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SYSTEMATIC REVIEW

Revealing the Information Delivery of Diabetes Prevention in K-12: A Systematic Literature Review

Revelando la Transmisión de Información sobre la Prevención de la Diabetes en la Educación K-12: Una Revisión Sistemática de la Literatura

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ABSTRACT

Introduction: diabetes mellitus in children and adolescents correlates with reduced quality of life and heightened mortality rates. Incorporating diabetes education into early learning is essential as a proactive prevention strategy.
Objective: this study seeks to examine and optimize the teaching of diabetes mellitus within K–12 education, aiming to bolster preventive measures among students.
Method: this research examines diabetes education within K–12 environments through a Systematic Literature Review (SLR), utilizing the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology. A total of 1192 articles were obtained from the Scopus database, with 17 studies fulfilling the inclusion criteria and selected for detailed analysis.
Results: the review identified various diabetes-related curricula and instructional strategies utilized in preschool, elementary, middle, and high school classrooms. The main learning objectives involved enhancing student awareness of diabetes and comprehending its risk factors. Preschool programs frequently involved parents to foster the development of healthy behaviors. Strategies employed in elementary and secondary schools encompassed class discussions, investigative learning, simulations, modelling, and community action projects. These methods enhanced students' comprehension of diabetes, facilitated sustained behavior modification, and fostered the acquisition of self-regulation skills.
Conclusions: the main objective of diabetes education in schools is to equip students with the understanding that diabetes can be largely prevented through healthy lifestyle choices. Effective lessons enable students to reflect on their behaviors and make informed decisions that promote long-term health and prevent diabetes.

Keywords: Diabetes; K12 Education; Learning; Prevention; PRISMA Method.

RESUMEN

Introducción: la diabetes mellitus en niños y adolescents se asosia con una disminucion en la calidaded de vida y un aumento en las tasas de mortalidad. La incorporación de la educación sobre la diabetes en las etapas termpranas de la ense ñanza es esencial como una estrategia de prevención proactiva
Objectivo: este studio tiene como objectivo investigar y foostalecer la ensenanza sobre la diabetes mellitus en la educación básica y media (K-12), con el fin de reforzar las medidas preventivas entre los estudiantes.
Método: este estudio examina la educación sobre diabetes en entornos escolares desde preescolar hasta el nivel secundario a través de una revisión sistemática de la literatura (SLR), utilizando la metodología PRISMA (elementos de informe preferidos para revisiones sistemáticas y metaanálisis). Se obtuvieron un total de

1192 artículos de la base de datos Scopus, 17 de los cuales cumplieron con los criterios de inclusión y fueron seleccionados para un análisis detallado.
Resultados: el estudio identificó una variedad de planes de estudio y estrategias pedagógicas relacionadas con la diabetes implementados en las aulas de preescolar, primaria, secundaria y preparatoria. Los principales objetivos de aprendizaje se centran en aumentar la conciencia de los estudiantes sobre la diabetes y su comprensión de sus factores de riesgo. Los programas dirigidos a niños en edad preescolar a menudo involucran a los padres para fomentar el desarrollo de hábitos saludables. Las estrategias utilizadas en la educación primaria y secundaria incluyen debates en clase, aprendizaje basado en la investigación, simulaciones, modelos y proyectos de acción comunitaria. Estos métodos mejoran la comprensión de los estudiantes sobre el tema, fomentan un cambio de comportamiento sostenible y facilitan la adquisición de habilidades de autorregulación.
Conclusiones: el objetivo principal de la educación sobre la diabetes en las escuelas es proporcionar a los estudiantes los conocimientos necesarios para comprender que la enfermedad se puede prevenir en gran medida mediante opciones de estilo de vida saludables. Las lecciones eficaces permiten a los estudiantes reflexionar sobre su comportamiento y tomar decisiones informadas que mejoran la salud a largo plazo y previenen la aparición de diabetes.

Palabras clave: Diabetes; K-12 Educación; Aprendizaje; Prevención; Método PRISMA.

INTRODUCTION

Diabetes mellitus is one of the foremost causes of global mortality. The World Health Organization (WHO) promulgated a resolution endorsing the Health for All approach, aimed specifically at eliminating diabetes-related complications[1] The projected number and percentage of adults diagnosed with diabetes are anticipated to increase to 39,7 million (13,9 %) by 2030 and 60,6 million (17,9 %) by 2060.[2] An estimated 1 211 900 children and adolescents under the age of 20 are diagnosed with type 1 diabetes mellitus.[3] Diabetes is the third most common chronic illness in this demographic, impacting around 2,22 per 1000 children and adolescents.[4] Type 1 diabetes arises from an autoimmune disorder when the immune system obliterates insulin-secreting beta cells in the pancreas.[5] In contrast, type 2 diabetes is frequently linked to inadequate nutrition, detrimental eating practices, and excessive carbohydrate intake.[6] Advancing health education and increasing awareness among children may diminish the future global incidence of diabetes.

Children and adolescents predominantly occupy their time in educational institutions, rendering schools a potent environment for diabetes education. Delivering diabetes education in formal educational environments is crucial for equipping students to maintain healthy lifestyles and mitigate their future risk of getting diabetes. Although numerous students may possess a rudimentary comprehension of diabetes, they frequently lack essential knowledge regarding its indicators, symptoms, prevention, and management. Students need to understand that children with type 1 diabetes ideally check their blood glucose at least four times a day.[7] While, type 2 diabetes remains preventable through the management of modifiable risk factors like obesity.[8] An informational framework that enhances understanding of diabetes and its implication is essential for effective diabetes education. Therefore, a literature review exploring how diabetes is taught is necessary. Integrating diabetes education in schools as a preventive measure can enhance health programs and inform policy decisions. This method corresponds with the Health Promoting School (HPS) framework established by the World Health Organization (WHO), which endorses the advancement of healthy behaviours inside educational institutions.[9] HPS acknowledges that educational institutions significantly impact student health, transcending official health curricula to include comprehensive school-wide initiatives and services.[10]

Despite the abundance of systematic literature reviews (SLRs) on diabetes mellitus, a notable deficiency exists in research focusing on diabetes education as a preventive measure. Current systematic literature reviews have examined subjects including overall health in school-aged populations,[11,12] school-based diabetic interventions,[13] digital health tools for adolescents with type 1 diabetes,[14] and gamification in diabetes education.[15] A scoping review of diabetes management in educational institutions has been published.[16] This study identifies a significant need by investigating methods to support teachers in providing diabetes education in the classroom, with an emphasis on prevention. This systematic literature review examines successful ways for educating children and adolescents about diabetes mellitus in K–12 settings. The results enhance formal education and academic research by providing practical insights to assist educators and inform further investigations. Educators are essential in delivering health-related knowledge and promoting healthy lives, thereby enabling students to make informed choices regarding health concerns.[17]

General Objective

This SLR aims to examine how diabetes mellitus is taught in K-12 schools. Tis SLR is guided by two research questions (RQ), namely.

RQ 1. What are the publication trends concerning diabetes learning implemented in school environments?
RQ 2. What teaching and learning strategies are used to deliver diabetes learning in the classroom?

METHOD

The present investigation utilized a Systematic Literature Review (SLR) methodology, executed in alignment with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The SLR approach facilitates the systematic acquisition of topic-specific knowledge, helps identify gaps in understanding, and enables the formulation of evidence-based conclusions within a defined field—making it particularly valuable for those engaged in inquiry and decision-making. The review process encompassed the formulation of a meticulous search strategy, the creation of inclusion and exclusion criteria, along with well-defined protocols for data extraction and analysis.[18] The PRISMA framework provides a systematic approach for identifying, selecting, evaluating, and synthesizing contemporary evidence from various scientific sources. Details of the SLR process are presented below.

Data Sources and Search Strategies

This study utilized Scopus as the principal database for the online search, chosen for its comprehensive coverage of high-quality peer-reviewed literature. The investigation concentrated on articles over the last 11 years (2014–2024) to guarantee a thorough examination. The search utilized keywords such as “diabetes education,” “diabetes,” “diabetes care,” “diabetes management,” “diabetes media,” in addition to “school” and “learning.” Boolean operators were utilized to enhance the search and guarantee the incorporation of pertinent literature. Furthermore, references from prior reviews and pertinent studies were examined to locate supplementary papers that corresponded with the research objectives. The inclusion criteria focused on research related to the instruction and acquisition of diabetes mellitus information in classroom settings, encompassing both diabetic and non-diabetic students. This encompassed research on interventions aimed at students and the creation or utilization of educational media pertaining to diabetes education. The target population consisted of pupils aged under 20, aligning with the classification of children and adolescents within the K–12 educational framework. Only studies that exhibited a distinct and impartial emphasis on students were included when involving educators.

Study inclusion and exclusion criteria

The research questions define the primary criteria for including or excluding articles in this review. Table 1 outlines the specific inclusion and exclusion criteria.

Table 1. Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
English language article available in full text	Non english article and or unavailable in full text
Published between january 2014 to december 2024	Published outside january 2014 to december 2024
Primary research articles (interventional research including randomized trial, non-randomized trial, field study, group study, single study)	Non primary research article (Books, reviews, short articles, and journal editorial statements, magazine)
The subject of the article is a K-12 student, or mixed population that was not difficult to analyse the impact of the study	Non students subject articles were excluded

A total of 1192 articles were initially identified using the Scopus database search. These articles were published between 2014 to 2024, composed in English, and accessible as open access. Following the preliminary abstract screening, 1169 publications were chosen, comprising exclusively original or experimental research. At this juncture, 23 review articles were omitted. During the second screening, papers were evaluated for their relevance to diabetes-related research, leading to the inclusion of 559 articles and the deletion of 610 articles that did not pertain to diabetes. A targeted screening on diabetes education resulted in the inclusion of 70 publications, whereas 484 items were eliminated due to insufficient educational substance. Subsequent screening removed 55 papers that did not concentrate on students as the key demographic, and an additional three articles were omitted for only partially addressing diabetes in broader contexts. Seventeen papers were ultimately considered appropriate for inclusion in this review after applying all inclusion, exclusion, and quality assessment criteria. Figure 1 delineates the article selection process comprehensively, in accordance with the PRISMA paradigm.

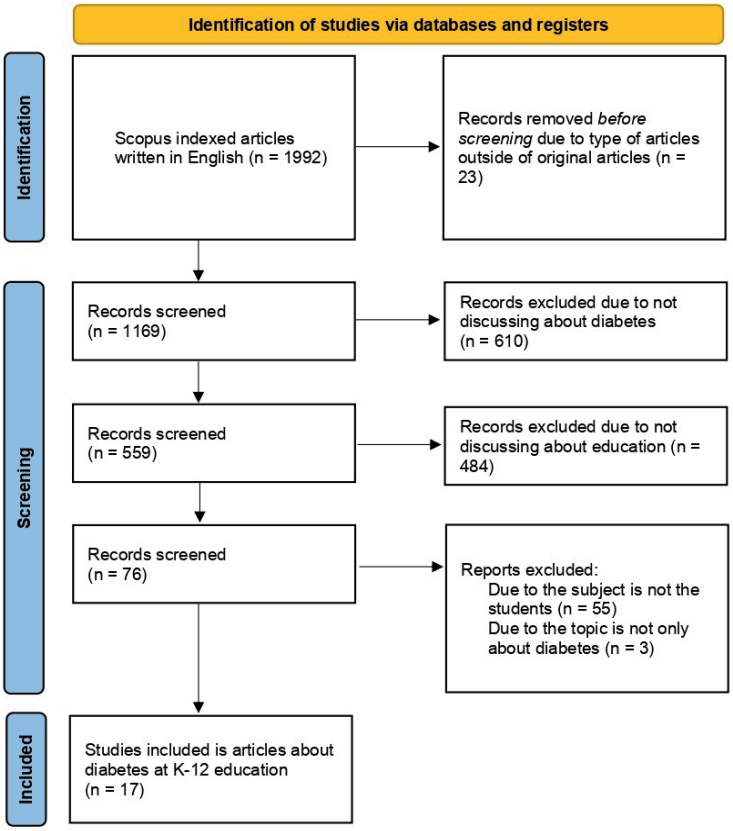

Figure 1. Article Selection Process based on PRISMA

RESULTS

Research Trend

In this SLR, 17 articles were analyzed, showing the trend of diabetes education research in schools. Research on diabetes education has been identified in several countries, notably in USA,[19,20,21,22,23,24] France,[25] Greece,[26] Rusia,[27] Spain,[28] dan Sweden.[29] The research was also conducted in developing counties, namely Malaysia,[30] Iran,[31,32] dan Brazil.[33,34,35] The results of the publication year in diabetes learning have an up and down trend, with the highest number of publications in 2023. In the 2014 there is one article[21], 2015 there is one article[25], in 2016 there is no article about diabetes at school, in 2017 there are three articles[27,28,29], in 2018 there is one article[35], in 2019 there is one article[34], in 2020 there is one article[22], in 2021 there are two articles[23], in 2022 there is one article[32], in 2023 there are five articles,[19,20,26,30,31,33] and in 2024 there is one article.[24] As showed in figure 2, the publication number illustrates the inconsistency, however the trend tends to increases.

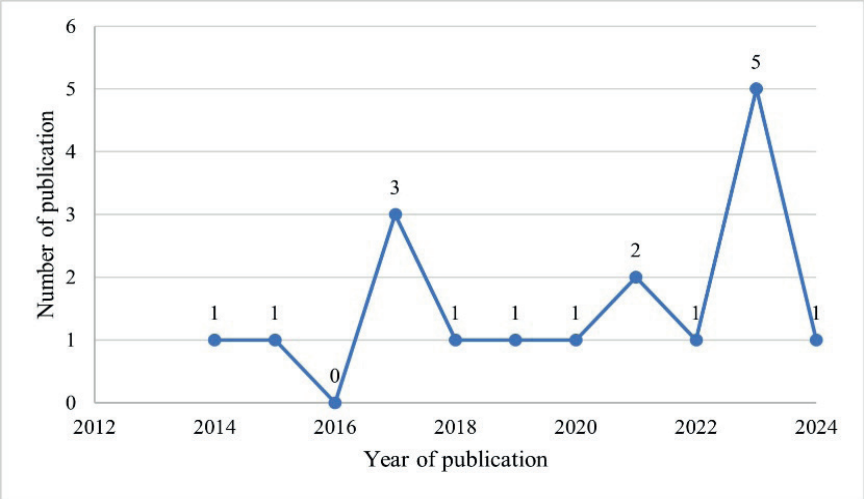

Figure 2. Publication trends

Table 2. Overview of diabetes education in schools

Author	Level of Education; student's status; diabetes learning	Research Design; Duration; Participants number/ aged (years old)	Teaching and learning platform/program/strategy	Assessment/evaluation	Learning Outcome; Additional finding
[29]	Pre-school/Non diabetic; T2D	Mixed method, 6 month with a follow up 18 months post baseline; 352/6	The A Healthy School Start Plus initiative seeks to avert childhood overweight and obesity through family assistance. The program employs health information, motivational interviewing (MI) as a client-centered methodology, classroom exercises, and a web-based T2D evaluation, all based on the concepts of social cognitive theory. The objective of the program was to evaluate the efficacy of this intervention relative to standard care, included into school-based education during the flexible initial year of deployment.	The poll evaluated parental behavioral competence, motivation, and self-efficacy, in addition to the child's motivation.	The principal outcomes encompass vegetable and fruit consumption alongside the intake of harmful foods. Secondary outcomes concentrate on physical activity and sedentary behavior, evaluated via accelerometer data.
[33]	Elementary School/ Non diabetic; T1D	Experimental design; 40 minutes intervention and 2 months intervention; 73/7-12	The intervention employed theatrical performances and games to assess the efficacy of an instructional program encompassing scenarios pertaining to glucometer utilization, insulin administration, dietary practices, physical exercise, hyperglycemia, and the indicators and manifestations of hypoglycemic crises. The educational content was derived from the Children and Diabetes in Schools (KiDS) curriculum, a program aimed at enhancing diabetes teaching in academic settings. The KiDS curriculum is a joint endeavor of the International Diabetes Federation (IDF) and the International Society for Pediatric and Adolescent Diabetes (ISPAD), funded by an educational grant from Sanofi.	Interviews, tests	Enhancements in diabetes knowledge were noted. Furthermore, occurrences of bullying associated with type 1 diabetes were observed in academic environments.
[26]	Elementary school; Non diabetic; T2D	Experimental design; 20 minutes interaction with media; 30/9-12	Interventions with social robots employ motivating strategic communication to effectively engage youngsters. These robots gather self-reported data via interactions with tangible objects and evaluate behavioral data to facilitate instruction on nutrition, physical exercise, and obesity prevention. Social robots, equipped with communication, guidance, and reinforcement capabilities, can effectively encourage children to embrace healthier behaviors.	An experimental assessment using an emoji-based questionnaire to evaluate health behaviors.	The platform was effective, with girls showing more performance in task completion than boys.
[35]	Elementary school; Diabetes; T1D	Quasi experimental design; a day practice, data collected before practice and 4-6 weeks after intervention; 33/6-11	A session on self-monitoring of blood glucose was held, with participants from two Diabetes Outpatient Clinics within the Endocrinology Service of a Brazilian university hospital.	Test	The session resulted in a heightened frequency of self-monitoring of blood glucose, accompanied by enhanced procedures such as lancet replacement, rotation of puncture sites, and regular calibration and monitoring of the glucose meter's date and time.

[27]	Elementary, middle school; Diabetes; T1D, T2D	R&D; No intervention; 20/10-14	A Russian comprehensive school dedicated to fostering a health-oriented atmosphere for pupils with diabetes mellitus has developed a content-functional model designed to assist children with diabetes.	Survey	This methodology employs a structural and functional framework, guided by social cognitive theory, to improve the health and well-being of students with diabetes.
[28]	Elementary, Middle school; Non diabetic; T2D	R&D; No intervention; 70/5-14	The creation of an Augmented Reality (AR) game aimed at educating students on the carbohydrate content of different foods may function as an effective instrument in therapeutic education for diabetes control..	Survey, poster, interview	Effective and valuable tool
[20]	Middle school; Non diabetic; T2D	Mixed method; 2 years; 1271/6-8	The genomics-oriented curriculum Health in Our Hand (HiOH) promoted learning via classroom discussions, in-class investigations, simulations, modelling exercises, and a community action research project centered on genetics and environmental factors. The HiOH curriculum integrated the Next Generation Science Standards with community action research initiatives to tackle two significant and intricate issues: type 2 diabetes and substance use disorder (SUD). This program was executed in the disadvantaged cities of Flint and Detroit, Michigan, USA.	Survey	Increase student perceived learning
[21]	Middle School; Non diabetic; T2D	Quantitative and Qualitative design; 1 semester; 4603	The FLASH (Fun Learning Activities for Students' Health) program is a comprehensive intervention aimed at fostering a healthy energy balance through enhancements in nutrition, physical exercise, and behavioral habits. The intervention was executed as a component of a communications campaign grounded in social marketing principles. The program comprised five modules per semester. Research assistants (RAs) performed unannounced, structured observations in a minimum of one randomly selected class per instructor each semester to assess the program's execution.	Interview, observation	FLASH was executed with precision, and peer interaction significantly contributed to the active engagement of students. Student misconduct was recognized as the principal obstacle to effective health promotion within the program.
[31]	Middle school; Non diabetic; T2D	Experimental design; 8x90 minutes sessions, post-test was two months after the treatment; 168/14	This educational intervention engaged a cohort of peers who received health information and instruction, while also cultivating the skills necessary to disseminate these concepts among their peers. The program sought to enhance understanding, health beliefs, and behaviors associated with type 2 diabetes among female adolescents.	Test	Peer education markedly enhanced diabetes knowledge. Subsequent to the intervention, there was a significant enhancement in health views. Moreover, socioeconomic characteristics were identified as influencing both knowledge and health perceptions.
[22]	Middle, High School; Non diabetic; T1D, T2D	Quantitative design; One hour; 30	The Physiology of Diabetes program seeks to augment students' comprehension of diabetes and its health consequences. The session featured presentations conducted by physicians and offered hands-on interactions with diabetes-related instruments.	Test	The strategy successfully heightened awareness of diabetes. Exposure to diabetes physiology was advantageous, shaping students' future career aspirations in health-related disciplines.

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[19]	High school; Non diabetic; T2D	R&D; No intervention; None	The online game Blood Sugar Balance (BSB) integrates gameplay components that represent environmental and biological influences, along with individual decisions, to emulate glucose metabolism. A lesson plan has been created to facilitate the utilization of the game in educational contexts, although it has not yet been executed.	Survey	Increasing participants' understanding
[23]	High school/ Non diabetic/ T2D	Quasi experimental design; Spring 2019 (baseline) to Spring 2020 (follow up); 300-500	The Bigger Picture (TBP) is a health literacy campaign employing a social justice framework and critical pedagogy to improve youth comprehension of the social and environmental determinants affecting the risk of type 2 diabetes (T2D). The initiative collaborates with the University of California, San Francisco's Centre for Vulnerable Populations and Youth Speaks (YS) to utilize spoken word art, aiding young folks in comprehending and contemplating the socioeconomic determinants of type 2 diabetes (T2D). TBP has been adopted in high schools throughout the San Francisco Bay Area. Students in intervention schools engaged in traditional SLAM (Student Led Arts Movement) Club activities alongside TBP programming. Students examined the contributions of genetics, sugar consumption, diet, income, and neighborhood access to the development of Type 2 Diabetes (T2D).	Interview, Poem	Improved understanding, motivation; Students linked race/ ethnicity to T2D as a social
[24]	High school/ Non diabetic/ T2D	Quantitative design; 1-5-day workshop; 3010	The educational methodology emulates real-world complexity via a type 2 diabetes curriculum that incorporates principles from genetics, biology, and health.	Test, survey	The intervention group's knowledge and self-efficacy were comparable to those of the comparison group.
[25]	High school/Non diabetic/ T1D	Quantitative design; 3 days; 420/15-17	A workshop centred on inquiry-based learning was created to improve students' comprehension of glycemia regulation and diabetes via open-ended enquiries and organized experiments. The workshop was established by the French Medical Research Council (Institut National de la Santé et de la Recherche Médicale, INSERM) at the scientific campus of Aix-Marseille University in France.	Survey	Improved understanding of scientific reasoning
[30]	High school/ Non diabetic/ T2D	Educational Design Research (EDR); No intervention; 4/15	The educational media, The Better Bites Narrative Game, examined the feasibility of employing a narrative game to encourage healthy lifestyle choices among adolescents. The game promotes self-regulation via a visual novel format, informed by the Integrative Model of Behavioral Prediction.	Interview	Improve healthy decision-making by targeting attitudes, perceived norms, and self-efficacy.
[32]	High school/ Non diabetic/ T2D	Experimental design; 5x60-minute training session; 143	The instructional program, grounded in the Health Belief Model (HBM), instructs pupils on the classifications, risk factors, complications, and symptoms related to diabetes. These strategies seek to inform students and promote suitable health practices around type 2 diabetes.	Survey	A beneficial effect on consciousness and the Health Belief Model (HBM).
[34]	High school/ Non diabetic/ T2D	R&D; No intervention; 64	An educational interactive booklet has been developed, containing instructional text on diabetes and obesity, complemented by an interactive game designed to engage students in the learning process.	Test	Increased knowledge, awareness

Note: T1D (type 1 diabetes), T2D (type 2 diabetes)

Research on diabetes education was found one study at the preschool level, five studies at the elementary level, six studies at the middle school level, and eight studies at the high school level. Moreover, various studies were conducted across different educational levels. Research on teaching delivery of diabetic mellitus in K12 present in table 2.

Preschool

The diabetes education program outlined in Study [29], named A Healthy School Start Plus, was executed at the preschool level. This initiative required collaboration among teachers, schools, and parents, emphasizing active parental involvement to aid children in cultivating healthy lifestyle habits at home. The intervention aimed to promote healthy eating habits and physical activity, seeking to educate and motivate parents to reinforce children's behaviors beyond the classroom.

Elementary School

Diabetes education at the elementary school level was implemented using diverse game-based methods to improve students' comprehension of diabetes mellitus.[26,33,35] A significant approach utilized theatre plays and games[33] to illustrate real-life scenarios, utilised the Children and Diabetes in Schools (KiDS) curriculum, created by the International Diabetes Federation (IDF). A separate study demonstrated that diabetes education was enhanced using a robot-assisted, game-based learning method incorporating child-friendly communication strategies.[26] Emoji-based questionnaires were employed to engage students and sustain their interest. Additionally, educational workshops that included games offered students practical experiences in self-monitoring blood glucose levels, enabling individuals with diabetes to manage their condition more effectively and independently.[35] In addition, Study [27] presented a structural and functional model designed to establish a health-oriented educational environment. Study [28] employed Augmented Reality (AR) as a novel educational tool to provide interactive visualizations of diabetes-related material. Meanwhile, study [33] highlighted the significance of incorporating social dimensions into diabetes education, specifically by promoting empathy and awareness for students affected by diabetes. The research indicated that certain students with diabetes experience bullying, which can adversely affect their mental health.

Middle school

Diabetes education at the middle school level was delivered using more sophisticated instructional strategies. Study [20] presented a genomics-focused curriculum titled Health in Our Hand (HiOH), which examined diabetes through a research initiative. This curriculum underscored that diabetes is affected by both genetic and environmental causes. Furthermore, Study [21] employed an experiential learning methodology via a software named FLASH (Fun Learning Activities for Students' Health) prioritised interactive learning and promoted peer involvement. The notion of peer education was included into study [31] wherein a chosen cohort of students got health advice and instruction, which they were subsequently urged to disseminate among their peers. The Diabetes Physiology program involved medical professionals, including physicians, to conduct presentations and offer practical experiences for students was implemented at both middle and high school levels.[22]

High school

Diabetes education at the high school level is frequently implemented through interdisciplinary interventions involving various stakeholders. The Bigger Picture (TBP) curriculum is an element of a health literacy campaign aimed at youth.[23] This program prominently utilized interviews and poetry as assessment methods, enabling students to reflect on their learning and yielding data regarding their comprehension of diabetes. Study [25] details the development of an inquiry-based learning workshop that involve students in active inquiry and a more profound exploration of diabetes-related subjects. A separate intervention, detailed in Study [32] aimed to educate students regarding the types, risk factors, complications, and symptoms of diabetes through the Health Belief Model (HBM) framework, which highlights individual perceptions of health risks and benefits in facilitating behavior change. Study [24] presented a real-world complexity model that incorporates a type 2 diabetes mellitus curriculum, aimed at educating students on relevant concepts in genetics, biology, and health.

Diabetes education at the high school level encompasses the creation of learning media. Study [19] developed a web-based game titled Blood Sugar Balance, which instructs students on the interplay between environmental and biological factors in modelling glucose metabolism. Study [30] developed Better Bites Narrative Game aimed at encouraging healthy lifestyle choices in adolescents. Meanwhile, study [34] created an interactive educational booklet that integrates instructional content on diabetes and obesity with engaging games. In high school education, the diabetes curriculum for non-diabetic students predominantly emphasises type 2 diabetes (T2D), whereas the material concerning type 1 diabetes (T1D) is specifically directed towards students diagnosed with the condition.

DISCUSSION

The publication trends concerning diabetes learning implemented in school

The variability in publication numbers over the last ten years indicates that diabetes learning has not yet established itself as a consistent priority. Diabetes learning has been implemented across multiple countries, with a higher prevalence observed in developed nations, suggesting an increased emphasis on diabetes education in these settings. Meanwhile, research indicates that a significant proportion of individuals with diabetes reside in low- and middle-income countries (LMICs), representing nearly 80 % of the worldwide diabetic population.[36] Diabetes in these countries poses intricate challenges, influenced by genetic predispositions, adverse environments, and socioeconomic factors.[37] The authors emphasize the urgent need to strengthen school-based diabetes education by focusing on early detection, improved care, and cost-effective strategies. This perspective aligns with the facts that school often face challenges such as limited funding and resources, which can hinder the support provided to the students.[38] Besides, children spend a significant amount of time at school.

Preschool

Effective diabetes learning in preschool necessitates active collaboration between educational institutions and parents to promote healthy habits among children. This study highlights the significant role of parental involvement, especially in modelling a healthy lifestyle for children. Parental involvement in preschool education is observed to be greater than in other educational stages.[39] High health-related self-efficacy in parents is associated with a greater likelihood of children adopting and practicing healthy behaviors. The research indicates that parents possessing higher educational qualifications and income tend to exhibit greater involvement in preschool education compared to their counterparts from lower socioeconomic backgrounds.[40] The findings underscore the significance of socioeconomic factors, which are closely associated with child development and educational outcomes.[41] Current discussion often emphasizes the role of adults as a priority in preschool level. But it is important to follow up on the students' own knowledge. A study suggest drawing as a useful method for students to express their understanding of diabetes.[42] Exploratory findings involving children aged 4 to 13 suggest that drawing can uncover emotional and psychosocial challenges, offering meaningful insights for healthcare professionals.[43]

Elementary School

Diabetes education and learning activities in elementary school classrooms frequently include aspects of play. Educational games utilising AR have demonstrated an ability to improve the visualisation of diabetes-related content, offering an interactive approach for students to engage with the subject matter.[44] The reward system is a fundamental aspect of game design. This system encompasses intangible rewards (e.g., glory), collectible items (e.g., sustenance), rewards that unlock new features or pathways (e.g., access), and rewards that enhance players' abilities within the game (e.g., facility).[45] Reward systems have demonstrated effectiveness in motivating student participation in educational settings and activities.[46] Educators planning to implement games must prioritise motivation and enjoyment to sustain student engagement.[47] However, it is important to note that the motivational impact of gamification depend on individual factors and is highly context-dependent. Educators intending to implement games are encouraged to emphasize the importance of motivation and enjoyment in order to sustain student engagement.[47]

Educational workshops aimed at self-care practices for students with diabetes could be effective models for diabetes education in elementary schools.[35] Self-monitoring of blood glucose enhances students' proficiency in utilising glucose meters. Students who engaged in insulin injection techniques via game-based strategies demonstrated higher scores compared to those who underwent standard education.[48] These activities enable students to independently manage their diabetes.

In elementary school wider adoption of specialized curricula, such as the KiDS program, is essential particularly in countries and schools that currently lack policies on diabetes education. This curriculum addresses diabetes-related stigma by fostering safe and supportive school environments for children with diabetes and promoting healthy habits to mitigate the risk of type 2 diabetes. The KiDS program seeks to facilitate the formulation and execution of national policies concerning diabetes education and the promotion of healthy lifestyles. Delivery occurs via sessions and training in partnership with school communities.[49] Curricula such as KiDS are crucial for students with diabetes and for enhancing preventive initiatives against the disease more broadly.

Regarding assessment tools in elementary school, emoji-based surveys are increasingly utilised to evaluate learning outcomes at the elementary school level. These surveys generally utilise a rating scale that spans from happy to sad emojis. The incorporation of emojis aids in acclimating children to digital communication tools, thus enhancing the reliability and validity of assessments.[50] Emojis function as an alternative method for capturing children's emotional profiles and improving the accuracy of predicting their preferences.[51]

It is important to concern about the external factors affecting diabetes education in schools such as bullying

among students with diabetes. A study examining adolescents with type 1 diabetes revealed that a significant number of students choose not to disclose their condition to others to prevent negative perceptions.[52] Learning during adolescence should be directed toward normalizing the diabetes mellitus as disease that can lead to other complications, but it is not a contagious disease. Educational institutions should actively engage in protecting students' health by providing flexible learning options, recognizing and addressing student issues, and promoting mindsets that enable students to navigate challenges within the school environment.[53]

Middle School

The primary focus of diabetes learning in middle schools is peer education. Participating in peer discussions enables students to recognise and rectify misconceptions, leading them to more precise conclusions. This method yields a greater incidence of accurate responses following peer discussions relative to earlier efforts.[54] Peer education is more effective than teacher-led instruction; however, training provided by healthcare professionals, especially doctors, demonstrates an even greater impact. This is due to the increased trust adolescents have in doctors when discussing their more profound health-related enquiries.[55]

At the middle school level, students enter adolescence, a developmental stage characterized by increased independence in decision-making. A significant obstacle to cultivating healthy habits at this age is student misbehavior. At this period, students undergo a social shift characterized by decreased reliance on their parents and develop stronger peer connections. This transition shift coincides with the adoption of new behaviors across various areas, including health. Frequent communication between teachers and students is essential to promote reflection on the causes and consequences of students' choices. Furthermore, mass media, advertisements, and social media significantly impact adolescent health behaviors.[56] Regulating these influences is crucial for optimising the effectiveness of diabetes education in middle schools.

High School

Diabetes learning at high school level emphasizes students' independent learning. Through learning such as inquiry-based workshop that incorporates open ended investigations and guided experiments, students are actively engaged in exploring practices related to diabetes mellitus. Inquiry based learning encompasses varying degree of teacher guidance and students' autonomy, In guided inquiry, teachers pose essential questions to initiate exploration, while student manage the investigation, analysis, and interpretation. In open inquiry places full responsibility on students, allowing them to formulate their own research questions and lead the investigation process.[57]

Additionally, the use of assessment such as poetry can assess the extent to which students understand diabetes mellitus. Poetry is valuable because it represents a central means by which human being use language to explore and understand their experiences, expressed through a creating. However, the challenges involved in generating content often slowdown in the writing process.[58] The use of models and concepts aligned with specific learning objectives can serve as an effective strategy to enhance the quality of instruction.

On the other hand, at the high school level, there is also a strong emphasis on content related to T2D. This matters because research on adolescents indicates that regular intake of sugary foods, fast food, and alcohol, along with smoking behaviors, significantly contributes to the onset of T2D. High-calorie diets and insufficient physical activity significantly contribute to the increasing prevalence of obesity and diabetes. Obesity serves as a mediating variable linking genetic risk factors with lifestyle and biological risk factors.

CONCLUSIONS

This paper presents an overview of diabetes education implementation across K-12 education levels. The methodology for diabetes education differs across educational levels, corresponding to the developmental stages of students. Interventions for students at lower educational levels frequently incorporate parental involvement and employ strategies such as games, role-playing, and simulations. Conversely, students in advanced educational settings engage in methods including class discussions, investigations, simulations, modelling, and community action projects, which prioritize activities that promote interaction among peers and pertinent stakeholders.

The main objective of schools as a venue for health promotion is to assist students in cultivating healthy habits and lifestyles that can aid in the prevention and management of diabetes. Increased efforts are necessary to improve awareness, knowledge, practices, and attitudes regarding diabetes in school settings. Additional research is necessary to comprehend the long-term effects of these interventions, to create more precise assessment indicators, and to formulate age-appropriate and cognitively appropriate learning models. Diabetes education should integrate cognitive, behavioral, and practical components. Stakeholder-driven policy reforms requiring diabetes education in all schools would enhance preparedness for addressing the diabetes pandemic.

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CONFLICT OF INTEREST

The authors declare that there is no potential conflict of interest.

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