imaging studies reveal that brain abnormalities occur even at early stages following diagnosis. 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. 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, and that the association between psychological distress and cognitive function observed in other clinical settings. Despite the evidence suggesting that T1D may negatively impact cognitive function in children and adolescents, studies on school performance in children with T1D have produced mixed results. To date, no systematic review has comprehensively examined this issue. Therefore, this review aims to compare school performance between children with T1D and their peers without the condition and to explore the relationship between glycemic control and academic achievement.	
Objectives	4	In this context, we conducted a systematic review to compare school performance between children with type 1 diabetes (T1D) and their peers without the condition, as well as to explore the relationship between glycemic control and academic achievement.	13
METHODS			
Eligibility criteria	5	The PECOS (Population, Exposure, Comparison, Outcomes, Study type) acronym was used to create the review question. To address whether school performance was different between children with T1D and children without T1D, P was ‘individuals aged under 18 years’, E was ‘type 1 diabetes’, C was ‘individuals without type 1 diabetes’, O was ‘academic performance assessed by school grades or other validated tools’, and S was ‘observational studies’. To address the association between school performance and glycemic control, P was ‘individuals aged under 18 years with T1D’, E was ‘poor glycemic control assessed by fasting glucose, glycated hemoglobin or continuous glucose monitoring’, C was ‘better glycemic control assessed by fasting glucose, glycated hemoglobin or continuous glucose monitoring’, O was ‘academic performance assessed by school grades or other validated tools’, and S was ‘observational studies’. We included studies investigating school performance in children with T1D, assessed by school grades or other validated tools, such as national exams or tests of achievement. Studies addressing the association between glycemic control and school performance were also included. We excluded studies involving only neuropsychological tests but not school grades or national exams to assess school performance, reviews, case reports, case series, personal opinions, book chapters, and conference abstracts.	14
Information sources	6	We searched PubMed, Scopus, Web of Science, and Google Scholar.	14
Search strategy	7	We used search terms related to the population (children and adolescents with Type 1 Diabetes), the exposure (glycemic control), and the outcome (academic performance), considering studies published in English, Portuguese, or Spanish. The search strategy is presented in Appendix A. We also conducted manual searches across reference lists of the included studies.	15
Selection process	8	A two-phase process was applied to select studies. In the first phase, two reviewers (L.O.A. and B.S.T.B) independently screened the articles based on their titles and abstracts to select eligible studies. In the second phase, the same reviewers independently applied the inclusion criteria to the full-text version of selected	15

Section and Topic	Item #	Checklist item	Location where item is reported
		studies. A third reviewer (A.A.A.) was consulted in case of disagreement between the first and second reviewers. Finally, one reviewer thoroughly examined the reference lists of all the included articles.	
Data collection process	9	For all included studies, the following information was collected using a standardized form: study characteristics (authors, year of publication, country, type of study), population characteristics (sample size, age, glycemic control), outcomes, and main findings. The outcome of interest was school performance assessed by school grades, score on national exams, or tests of academic achievement.	15
Data items	10a	Outcomes: (i) Academic performance in children with T1D compared to non-diabetic controls (ii) School attendance rates in children with T1D versus non-diabetic peers (iii) The relationship between glycemic control (HbA1c levels, frequency of hypo/hyperglycemia) and academic performance (iv) The impact of age at diagnosis and disease duration on academic outcomes (v) Influence of socioeconomic factors and access to diabetes management technologies on school performance	15
	10b	Age, sex, school type (public or private), assessment methods for academic performance (grades, national exams, validated cognitive tests)	15
Study risk of bias assessment	11	Risk of bias was assessed by using the Joanna Briggs Institute Critical Appraisal Checklist for Analytical Cross-Sectional Studies (Appendix B), Cohort Studies (Appendix C), and Case-Control Studies (Appendix D), by two independent reviewers (L.O.A. and B.S.T.B). Any disagreement was resolved by discussion with a third reviewer (A.A.A.). 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.'	15
Effect measures	12	Due to differences among studies concerning the tool used to assess school performance, we could not pool findings from individual studies in 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).	15
Synthesis methods	13a	Studies were included in the qualitative synthesis if they provided data on the academic performance of children with type 1 diabetes (T1D) and healthy controls, glycemic control levels (such as HbA1c or fasting glucose) in children with T1D, and the correlation between glycemic control and academic performance.	18-23
	13b	Data were tabulated in Microsoft word.	18-23
	13c	Data were tabulated in Microsoft word.	18-23
	13d	The method used to summarize the results in this systematic review was qualitative synthesis, including data extracted from the selected studies that addressed academic performance in children with type 1 diabetes (T1D) and healthy controls, as well as glycemic control levels, such as HbA1c or fasting blood glucose, in children with T1D. The correlation between glycemic control and academic performance was also analyzed. The choice of qualitative synthesis was driven by the heterogeneity of the data and the methodological diversity across the included studies. This approach was particularly useful due to the variability in the instruments used to measure academic performance and the different methods employed to assess glycemic control.	24-27
	13e	In this systematic review, qualitative methods were used to explore the possible causes of heterogeneity between the study results, given the methodological diversity and variability in the collected data. The primary approach used to investigate this heterogeneity was subgroup analysis. Subgroup analysis was conducted to examine how different study characteristics, such as the age range of children, time since diagnosis of type 1 diabetes (T1D), types of instruments used to assess academic performance, and methods for measuring glycemic control (such as HbA1c or fasting glucose), could influence the relationship between glycemic control and academic performance. This approach allowed for the identification of patterns and potential factors that could be contributing to the differences in results across studies.	24-27

Section and Topic	Item #	Checklist item	Location where item is reported
	13f	-	-
Reporting bias assessment	14	-	-
Certainty assessment	15	-	-
RESULTS			
Study selection	16a	A total of 4026 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, and 28 studies were excluded (Figure 1). The reasons for exclusion are detailed in Appendix E.	16
	16b	Appendix E. Twenty-eight studies were excluded: twenty-two due to wrong design (assessing memory, attention, and cognitive dysfunction), one due to the control group including individuals with other chronic diseases, two for being in languages other than English, Portuguese, or Spanish, and three for being reviews or commentaries.	16
Study characteristics	17	Characteristics of studies examining school performance in children with type 1 diabetes (T1D) Nine studies were included that investigated school performance in children with T1D, comparing them to healthy controls or using national databases. Four studies found that children with T1D (n = 7,620) had lower academic performance compared to those without T1D (n = 1,340,596). In contrast, four studies indicated no significant difference in school performance between children with T1D (n = 3,773) and controls (n = 634,011). One study reported that children with T1D performed worse in primary education but similarly to controls in secondary education. The studies used various methodologies, including assessment tools such as the Wide Range Achievement Test and the Iowa Tests of Basic Skills. The results varied, with some studies showing poorer performance in specific areas such as reading, mathematics, and overall academic tasks, while others found similar or even better performance in children with T1D compared to their peers. Factors such as age, socioeconomic background, and education level were often adjusted for in these analyses to ensure accurate comparisons. Overall, the studies highlighted the impact of T1D on school performance, with some suggesting that children with T1D might face academic challenges, particularly in primary education, while others showed minimal or no differences in performance across various educational stages. Further research with larger sample sizes and more diverse settings may provide more definitive conclusions on the long-term academic outcomes for children with T1D. Characteristics of studies examining the association between glycemic control and school performance in children with type 1 diabetes Eight studies investigated the relationship between glycemic control and academic performance in children with T1D, assessing HbA1c and peripheral glucose levels. Six studies reported that poorer glycemic control was associated with lower academic performance, including lower school grades and results from other academic achievement tools. For example, McCarthy et al. (2002) found that higher HbA1c levels in children with T1D were associated with lower scores in reading, mathematics, and grade point averages. However, they also noted that some children with tight metabolic control and hypoglycemia hospitalizations exhibited low scores. Potts et al. (2015) reported that poorer glycemic control, measured by peripheral glucose levels, was linked to lower school grades, but this association disappeared after adjusting for neuropsychological assessments. Cooper et al. (2016) found that higher HbA1c levels were negatively associated with lower scores on a national exam, while Lansing et al. (2016) confirmed that higher HbA1c levels correlated with lower school grades even after adjusting for various socio-demographic and psychological factors.	17

Section and Topic	Item #	Checklist item	Location where item is reported
		In contrast, Román et al. (2017) found no association between HbA1c levels and school grades in their study of 66 children with T1D. Overall, the findings suggest that poor glycemic control, particularly high HbA1c levels, tends to be associated with worse academic outcomes, although some studies show inconsistent results. Study characteristics are presented in Table 1.	
Risk of bias in studies	18	All eight cross-sectional studies were considered to have a low risk of bias, while one was considered to have a moderate risk of bias (Appendix B). In the cohort studies, four were considered to have a low risk of bias, and one had a high risk of bias (Appendix C). In the case-control studies, two were considered to have a low risk of bias (Appendix D).	27
Results of individual studies	19	Table 1	18
Results of syntheses	20a	Cross-Sectional Studies (Appendix B): Of the nine cross-sectional studies, all were considered to have a low risk of bias, except for one study which was considered to have a moderate risk of bias. These studies assessed the association between academic performance and factors such as type 1 diabetes, sociodemographic characteristics, and other environmental factors. Cohort Studies (Appendix C): Four cohort studies were considered to have a low risk of bias, while one was considered to have a high risk of bias. These studies followed participants over time to investigate the relationship between glycemic control and academic performance in children with type 1 diabetes, including variables such as age, time since diagnosis, and socioeconomic status. Case-Control Studies (Appendix D): The two case-control studies were considered to have a low risk of bias. These studies compared children with type 1 diabetes and healthy controls to investigate the association between glycemic control and academic performance, considering variables such as sociodemographic characteristics and methods of assessing glycemic control.	37-39
	20b	-	-
	20c	-	-
	20d	-	-
Reporting biases	21	-	-
Certainty of evidence	22	-	-
DISCUSSION			
Discussion	23a	The findings of this systematic review indicate that there is no consistent evidence that children and adolescents with Type 1 Diabetes (T1D) perform differently in school compared to their peers without T1D. However, most studies examining the relationship between glycemic control and academic performance suggest that poorer glycemic control is associated with lower academic achievement. This finding aligns with existing evidence on the negative impact of poor glycemic control on cognitive function. Previous meta-analyses have demonstrated reduced cognitive abilities in individuals with T1D, which supports the biological plausibility of the observed association between poor glycemic control and diminished academic performance. The lack of consistent	27-31

Section and Topic	Item #	Checklist item	Location where item is reported
		findings in studies examining school performance may be attributed to methodological differences and the diverse factors influencing academic achievement beyond glycemic control.	
	23b	The review highlights several limitations in the studies included. The most significant limitation is the methodological heterogeneity, particularly in how academic performance was assessed, preventing the pooling of data for a meta-analysis. Additionally, there was a lack of standardized measures for school performance, and most studies only assessed glycemic control through HbA1c or peripheral glucose levels, without considering other potential confounding factors such as psychological distress or fluctuations in blood glucose at the time of academic assessment. Furthermore, most studies included in the review were conducted in high-income countries, limiting the generalizability of the findings to populations in low- and middle-income countries with different access to healthcare and diabetes management.	27-31
	23c	Several limitations were noted in the processes of this review. Given the heterogeneity of the included studies, the inability to conduct a meta-analysis and perform subgroup analyses left a gap in understanding the specific factors that might explain the variations in study findings. For example, it was not possible to fully assess the role of age, time since diagnosis, socioeconomic status, or other variables that could influence school performance. Additionally, the variation in the methods used to assess school performance across studies suggests that future reviews should prioritize a more standardized approach for measuring academic achievement in order to facilitate meaningful comparisons.	27-31
	23d	The results of this review suggest that while glycemic control is an important factor in academic achievement for children and adolescents with T1D, more research is needed to understand the full impact of T1D on school performance. From a practical standpoint, healthcare providers should emphasize the importance of glycemic control not only for the physical health of children with T1D but also for their academic success. Additionally, policies aimed at improving the quality of life for children with T1D should consider the impact of metabolic control on academic outcomes. Future research should address the limitations of the current body of evidence by including larger, population-based samples, assessing school performance through standardized measures, and accounting for additional factors such as psychosocial distress, family support, and access to healthcare. Furthermore, studies should explore how blood glucose fluctuations at the time of academic assessments affect performance, and investigate whether improvements in diabetes management over the years have led to better academic outcomes.	27-31
OTHER INFORMATION			
Registration and protocol	24a	The review was registered in PROSPERO (CRD42024602495).	14
	24b	PROSPERO (CRD42024602495).	14
	24c	-	-
Support	25	None	-
Competing interests	26	None	-
Availability of data, code and other materials	27	All data are presented in the manuscript.	-