Preventive Medicine Reports 41 (2024) 102688

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: www.elsevier.com/locate/pmedr

Short communication

Prevalence trends and racial-ethnic disparities of diabetes and prediabetes among children and adolescents in the United States from 2019 to 2021

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ARTICLE INFO

Keywords:
Pediatric diabetes prevalence
Diabetes rates
Racial-ethnic disparities
National Health Interview Survey
Sociodemographic factors

ABSTRACT

Objective: This study investigated disparities in diabetes and prediabetes prevalence among US children and adolescents using 2019–2021 National Health Interview Survey (NHIS) data. With rising trends in diabetes, understanding prevalence rates and associated disparities is crucial for targeted interventions.
Methods: Analyzing a cross-sectional sample of 19,490 participants aged 3–17, we employed NHIS data to calculate prevalence rates. Stratification by sociodemographic factors, race/ethnicity, and family income allowed for in-depth analyses.
Results: Between 2019 and 2021, overall diabetes prevalence was 1.18%, comprising 0.87% prediabetes and 0.46% diabetes rates. Disparities were evident, with higher prediabetes rates in non-Hispanic black and Hispanic children and elevated diabetes rates in non-Hispanic white and Hispanic children. Subgroup analyses revealed associations within age, gender, education, and income strata.
Conclusions: The study highlighted potential increases in diabetes prevalence from 2017 to 2021 and persistent racial/ethnic disparities. The 12–17 age subgroup exhibited significant disparities, emphasizing the need for early intervention. Targeted strategies were imperative to mitigate diabetes and prediabetes prevalence in vulnerable populations, particularly non-Hispanic black and Hispanic children. This study underscored the urgency of addressing health disparities for improved overall well-being and healthcare outcomes.

1. Introduction

Type 1 diabetes (T1D), typically diagnosed in childhood, is a chronic condition resulting from the autoimmune destruction of pancreatic β cells, leading to insulin insufficiency and hyperglycemia (Quattrin et al., 2023). In contrast, type 2 diabetes (T2D) is primarily caused by impaired insulin secretion and insulin resistance (Galicia-Garcia, 2020). Prediabetes, distinct from T1D and T2D, represents an intermediate stage characterized by elevated blood glucose levels that do not meet the criteria for diabetes ("Classification and Diagnosis of Diabetes, 2020).

Lawrence et al. (Lawrence, 2021) demonstrated a significant increase in the prevalence rates of T1D and T2D among children and adolescents in the United States (US) from 2001 to 2017. Specifically, the prevalence rates for T1D in 2009 and 2017 were 1.95 and 2.15 per 1000 children, while those for T2D were 0.46 and 0.67 per 1000 children, respectively. According to the Centers for Disease Control and Prevention, approximately 283,000 children and adolescents under the age of 20, or 3.5 per 1000 children, had diagnosed diabetes in 2018, including 244,000 cases of T1D (The Centers for Disease Control and Prevention, 2022).

In the short term, children and adolescents with T1D experience diabetic ketoacidosis, hypoglycemia, and visual or psychosocial complications. In the long run, they may suffer from retinopathy, nephropathy, neuropathy, coronary artery disease, cerebrovascular disease, and peripheral vascular disease (White, 2015). The Treatment Options for Type 2 Diabetes in Adolescents and Youth (TODAY) study had indicated an elevated risk of microvascular complications in adulthood for individuals diagnosed with T2D during adolescence at the age of 13.3

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https://doi.org/10.1016/j.pmedr.2024.102688
Received 28 November 2023; Received in revised form 13 March 2024; Accepted 14 March 2024
Available online 15 March 2024

years with a standard deviation of 1.8 years (Bjornstad, Jul. 2021). The increasing trend in diabetes prevalence poses a significant threat to the health of US children and adolescents, resulting in long-term complications that carry substantial economic, societal, and health burdens. In 2017, black, white, and Hispanic children had T1D prevalence rates of 2.18, 2.79, and 1.56 per 1000 children, respectively. Moreover, American Indian, Black, and Hispanic children had the three highest T2D prevalence rates, with 1.63, 1.80, and 1.03 per 1000 children, respectively (Lawrence, 2021). Consequently, the high prevalence rates of T1D and T2D in Black and Hispanic populations, along with the associated long-term complications, may impose a significant burden upon black and Hispanic children populations.

The objectives of this study were to examine the presence of disparities in the prevalence rates of children diabetes in the US population using a nationally representative sample. Additionally, the study aimed to investigate prevalence rate disparities within strata of sociodemographic factors and analyze trends in prevalence rates. To achieve these aims, we utilized the National Health Interview Survey (NHIS), a cross-sectional household interview survey that provides nationally representative data on an annual basis.

The NHIS collects extensive health-related data, covering topics such as healthcare access, behavior, status, and usage. It serves as a valuable tool for revealing population-level health trends and elucidating associations between risk factors and diseases. Conducted by the National Center for Health Statistics (NCHS), a part of the Centers for Disease Control and Prevention (CDC) in the US (The Centers for Disease Control and Prevention, 202; National Centers for Health Statistics, 2023) , the NHIS comprises three modules: household roster, sample adult interview, and sample child interview (The Centers for Disease Control and Prevention, 2023). The sample child interview, conducted between 2019 and 2021, covered diagnosed diabetes and diagnosed prediabetes in US children and adolescents. While T1D typically manifests in childhood or adolescence, T2D has become more prevalent in recent times (Lawrence, 2021). The various subtypes of diabetes manifest with short-term impacts, including increased thirst, frequent urination, and mood swings, and long-term impacts that involve cardiovascular, renal, and neurological damages or complications.

2. Methods

The NHIS employed a sophisticated, multi-stage probability sample incorporating stratification and clustering, where interviews were conducted with either adults or parents and guardians of children. It aimed to gather comprehensive health status data from nationally representative non-institutionalized US residents, residing in households or non-institutional group quarters within the 50 states or the District of Columbia at the time of the interview (Division of Health Interview Statistics, 2023; Moriarity et al., 2022). The NHIS sampling plan, designed by the Division of Health Interview Statistics at the National Center for Health Statistics, was executed throughout the year. For readers seeking detailed information on the sampling design and implementation, comprehensive resources are available in the NHIS survey design documents (Division of Health Interview Statistics, 2023).

Our study employed a cross-sectional design using NHIS survey data collected between 2019 and 2021, treating the 3-year combined survey data as a dataset with a repeated cross-sectional design, referred to henceforth as the combined data for brevity. Children and adolescents aged 3 to 17 were the focus of our study, with data drawn from the 2019, 2020, and 2021 waves of the NHIS sample child interview. We concentrated on responses to NHIS survey questions pertaining to diabetes and prediabetes. Specifically, parents or guardians were queried about prediabetes with the question, “Has a doctor or other health professional EVER told you that [sample child’s name] had prediabetes or borderline diabetes?” For diabetes, parents or guardians of non-prediabetic children or adolescents were asked, “Has a doctor or other health professional EVER told you that [sample child’s name] had diabetes?”.

The objectives of this study were to analyze trends and disparities in the rates of diabetes and prediabetes prevalence and to examine prevalence rates among various sociodemographic subgroups stratified by racial-ethnic groups. To achieve this, we examined the outcomes of the survey questions, stratifying by racial-ethnic groups. The combined dataset encompassed sociodemographic variables of sample children, including age, sex, racial-ethnic groups with Hispanic origin, the highest education level attained by all adults in the sample children’s family, and the family income to poverty ratio of the sample children’s family.

Following NHIS guidelines (Division of Health Interview Statistics, 2023; Moriarity et al., 2022), we computed race-ethnicity-specific rates of diabetes and prediabetes prevalence, along with 95 % confidence intervals (CI), using the survey procedure of SAS 9.4 (SAS Institute Inc.), accommodating the complex survey design. Subsequently, we provided subgroup estimates of stratified prevalence rates of diabetes and prediabetes across all age, gender, highest family education, and family income to poverty ratio subgroups.

To assess the association between race/ethnicity and prevalence rates, we utilized the Rao-Scott likelihood ratio chi-square test, accommodating the complex survey design. Additionally, we employed weighted linear regression analysis to identify trends. As our study did not involve human subjects or animals and the data was de-identified, it was exempt from institutional review board oversight. A p-value less than 0.05 was considered statistically significant. We adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines (von Elm et al., 2008). Our study conducting analysis on publicly available deidentified data did not involve research on human subjects and animals, and thus, it was exempt from the requirement for ethical approval.

3. Results

Between 2019 and 2021, a total of 19,490 children and adolescents aged 3–17 participated in the NHIS survey. Table 1 illustrates the prevalence rates of diabetes, prediabetes, and overall diabetes for the years 2019–2021, with respective 95 % confidence intervals (CI) of 0.46 % ([0.32 %, 0.59 %]), 0.87 % ([0.72 %, 1.03 %]), and 1.18 % ([0.99 %, 1.38 %]), where overall diabetes included both diabetes and prediabetes. Prediabetes was notably higher among non-Hispanic black and Hispanic children, with prevalence rates of 1.25 % ([0.66 %, 1.83 %]) and 1.32 % ([0.94 %, 1.71 %]) respectively. Conversely, non-Hispanic white and Hispanic children exhibited elevated diabetes rates at 0.54 % ([0.31 %, 0.74 %]) and 0.50 % ([0.24 %, 0.75 %]) respectively. Notably, Hispanic children demonstrated the highest prediabetes prevalence compared to other ethnic groups ($p = 0.0002$). Furthermore, in comparison to other racial/ethnic groups, Hispanic children exhibited the highest overall diabetes prevalence at 1.65 % ([1.21 %, 2.09 %]), with non-Hispanic black children following closely at 1.29 % ([0.70 %, 1.88 %]) ($p = 0.0132$).

Upon closer examination of overall diabetes prevalence in Table 1 Diabetes or Pre-diabetes section, we identified associations of the overall diabetes prevalence with race/ethnicity within the age 12–17 subgroup and family income to the subgroup with poverty ratio > 4 ($p = 0.0006$ and $p = 0.0055$ respectively). In these subgroups, Hispanic children had the highest prevalence rates at 3.10 % ([2.17 %, 4.03 %]) and 1.76 % ([0.72 %, 2.80 %]) respectively, surpassing rates in corresponding subgroups across all ethnicities. However, such associations were not observed in other subgroups.

As demonstrated in the Diabetes Only section of Table 1, significant associations were observed between diabetes prevalence and race/ethnicity within the age 12–17 subgroup ($p = 0.0399$). Hispanic children exhibited the highest prevalence rate at 0.93 % ([0.38 %, 1.48 %]), surpassing other races/ethnicities. Nonetheless, no such associations were identified in other subgroup analyses for diabetes cases.

In the Prediabetes Only section of Table 1, subgroup analyses for

Table 1
Weighted prevalence of either diabetes or pre-diabetes, diabetes only and pre-diabetes only in the United States children and adolescents aged 3 to 17 by race/ethnicity in the National Health Interview Survey, 2019–2021.

Characteristics		Weighted prevalence[a], % (95% confidence interval)					P-value[b]
		All	Non-Hispanic White	Non-Hispanic Black	Hispanic	Non-Hispanic Others	
Diabetes Only		0.46 (0.32,0.59)	0.54(0.34,0.74)	0.15(0.03,0.28)	0.50 (0.24,0.75)	0.31(0.08,0.54)	0.0633
Pre-diabetes Only		0.87 (0.72,1.03)	0.58(0.40,0.75)	1.25(0.66,1.83)	1.32 (0.94,1.71)	0.78(0.42,1.14)	0.0002
Diabetes or Pre-diabetes		1.18 (0.99,1.38)	0.97(0.72,1.22)	1.29(0.70,1.88)	1.65 (1.21,2.09)	0.92(0.54,1.30)	0.0132
Diabetes or Pre-diabetes	Age						
	3-11	0.64 (0.44,0.84)	0.58(0.29,0.86)	0.81(0.04,1.58)	0.67 (0.32,1.01)	0.71(0.24,1.17)	0.8848
	12-17	1.95 (1.58,2.32)	1.52(1.07,1.97)	1.93(0.99,2.88)	3.10 (2.17,4.03)	1.25(0.58,1.93)	0.0006
	Sex						
	Male	1.13 (0.86,1.40)	0.88(0.52,1.24)	1.47(0.54,2.39)	1.55 (0.94,2.17)	0.88(0.31,1.46)	0.1433
	Female	1.24 (0.96,1.51)	1.07(0.73,1.40)	1.10(0.37,1.83)	1.76 (1.13,2.39)	0.95(0.43,1.47)	0.0961
	Education[c]						
	High School	1.31 (0.93,1.69)	1.28(0.61,1.95)	1.18(0.35,2.00)	1.52 (0.93,2.12)	0.45(0.00,0.98)	0.4309
	College	1.25 (0.97,1.54)	0.93(0.59,1.27)	1.47(0.51,2.43)	1.85 (1.17,2.54)	1.33(0.66,2.00)	0.0528
	Graduate	0.88 (0.55,1.21)	0.91(0.48,1.33)	0.88(0.00,1.86)	1.23 (0.09,2.38)	0.45(0.06,0.84)	0.5954
	Family income to poverty ratio						
	<1	1.55 (0.89,2.22)	1.45(0.00,3.03)	1.28(0.37,2.18)	1.96 (0.92,3.01)	0.71(0.00,1.53)	0.6369
	1-2	1.32 (0.91,1.72)	1.34(0.75,1.93)	1.41(0.05,2.76)	1.34 (0.66,2.01)	0.99(0.05,1.94)	0.9676
	2-4	1.24 (0.88,1.59)	0.93(0.55,1.30)	1.55(0.28,2.83)	1.69 (0.78,2.60)	1.54(0.56,2.53)	0.2475
	>4	0.84 (0.58,1.09)	0.76(0.46,1.07)	0.52(0.00,1.05)	1.76 (0.72,2.80)	0.44(0.08,0.80)	0.0055
Diabetes Only	Age						
	3-11	0.32 (0.17,0.47)	0.42(0.15,0.69)	0.09(0.00,0.24)	0.20 (0.05,0.35)	0.37(0.03,0.72)	0.1515
	12-17	0.66 (0.45,0.86)	0.71(0.41,1.00)	0.24(0.02,0.45)	0.93 (0.38,1.48)	0.20(0.00,0.44)	0.0399
	Sex						
	Male	0.48 (0.28,0.69)	0.55(0.22,0.87)	0.16(0.00,0.32)	0.54 (0.11,0.98)	0.42(0.02,0.83)	0.4692
	Female	0.43 (0.29,0.57)	0.54(0.31,0.77)	0.15(0.00,0.34)	0.45 (0.19,0.70)	0.19(0.00,0.40)	0.1110
	Education[c]						
	High School	0.41 (0.18,0.64)	0.67(0.12,1.22)	0.23(0.00,0.55)	0.37 (0.05,0.69)	-[e]	0.1560[d]
	College	0.45 (0.28,0.62)	0.47(0.21,0.74)	0.15(0.02,0.29)	0.56 (0.18,0.95)	0.41(0.02,0.81)	0.3982
	Graduate	0.53 (0.26,0.79)	0.61(0.24,0.97)	-[e]	0.73 (0.00,1.50)	0.29(0.00,0.61)	0.1423[d]
	Family income to poverty ratio						
	<1	0.42 (0.01,0.82)	0.77(0.00,2.11)	0.16(0.00,0.41)	0.40 (0.07,0.72)	-[e]	0.2565[d]
	1-2	0.38 (0.16,0.61)	0.49(0.16,0.82)	0.30(0.00,0.62)	0.34 (0.00,0.79)	0.30(0.00,0.88)	0.8934
	2-4	0.50 (0.27,0.73)	0.46(0.18,0.74)	-[e]	0.83 (0.15,1.51)	0.54(0.00,1.11)	0.0685[d]
	>4	0.49 (0.28,0.70)	0.57(0.29,0.85)	0.11(0.00,0.32)	0.41 (0.00,0.87)	0.25(0.00,0.52)	0.2964
Pre-diabetes Only	Age						
	3-11	0.43 (0.28,0.59)	0.28(0.11,0.44)	0.79(0.02,1.56)	0.52 (0.20,0.85)	0.57(0.14,1.00)	0.1727
	12-17	1.50 (1.17,1.83)	0.99(0.64,1.34)	1.86(0.92,2.80)	2.50 (1.67,3.34)	1.13(0.47,1.79)	0.0002
	Sex						
	Male	0.74 (0.54,0.95)	0.37(0.20,0.54)	1.41(0.48,2.33)	1.16 (0.65,1.66)	0.74(0.20,1.29)	0.0009

(*continued on next page*)

Table 1 (*continued*)

Characteristics	Weighted prevalence[a], % (95% confidence interval)					P-value[b]
	All	Non-Hispanic White	Non-Hispanic Black	Hispanic	Non-Hispanic Others	
Female	1.01 (0.75,1.27)	0.79(0.48,1.10)	1.07(0.35,1.80)	1.50 (0.90,2.10)	0.82(0.33,1.31)	0.0703
Education[c]						
High School	1.15 (0.78,1.52)	0.98(0.36,1.60)	1.18(0.35,2.00)	1.36 (0.77,1.95)	0.45(0.00,0.98)	0.4736
College	0.95 (0.70,1.19)	0.58(0.34,0.82)	1.39(0.43,2.35)	1.46 (0.86,2.06)	1.19(0.54,1.83)	0.0075
Graduate	0.42 (0.22,0.62)	0.38(0.16,0.61)	0.88(0.00,1.86)	0.51 (0.00,1.36)	0.26(0.00,0.55)	0.5477
Family income to poverty ratio						
<1	1.22 (0.71,1.74)	0.77(0.00,1.62)	1.22(0.32,2.12)	1.66 (0.71,2.60)	0.71(0.00,1.53)	0.3947
1-2	1.09 (0.73,1.46)	1.01(0.48,1.55)	1.36(0.01,2.71)	1.08 (0.55,1.60)	0.99(0.05,1.94)	0.9359
2-4	1.00 (0.68,1.32)	0.72(0.37,1.06)	1.55(0.28,2.83)	1.30 (0.50,2.10)	1.28(0.36,2.19)	0.2266
>4	0.40 (0.25,0.56)	0.26(0.12,0.40)	0.41(0.00,0.90)	1.35 (0.41,2.29)	0.28(0.00,0.57)	<0.0001

[a]Weighted point estimates were estimated using SAS version 9.4 survey procedures (SAS Institute Inc). [b]Unadjusted p-values were estimated for the difference in prevalence by race/ethnicity groups using Rao-Scott chi-square test. [c]Highest level of education of all the adults in sample children's family. [d]One observation with a weight of 10^{-8} was added to the cell with zero value. [e]The cell had zero observations.

prediabetes in children revealed significant associations between prediabetes prevalence and race within various subgroups, including the age 12–17 subgroup, male subgroup, college-educated parental subgroup, and family income to poverty ratio > 4 subgroups ($p = 0.0002$, $p = 0.0009$, $p = 0.0075$, and $p < 0.0001$, respectively). Within the age 12–17 subgroup, Hispanic children exhibited the highest prediabetes prevalence at 2.50 % ([1.67 %, 3.34 %]), while non-Hispanic black children had the second-highest rate at 1.86 % ([0.92 %, 2.80 %]). In the male subgroup, both Hispanic and non-Hispanic black children showed higher prediabetes prevalence rates at 1.16 % ([0.65 %, 1.66 %]) and 1.41 % ([0.48 %, 2.33 %]), respectively. Within the college-educated parental subgroup, non-Hispanic black and Hispanic children had higher prediabetes prevalence rates at 1.39 % ([0.43 %, 2.35 %]) and 1.46 % ([0.86 %, 2.06 %]), respectively. In the family income to poverty ratio > 4 subgroup, Hispanic children displayed the highest prediabetes prevalence at 1.35 % ([0.41 %, 2.29 %]).

Among different racial/ethnic groups, no significant upward or downward trends between 2019 and 2021 were observed in the prevalence rates of overall diabetes and prediabetes. Fig. 1 illustrates a significant increasing trend in diabetes prevalence rates among the non-Hispanic others ($p = 0.0124$). Our analysis did not reveal any statistically significant trends within other racial/ethnic groups or in the

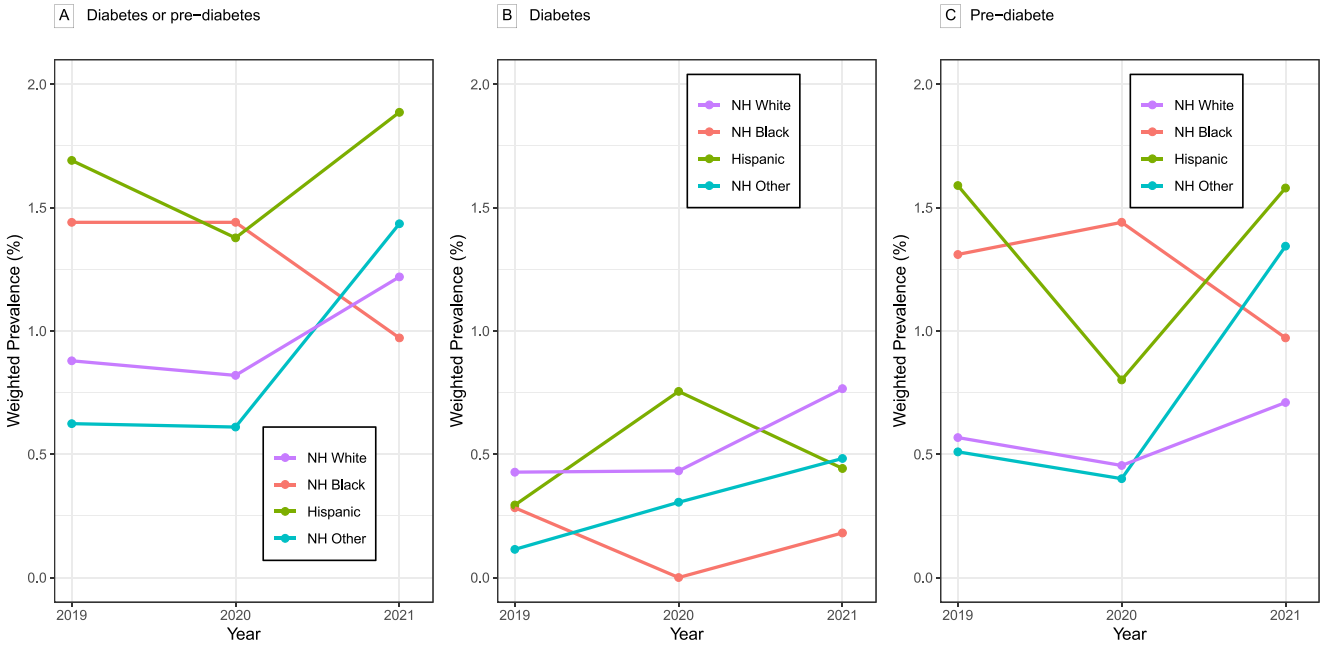

Fig. 1. Race/ethnicity-stratified weighted prevalence of either diabetes or pre-diabetes, diabetes only and pre-diabetes only in the United States children and adolescents aged 3 to 17 by year in the National Health Interview Survey, 2019–2021.

prediabetes or overall prevalence rates.

4. Discussion and conclusions

This study provided the latest update on prevalence rates and racial-ethnic disparities concerning diabetes, prediabetes, and overall diabetes. Lawrence et al. (Lawrence, 2021) reported prevalence rates of 0.215 % for T1D and 0.067 % for T2D among children and adolescents in the United States in 2017. Consequently, the prevalence rate for either T1D or T2D in 2017 was, at most, 0.282 %. In contrast, our analysis revealed a diabetes prevalence rate of 0.46 % (95 % CI [0.32 %, 0.59 %]) during 2019–2021, significantly higher than the upper bound of 0.282 %, suggesting a potential increase in diabetes prevalence among U.S. children and adolescents from 2017 to 2021. However, it's important to note that Lawrence et al. (Lawrence, 2021) reported the prevalence rate from the SEARCH for Diabetes in Youth (SEARCH) registry study, whereas our study is based on the analysis of the NHIS survey. As a result, direct comparisons between these rates may be limited.

Our study highlighted disparities in the prevalence of prediabetes and overall diabetes, with non-Hispanic Black and Hispanic children showing higher rates compared to non-Hispanic white and non-Hispanic other racial/ethnic children. While we did not find disparities in diabetes prevalence, our findings were consistent with those of Lawrence et al. (Lawrence, 2021) over time, indicating persistent disparities. During the 2019–2021 period, within the age 12–17 subgroup, Hispanic children displayed high prevalence rates of prediabetes, diabetes, and overall diabetes, non-Hispanic Black children exhibited high prevalence rates of prediabetes and overall diabetes, and non-Hispanic white children had a high prevalence of diabetes. Significant disparities in the prevalence of diabetes, prediabetes, and overall diabetes were observed within the 12–17 age subgroups, suggesting that Hispanic and non-Hispanic Black children may have experienced higher prevalence of prediabetes or diabetes. Notably, no discernible change in the trend of diabetes or prediabetes was observed within subgroups of racial/ethnic groups, except for the non-Hispanic other racial/ethnic group, which exhibited an increasing trend in diabetes prevalence between 2019 and 2021.

In interpreting the findings of our study, it is important to acknowledge several limitations that may impact the generalizability and robustness of our results. Firstly, our study relied on self-reported data obtained from the NHIS, which was subject to recall bias and misclassification bias. Parents or guardians may not accurately recall or report the diagnoses of diabetes and prediabetes among children and adolescents, leading to potential underestimation or overestimation of prevalence rates. Additionally, the NHIS survey only included two general questions regarding prediabetes and diabetes, but it lacked specific questions to differentiate between T1D and T2D. This deficiency impeded our ability to interpret study results effectively, hindering efforts to enhance surveillance and prevention strategies for both types of diabetes separately. Finally, while the NHIS provided nationally representative data, our study focused exclusively on the US population and may not be generalizable to other countries or regions with different healthcare systems, sociodemographic characteristics, and prevalence patterns of diabetes and prediabetes.

By adopting a comprehensive approach that encompasses early detection, prevention, education, community engagement, policy changes, and research, the health sectors can effectively intervene to address the increasing rates of pediatric diabetes and prediabetes and improve the health outcomes of children and adolescents. The actions that can be taken are as follows. Implementing widespread screening programs to identify children at risk for diabetes or prediabetes early on can facilitate timely intervention and management. Launching public health campaigns aimed at promoting healthy behaviors such as regular physical activity, balanced nutrition, and maintaining a healthy weight can help prevent the onset of diabetes and prediabetes in children. Educating children, parents, caregivers, and healthcare providers about diabetes prevention, management, and risk factors can empower individuals to make informed decisions about their health and lifestyle choices. Implementing interventions within schools to create supportive environments for healthy behaviors, such as providing nutritious meals, incorporating physical activity into the curriculum, and offering diabetes education and support services. Advocating for policy changes at the local, state, and national levels to support diabetes prevention and management efforts, such as implementing regulations on sugary beverage consumption, improving access to healthy foods in underserved communities, and supporting initiatives to increase physical activity in schools and neighborhoods.

In conclusion, this study demonstrated that racial/ethnic disparities in the prevalence of overall diabetes and prediabetes persisted between 2019 and 2021, with no observed change in the trend among different racial/ethnic subgroups. Further efforts to mitigate the prevalence of diabetes and prediabetes in non-Hispanic black and Hispanic children and adolescent may be warranted.

CRediT authorship contribution statement

Cancan Zhang: Writing – review & editing, Writing – original draft, Validation, Software, Formal analysis. **Hui Zhang:** Writing – review & editing, Validation, Project administration, Conceptualization. **Bo Zhang:** Writing – review & editing, Validation, Project administration, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The NHIS survey data is publicly available.

Dr. Hui Zhang's research was in part supported by the Northwestern Brain Tumor SPORE (NCI Grant No. P50CA221747), the Mesulam Center for Cognitive Neurology and Alzheimer's Disease (NIA Grant No. 5P30AG072977), and the Robert H. Lurie Comprehensive Cancer Center (NCI Grant No. P30CA060553), all of which were affiliated with the Northwestern University Feinberg School of Medicine in Chicago, IL, USA. We express gratitude to Shanshan Liu for her initial attempt in data analysis for this research article, despite not making further contributions.

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