Incidence of Diabetes Mellitus in Children and Adolescent: Systematic Review

Abstract

Background: Diabetes mellitus stands out as one of the most prevalent chronic diseases among pediatric patients. Presently, the existing body of work indicates that efforts aimed at preventing diabetes in youngsters and teenagers have not yielded successful outcomes. This lack of success could be linked to unclearly defined risk factors. Scientific findings propose a correlation between diabetes and a combination of factors that can be modified and those that cannot be altered.

Aim: To evaluate through a systematic review the risk factors associated with diabetes among children and adolescents.

Materials & Methods: Literature search conducted in PubMed, ScienceDirect, Cochrane Library, and Medline databases. A search filter composed of various items including Diabetes Mellitus, T1DM, T2DM, Child, and Adolescent.

Findings: The initial database search retrieved 9,949 articles. Ultimately, only 15 studies met the criteria and will proceed to the next stage for extraction and analysis. Berdasarkan hasil analisis yang dilakukan pada studi-studi yang eligible, ditemukan berbagai variasi yang berkaitan dengan factor resiko kejadian Diabetes pada anak dan remaja yang dikategorisasi menjadi non-modifiable dan Modifiable risk factors. Yang termasuk kedalam non-modifiable factors including family history of DM, Ethnicity Gender, and Age. Additionally, maternal pregnancy and unmarried parents were found to contribute to the incidence of DM in children. Yang termasuk kedalam Modifiable risk factors including Obesity, Sedentary life behavior, Physical activity, smoking history, and dietary.

Conclusion: Family history of DM dan Obesitas merupakan factor resiko yang dominan diantara studi-studi yang eligible. Ada keterkaitan erat antar factor resiko modifiable dan non-modifiable.

Keywords

Diabetes [Not in MeSH];
T1DM [Not in MeSH];
T2DM [Not in MeSH];
Children [Not in MeSH];
Adolescent [https://ncbi.nlm.nih.gov/mesh/68000293];
Obesity [https://www.ncbi.nlm.nih.gov/mesh/68009765];
Family History [Not in MeSH]

Introduction

Diabetes mellitus (DM) is a chronic metabolic condition that cannot be cured but can be managed. It may develop through hereditary factors or due to environmental influences and lifestyle choices. DM arises from impaired insulin secretion or action, leading to abnormalities in carbohydrate, protein, and lipid metabolism. The reduction in insulin secretion and increased resistance forms the basis for categorizing DM into type 1 diabetes (T1DM) and type 2 diabetes (T2DM). According to global surveys, a majority of children and adolescents across various age groups are affected by T1DM [1].

While type 1 diabetes (T1DM) remains the most commonly observed type among children and adolescents, there has been a notable rise in the occurrence of type 2 diabetes (T2DM) within this age demographic [2, 3]. Additionally, other less prevalent types of diabetes have been identified within the community, including monogenic diabetes, diabetes induced by medication, and diabetes triggered by secondary diseases [4]. The diagnostic criteria used for identifying diabetes mellitus (DM) and the heightened risk of developing diabetes (prediabetes) in children and adolescents mirror those employed for adults [5]. Nonetheless, the treatment and management of diabetes in youngsters involve unique considerations [6]. These factors encompass alterations in insulin sensitivity, reliance on medication, and neurological issues associated with the instability of blood sugar levels [7]. The escalating prevalence of childhood obesity correlates directly with the increased incidence and prevalence of T2DM, complicating the differentiation between T2DM and T1DM since more children diagnosed with T1DM are overweight at diagnosis. Additionally, research has indicated the presence of β-cell autoimmunity in children affected by T2DM [8].

Concentrating on identifying the factors influencing shifts in epidemiology, especially regarding diabetes mellitus (DM) in children and adolescents, holds significant importance due to this age group representing a crucial phase for shaping habits and mitigating the risk of diabetes onset from adjustable factors like obesity and sedentary behavior [9]. Studies have highlighted that preventive strategies for Type 1 Diabetes (T1D) have not achieved maximum success, and the precise risk factors remain unclear [10]. Nevertheless, certain research has unveiled connections between factors that can be changed and those that cannot be altered, linked to DM in children and teenagers [11]. Apart from a strongly hereditary predisposition to the disease, additional elements such as rapid economic growth that leads to dietary shifts, breastfeeding practices, and epigenetic modifications associated with an unfavorable prenatal environment have been recognized [12]. Similar risk factors are prevalent in children and adolescents residing in Asia [13] and the Middle East and North Africa [14], regions witnessing a significant surge in diabetes cases within this age range. Both types of diabetes (T1D and T2D), along with an elevated susceptibility to pre-diabetes, are indeed present among children and adolescents [15].

One of the reviews we encountered during our literature search focused on interventions tailored for adolescents dealing with T2DM. The study emphasized the underuse of pediatric registries, recognizing their role as platforms for sharing data, swiftly generating insights, and guiding decisions to enhance health outcomes [16]. Additionally, Lascar *et al.* [17], conducted a study summarizing the epidemiology, risk factors, complications, and management of T2D in adolescents. They concluded that there is a necessity to explore lifestyle measures for prevention within family dynamics and improve health education within school programs. Despite the growing attention toward T2D, gaps in knowledge persist regarding its epidemiology due to incomplete enrollment and limited population-based investigations examining the widespread presence of prediabetes and undiagnosed T2DM adolescents [18]. In adults, obesity is considered a significant contributor to the risk of DM, alongside other key factors like age, race/ethnicity, family medical history, lack of physical activity, and unhealthy dietary habits [19]. Consequently, there's a pressing requirement for more extensive research focused on comprehending and tackling the diabetes and prediabetes epidemic, specifically investigating the primary risk factors affecting children and adolescents. With this goal in mind, the present study aimed to systematically review and assess the risk elements linked to diabetes within this younger age demographic.

Method

Protocol

The present review complies with the Preferred Reporting Items for Systematic review and Meta Analysis (PRISMA) guidelines 2020 version [26]. The review included published studies from the period 2000 to 2023.

Search strategy

We conducted searches across multiple databases like PubMed, ScienceDirect, Cochrane Library, and Medline. The search terms used for articles were "Diabetes Mellitus", "T1DM", "T2DM", "Child", and "Adolescent", tailored to match the vocabulary of each specific database. These keywords were merged using Boolean operators like "AND" and "OR". Our search was restricted to articles available in English. We further refined the filters to yield more precise and pertinent results.

Eligibility criteria

This review encompassed all research examining risk factors for diabetes mellitus in children and adolescents. There was no restriction on the search timeframe to ensure a thorough compilation of relevant studies. However, studies published in conference proceedings, reviews, meta-analyses, commentaries, book chapters, reports, case studies, and letters to the editor were excluded from consideration.

Selection process

Two authors independently and separately screened the titles or abstracts of the located studies. In cases of conflicting opinions between the two screening authors, the first author made the final decision. This rapid screening involved assessing the titles, objectives, and conclusions of the pertinent studies. Further investigation into specific studies was pursued by delving into the main text to gather additional information as needed.

Study quality

The evaluation of article quality utilized the National Institutes of Health (NIH) tool designed for controlled intervention studies. This assessment tool comprises 14 statements gauging the comprehensiveness of reports derived from the reviewed studies. The assessment criteria are categorized based on the number of affirmative responses (YES). Results were categorized as follows: A score of <30% labeled as "poor", 30-70% as "fair", and a score exceeding 70% considered as "good" according to the provided guidelines.

Risk of bias

The Risk of Bias in Non-Randomized Studies-Exposure Studies (ROBINS-E) was used to evaluate the types of bias in each study [27]. The ROBINS-E tool consists of seven domains that assess the internal and external validity of the study. The assessment of the results of the assessment of these domains consists of Low, Some concerns, High, and Very High. The results of the Risk of Bias assessment involved and were approved by all authors taking into account the opinions of external reviewers.

Data extraction and synthesis

To facilitate comprehension of the eligible studies' contents, crucial information has been summarized in a table. Two authors collaborated in this extraction process. In cases where there were differing opinions regarding the extracted data, they were reconciled through consensus. The extraction criteria included the first author and publication year, study aim, observational design, participants, modifiable and non-modifiable factors, as well as key findings (Tabel 1).

Tabel 1. Characteristics of studies included

Authors, Year, Country	Aim	Design	Participants	Types of DM	Non-modifiable	Modifiable	Main findings
Amed *et al.*, 2010, Canada [1]	To determine in Canadian children aged 18 years the incidence of type 2 diabetes	Prospective	345 children aged <19 years	T2DM	- Family History - Ethnicity	- Obesity	- Family history (91%) - Obesity (95%)
Gaidhane *et al.*, 2017, India [28]	To find out the awareness regarding T2DM and distribution of risk factor for T2DM in adolescents	Cross-sectional	412 adolescents aged 11-19 years	T2DM	- Family history of DM	- Sedentary life style - Dietary	- Sedentary life style (p=0.07) - Dietary (p=0.01) - Family history (p=0.001)
Kolahdooz *et al.*, 2018, Canada [29]	To examine the risk factors for type 2 diabetes in multiethnic urban	Cross-sectional	557 (328 girls and 229 boys) multiethnic youth 11 to 23	T2DM	- Sex - Ethnicity - Family history of	- Obesity - physically inactive - did not	- Boys>girls (p<0.0001) - Asian youth>than any other ethnic

	youth		years of age		DM	consume sufficient amounts of fruits and vegetables	group (p<0.0001)
Lee *et al.*, 2015, Korea [31]	To investigate the incidence and associated factors of T1DM and T2DM in children and adolescents younger than 15 years of age	Cohort	328 patients (160 males and 168 females) living in Busan and Gyeongnam, aged 15 years of age or younger	T1DM & T2DM	- Age - Sex	-	- The 10-year average crude T1DM incidence rate for children and adolescents younger than 15 years was 2.01/100,000, 2.68 times greater than the rate of 0.75/100,000 - The age-specific adjusted IRR was highest in the 10- to 14-year-old group for both T1DM (OR 1.56) and T2DM (OR 2.87)
Majeed & Hassan, 2011, Iraq [32]	To determine the potential maternal, neonatal and early childhood risk factors for T1DM in children and adolescents	Case-control	96 children and adolescents with type 1 diabetes and 299 non-diabetic children	T1DM	- Family history	- Thyroid diseases - Tea drinking	- Family history of type 1 diabetes mellitus and thyroid diseases (p=0.001) - Tea drinking during pregnancy (p<0.05)
Vasconcelos *et al.*, 2010, Brazil [33]	To identify DM2 risk factors among adolescents of private schools	Cross-sectional	794 students aged 12-17 years	T2DM	- Family history	- Sedentary lifestyle	- 73.5% had family history of DM2 (p=0.04) - 65% were sedentary and 51% had family history of DM2
Young *et al.*, 2002, Canada [40]	To identify explanatory factors to which the child may have been exposed in the intrauterine environment and during early infancy	Case-control	46 patients Aged <18 years	T2DM	-	- Gestasional diabetes - Breastfeeding longer than 12 months - Birth weight - Maternal obesity	- Gestational diabetes (OR=4.40) - Breastfeeding longer than 12 months (OR=0.24) - Low (2500 g) and high (4000 g) birth weight and maternal obesity
Zamani *et al.*, 2021, Iran [36]	To investigate the association between Type-1 Diabetes Mellitus and diet in the rest two years of life as well as a select group of demographic variables	Case-control	76 children with T1DM and 209 non-diabetic children	T1DM	- Maternal pregnancy history	- BMI - Breastfeeding	- BMI of the mother being <18.5 before pregnancy (OR=4.4) - Mothers without a history of diabetes (OR=0.02) - Mother's weight before pregnancy (OR=0.88) - Mother's excess weight during pregnancy (OR=0.83) - Exclusive breastfeeding for more than six months (OR=0.19) - Low weight gain in the first two years of life (OR=6.98) - Breastfeeding less than 12 months (OR=10.52, p<0.05)
Barakat *et al.*, 2021,	To identify other characteristics of	Cross-sectional	6365 school-attending	T1 & T2 DM	- Age -	- Smoking	- Males 1.5%> than females 0.5%

UAE [35]	those with diabetes including parental marital status, smoking/illegal drug use, quality of life and nationality		adolescents (12-22 years; mean=16 years)	Unmarried parents		(p<0.001) - Parents unmarried>twice the odds of self-reporting diabetes (p=0.031) - Smoking/using illegal drugs OR 3 (p<0.001)
Bang *et al.*, 2022, Korea [38]	To identify significant factors for diabetes and prediabetes in adolescents aged 12 to 18 years	Retrospective surveillance	416 Korean adolescents aged 12-18 years	T1 & T2 DM	-	- BMI - Fasting plasma glucose, - Hemoglobin A1c - Insulin	- BMI (p=0.001) - Sleeping hours/day (p=0.038) - Sitting time (p=0.316) -Increased FPG, HbA1c, and insulin (p=0.001)
Xie *et al.*, 2019, China [39]	To determine the incidence of DM, and identified the risk factors for this complication in pediatric and adult CP patients	retrospective-prospective cohort	324 pediatrics diagnosed with DM <18 years	T1 & T2 DM	-	-BMI -Smoking history	- Higher BMI (HR=1.195; p=0.058) - Smoking history (HR=5.030; p=0.003)
Ouyang *et al.*, 2023, US [34]	To assess the national trends in prevalence of diabetes and prediabetes and their major risk factors among adolescents	Cross-sectional	3717 youth aged 11-21 years	Diabetes and pre-diabetes	- Age	- BMI - Obesity	- Adolescents aged 17-19 years (p<0.001) >12-16 years (p=0.036) - Obesity (OR=3.79)
Belsky *et al.*, 2023, US [7]	To determine risk factors for progression to T2D	Retrospective	552 patients aged <18	T2DM	- Family history	- BMI	- 94% had a family history of T2D - 89% had an increasing BMI
Lee, 2014, China [37]	To identify the association between PA and SB patterns during adolescents on the future increase in BMI and risk of diabetes during young adulthood	Longitudinal	3,717 participants aged 11 to 21	T2DM	- Family history	- Sedentary behaviors - BMI - Smoking - Physical activity	- Family History (p 0.03) - The LPAHSB cluster had significantly greater odds for developing diabetes (OR = 1.69, P = 0.03) - The HPALSB had lower increase in BMI (p=0.04)
Jaja & Yarhere, 2015, Nigeria [30]	To assess for easily identifiable risk factors for T2DM in adolescents	Cross-sectional	880 students aged 10 to 19 years	T2DM	- Age -Family history	- IFG - Hypertension	- Family history (p=0.558) - IFG (p=0.0001) - Hypertension (p=0.0001)

Findings

The initial database search retrieved 9,949 articles. After removing 5,430 duplicates and ineligible articles not relevant to the review's theme, 4,519 articles remained for screening. During the eligibility assessment, 54 studies were evaluated, and 39 articles were excluded for various reasons. Ultimately, only 15 studies met the criteria and will proceed to the next stage for extraction and analysis (Figure 1).

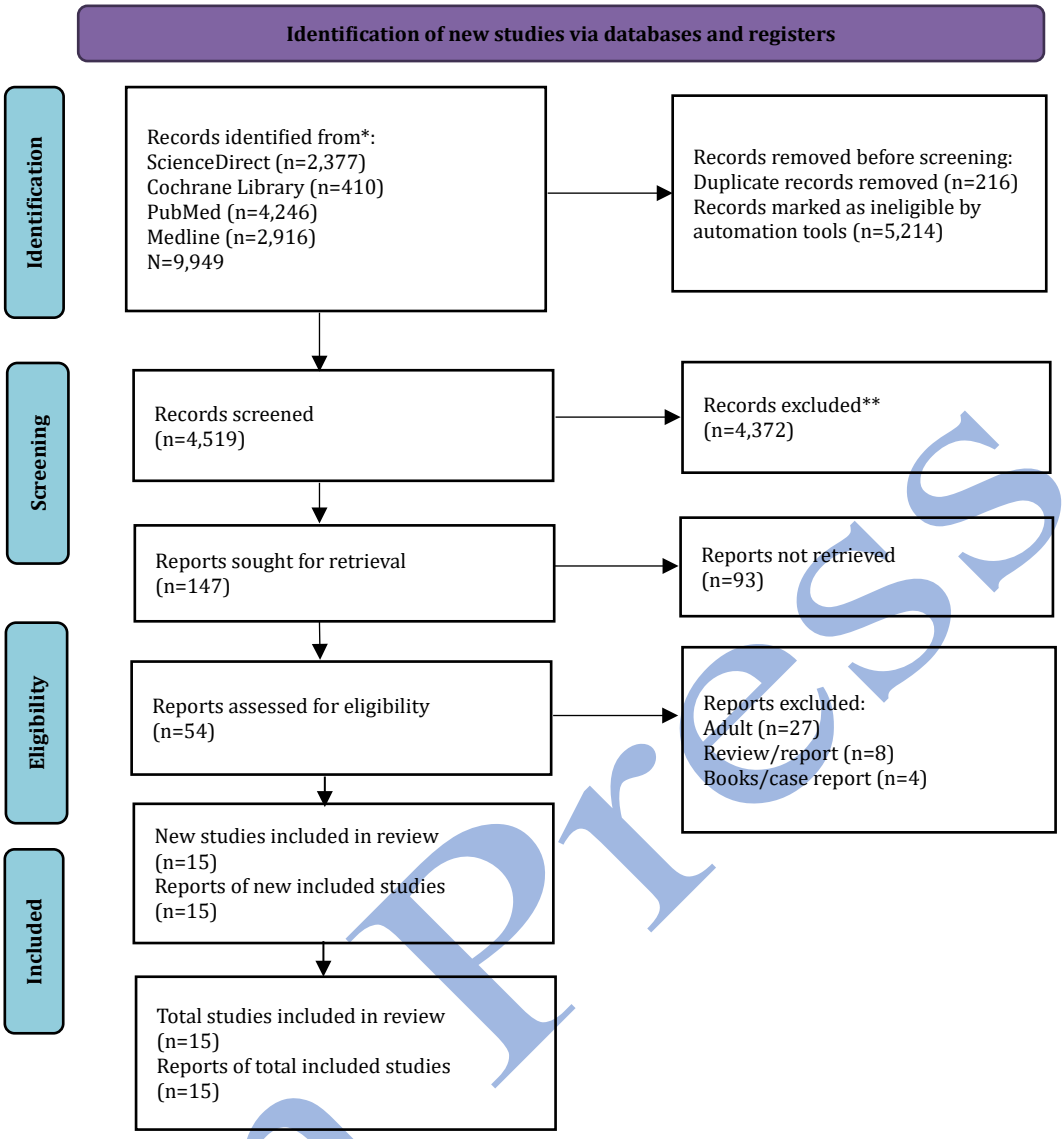

Figure 1. PRISMA flow diagram for literature search

Characteristics of studies included

There were 15 studies reviewed in this review from several countries including Canada (n=3), Korea (n=2), China (n=2), US (n=2), India, Iraq, Brazil, Iran, UA, and Nigeria with one study each. The study design of each study included cross-sectional, prospective, cohort, case-control, retrospective, and longitudinal. The total number of participants involved in the studies included in this review amounted to 19,235 children and adolescents.

Quality assessment of included studies

Based on the results of the study quality assessment using the NIH tool for observational cohort and cross-sectional studies. The assessment process and summary of the assessment results of each study are shown in Table 2.

Table 2. Summary of study quality assessment

Studies	NIH criteria													
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14
Amed *et al.*, 2010 [1]	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	CD	Y	Y
Gaidhane *et al.*, 2017 [28]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NR	Y	Y
Kolahdooz *et al.*, 2018 [29]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	CD	Y	Y
Lee *et al.*, 2015 [31]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	CD	Y	Y
Majeed & Hassan, 2011 [32]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	CD	Y	Y
Vasconcelos *et al.*, 2010 [33]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	CD	Y	Y
Young *et al.*, 2002 [40]	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	CD	Y	Y

Zamani *et al.*, 2021 [36]	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	CD	Y	Y
Barakat *et al.*, 2021 [35]	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	CD	Y	Y
Bang *et al.*, 2022 [38]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	CD	Y	Y
Xie *et al.*, 2019 [39]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	CD	Y	Y
Ouyang *et al.*, 2023 [34]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	CD	Y	Y
Belsky *et al.*, 2023 [7]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	CD	Y	Y
Lee, 2014 [37]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	CD	Y	Y
Jaja & Yarhere, 2015 [30]	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	CD	Y	Y

*Q=Question; Y=Yes; N=No; CD=Cannot determine

According to the findings from the study quality assessment conducted above, the majority of the studies fall within the good quality category. This classification is derived from scores surpassing 70% of the total NIH criteria designated for observational cohort and cross-sectional studies.

Assessment of Risk of Bias from included studies

The outcomes of the RoB assessment for the included studies are showcased through a traffic-light plot displayed in Figure 2. During the assessment process, all authors unanimously concurred with the assessment outcomes, without engaging in significant debate. External reviewers contributed noteworthy feedback, particularly concerning domain five, which focuses on Missing Data, for certain studies.

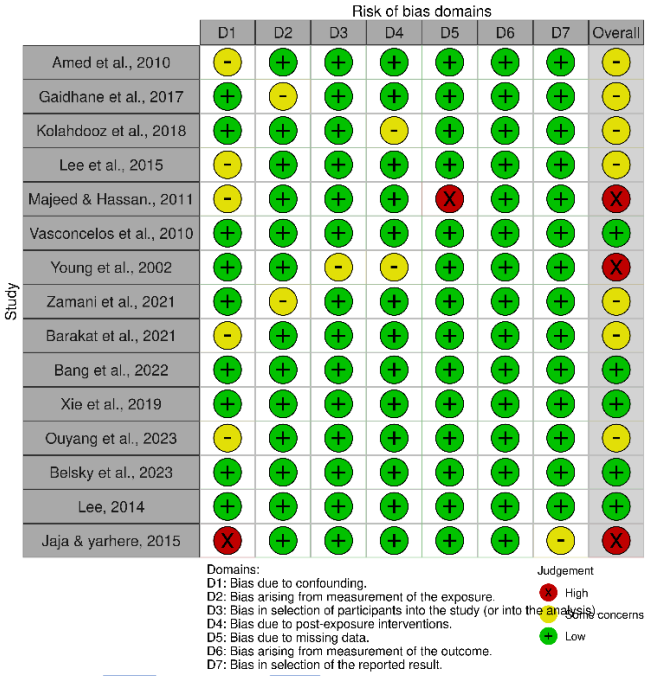

Figure 2. Summary of RoB of the studies included

The traffic-light plot illustrates three studies classified under the High Risk of Bias category, seven studies under the Some Concern category, and five studies under the Low Risk of Bias category. To ensure the thoroughness of this review, we incorporated three studies, despite their placement within the High Risk of Bias category.

Type of diabetes mellitus targeted by each included study

The focus of most studies was on Type 2 Diabetes Mellitus (T2DM), with eight studies specifically dedicated to T2DM, while only two studies concentrated on T1DM. Additionally, the remaining five studies addressed both types of diabetes mellitus collectively.

Non-modifiable risk factors associated to DM

Among the fifteen studies included, the family history of DM emerged as the most extensively discussed risk factor [1, 7, 28-33]. Ethnicity was another notable risk factor elaborated in multiple studies (n=4) [1, 7, 29, 34]. Gender was also identified as a risk factor associated with the incidence of DM [29, 31]. Age was linked to DM across four studies [29-31, 34, 35]. Additionally, maternal pregnancy and unmarried parents were found to contribute to the incidence of DM in children, as indicated by two studies [35, 36].

The statistical analysis conducted on non-modifiable risk factors highlighted the prominence of family history of DM among other non-modifiable risk factors. The reported p-values were 0.001 for both T1DM and T2DM [28, 32], and for T2DM, values of 0.04, 0.03, and 0.558 were presented [30, 33, 37]. Regarding the risk factor of ethnicity, presented p-values were 0.1 [1], 0.0001 [29], 0.001 [34], and 0.63 [7]. Notably, all studies addressing ethnicity associated it with T2DM. In the context of gender, statistical analysis results indicated boys>girls in T2DM (p=0.0001) [29], male<female in both types of DM (p=0.619; p=0.044) [31]. Concerning age, statistical values reported across the included studies were 0.073 for age 11-15 [29], 0.009 for age 10-14 [31], 0.668 for age 16 [35], 0.94 for age group 12-16>17-19, and 0.83 [34], as well as 0.304 for age group 13-15.9 [30]. Additionally, unmarried parents displayed a statistical value of p=0.031 [35].

Modifiable risk factors associated to DM

Modifiable risk factors were identified from the fifteen studies included in this review. These risk factors included obesity-BMI [1, 7, 29, 34, 36-39], sedentary life behavior [28, 33, 37], physical activity [29, 37], smoking history [35, 37, 39], dietary [28, 29, 32, 36, 40], other disease conditions including thyroid disease p=0.001, gestational diabetes OR=4.40, and hypertension p=0.0001 [30, 32, 40].

Of all the modifiable risk factors, obesity measured by BMI showed the most dominant risk factor discussed in eight studies with results of 95% [1], 26.7% [29], OR=4.4 [36], p=0.001 [38], p=0.058 [39], OR=3.79 [34], 89% [7], p=0.13 [33], and p=0.04 [37]. For the risk factor of sedentary behavior, the statistical values shown include p=0.07 [28], 65% [33], and p=0.001 [37]. The statistical values shown for the risk factor of physical activity include 46.3% [29], p=0.03 [37], smoking history is also identified as a risk factor for the incidence of DM in children and adolescents with statistical values in each including p=0.001 [35], p<0.15 [39], 46.2% [37], HR=5.030; p=0.003 [39], OR=3; p=0.001 [35].

Discussion

Principal findings

This systematic review provides a comprehensive synthesis of the factors associated with DM in children and adolescents presenting with new onset of type 1 and 2 diabetes. We discovered that obesity emerged as a predominant and frequent risk factor across the studies examined in this review. Its significance surpassed other risk factors in terms of percentage, p-value, and OR. This consistent pattern instills confidence in recognizing obesity as a major issue demanding focused attention in the future concerning children and adolescents. Additionally, considering the statistical significance of sedentary behavior as a risk factor, it appears to hold a substantial relationship. This is supported by prior research, where a link between overweight and obesity with increased levels of sedentary behaviors was established (RRR=1.33; 1.27-1.39 and RRR=1.73; 1.63-1.84) [41].

Factors associated to DM in children and adolescents

Comprehending the risk elements linked to diabetes in children and teenagers will aid in devising tailored strategies to hinder the onset of such risk factors or manage those already present, especially in younger populations [42]. The rise in diabetes prevalence among this demographic might amplify the occurrence of additional health issues or complexities associated with diabetes, including high blood pressure, abnormality fat level, retinopathy, and cardiovascular ailments. Furthermore, the emergence and advancement of diabetic complications during early stages of life could potentially present a remarkable future public health issue [21].

In terms of non-modifiable risk factors, family history emerges as a potent predictor influencing the incidence of DM in children and adolescents, displaying strong significance in most of the studies reviewed. Individuals with first-degree relatives affected by DM2 face a notably heightened risk, being two to six times more prone to developing the disease than those without a family history of diabetes [43]. This strong association underscores the genetic component's pivotal role, indicating that individuals came from parents with diabetes carry a five to tenfold higher likelihood of developing the condition compared to the general population [44]. Furthermore, other research indicates that this state elevates the likelihood of obesity, decreased HDL levels, and heightened blood pressure among adolescents of Asian Indian descent [45]. Children and teenagers in Mexico with family history of diabetes face higher occurrences of hypertension, obesity, elevated insulin and triglyceride levels, along with an increased insulin resistance index, in contrast to those from non-diabetic families [46].

Other non-modifiable risk factors also play a role in diabetes among children and adolescents. Lee [31] discovered that the incidence rate ratio for both T1DM and T2DM increased notably in the age bracket of 10 to 14 years, ranging from 1.56 to 2.87. Additionally, another study highlighted a surge

in DM incidence among individuals aged 17 to 19 years, demonstrating statistically significant outcomes [34]. Aligning with Lee's findings, Jaja & Yarhere [30] observed a rise in DM incidence within a similar age range of 10 to 12.9 years, which served as the reference group in their study. A Korean study echoed these trends, reporting a 6.39 times higher prevalence of diabetes among adolescents aged 10 to 14 years and a 5.34 times higher prevalence among those aged 15 to 19 years. The rising occurrence of diabetes in Korean teens is evident at younger ages, posing challenges for them in understanding and handling their health, especially in managing diabetes-related risks, which can be demanding. Therefore, the assistance and guidance offered by parents and school educators are crucial in aiding these adolescents [38]. However, in the UAE, age doesn't appear to serve as a significant predictor for the incidence of DM in adolescents, as observed in a study by Barakat *et al.* [35]. Similarly, in a US-based study, the statistical outcomes didn't indicate significance regarding age. Regarding ethnicity, the findings from various studies displayed divergent results. For instance, one study indicated that Asian adolescents showed a higher incidence compared to other ethnicities [29], whereas another study highlighted that Mexican-American ethnicity had a higher prevalence of diabetes [34]. Consequently, the authors have opted to put ethnicity on hold as a risk factor for diabetes incidence among children and adolescents. This underscores the necessity for comprehensive studies involving broader population samples with diverse ethnicities analyzed together or in a cohort setting.

In modifiable risk factors, there are several factors that show strong significance, including obesity, sedentary life behaviors, and physical activity. It is known that obesity is an important risk factor in the incidence of DM in children and adolescents. Children struggling with obesity confront a notably heightened risk of facing diverse health complications, both physical and psychological. The origin of obesity usually links back to the concept of early adiposity rebound, denoting the phase when a child's body mass index (BMI) begins its ascent following its lowest fat level, typically occurring around age 5 or 6. Individuals experiencing adiposity rebound as early as 3 years old often witness a consistent climb in their BMI from early childhood through adolescence, continuing into adulthood [47]. Comprehending the association between obesity and T2DM entails intricate physiological and cellular mechanisms, involving alterations triggered by surplus fat in beta-cell function, adipose tissue biology, and insulin resistance across various organs. These aspects can often ameliorate and might even normalize with substantial weight reduction.

In India, sedentary lifestyle is more prevalent in adolescents aged 15-19 years compared to younger age groups [28]. Vasconcelos *et al.* reported that the most significant risk factors were overweight and sedentary behavior [33]. The research clearly demonstrates that both sedentary behaviors and physical activity independently contribute to the development of type 2 diabetes among adults [20, 48]. However, this particular study focused on confirming the impact of sedentary behaviors [23] among adolescents without delving into the effects of physical activity. Several reasons may explain this observation. Initially, previous suggestions propose that the connection between physical activity and type 2 diabetes may be influenced by body fat [49]. Consequently, the 14-year follow-up solely observed body fat management through physical activity, requiring a longer duration to fully understand the relationship between body fat and type 2 diabetes. Second, a previous study highlighted a stronger correlation between blood glucose levels and cardiorespiratory fitness compared to energy expenditure [50], suggesting that the ability of the heart and lungs to carry out their activities properly could be the mediator between physical activity and T2DM. Third, the most common sedentary behavior in the studies included, TV viewing, was linked with unhealthy dietary habits [5], potentially explaining the association between sedentary behaviors and type 2 diabetes. Therefore, it's possible that a lack of physical activity contributes to BMI changes.

Limitation

This review may not fully summarize studies that have been published in reputable journals. This review also included three studies that were categorized as High Risk of Bias; Therefore, caution should be exercised in using the results of this review.

Conclusion

Based on a review of fifteen included studies, no singular risk factor emerged as significantly prevalent across these studies. Furthermore, no substantial differences in risk factors for T1DM and T2DM were observed. The findings suggest a focus on diabetes prevention in children and adolescents by emphasizing weight management, reducing sedentary habits, and promoting

physical activity. Additionally, attention to other factors like smoking, dietary habits, and augmenting fruit intake is recommended.