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Unveiling inequalities: Racial, ethnic, and socioeconomic disparities in diabetes: Findings from the 2007-2020 NHANES data among U.S. adults

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ABSTRACT

Objective: Despite persistent disparities in diabetes prevalence among racial and ethnic minorities, there remains a significant lack of understanding regarding the intersectionality of racial and ethnic groups and socioeconomic status (SES) with diabetes.

Methods: The data came from the National Health and Nutrition Examination Survey (NHANES; $N = 30{,}754$, mean age = 47.4) using cross-sectional survey cycles from 2007 to 2008 through 2017–2020. Diabetes status was self-reported by physician diagnosis. Sociodemographic factors included racial and ethnic groups and SES. Weighted Poisson models were used to examine the association of racial and ethnic groups and SES with diabetes, stratified by age groups (20–44, 45–64, 65–79), sex, and racial and ethnic groups for SES, separately.

Results: Non-Hispanic Black, Hispanic, and other adults had a 47 %, 31 %, and 76 % higher prevalence of diabetes than non-Hispanic White adults, while adults from low and middle SES compared to high SES had a 37 % and 22 % higher prevalence of diabetes. Non-Hispanic Black, Hispanic, and other adults aged 45–64 years had a 45 %, 34 %, and 78 % higher prevalence of diabetes, and low and middle SES had a 57 % and 32 % higher prevalence of diabetes. Similar patterns were observed for adults aged 65–79. Males among non-Hispanic Black, Hispanic, and other adults and females from low and middle-SES families had a higher prevalence of diabetes.

Conclusion: Minority groups, middle and older-aged adults, males from minority groups, and females from low SES had a greater prevalence of diabetes. Effective interventions should prioritize tailoring efforts to specific minoritized and low SES groups to address diabetes disparities.

1. Introduction

Diabetes mellitus has become one of the most common metabolic diseases (Hassan et al., 2023; Sun et al., 2022). Diabetes increases the risk of cardiovascular disease (Matheus et al., 2013), dysfunction of different organs (Krishnan et al., 2013) (e.g., eyes, kidneys, foot), and mortality (Raghavan et al., 2019; Saeedi et al., 2020). Recent surveillance data from the Centers for Disease Control and Prevention (CDC) estimate that 14.7 % (approximately 38.4 million) of U.S. adults aged ≥18 years have diabetes (CDC, 2020). Furthermore, the latest data showed that the U.S. direct estimated costs of diabetes have increased by 7 % from $286 billion in 2017 to $307 billion in 2022 (Parker et al., 2024). Diabetes disproportionately varies by certain racial and ethnic minorities (i.e., non-Hispanic Black, Hispanic, and non-Hispanic Asian adults) and those from lower socioeconomic status (SES) (Agardh et al., 2011; Bullard et al., 2018; Cameron et al., 2021; Tan et al., 2020; Tatulashvili et al., 2020). Previous research indicated that the most persistent disparities in diabetes were shown by minority groups (Antonio-Villa et al., 2022; Cheng et al., 2019; Wang et al., 2021). For instance, one study found that non-Hispanic Black adults reported having type 2 diabetes at a higher rate than non-Hispanic White adults (13.2 vs 7.6 %) (Ferdinand and Nasser, 2015). Previous studies have also found that individuals with lower SES had a high risk of diabetes, which was associated with limited access to health resources and care (Agardh

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et al., 2011; Kyrou et al., 2020; Lee et al., 2011; Lipscombe et al., 2010; Lysy et al., 2013). These findings underscored the disparities in diabetes among racial and ethnic minorities and socioeconomically disadvantaged populations (Liu et al., 2023). Other sociodemographic factors, such as age and sex, were also significant risk factors for diabetes (Cheng et al., 2013; Fagot-Campagna et al., 2005; Fang et al., 2023; Liu et al., 2023; Wright et al., 2020). Despite these findings, there remains a dearth of research examining the intersectionality of racial and ethnic groups and SES, and sociodemographic factors, such as age and sex and how these factors interact with racial and ethnic groups and SES in relation to diabetes. Taken together, a critical gap remains in understanding the intersectionality of racial and ethnic groups and SES with diabetes.

The latest perspective article from the National Institute on Minority Health and Health Disparities strongly emphasizes that racial and ethnic groups and SES are fundamental drivers of health disparities (Pérez-Stable and Webb Hooper, 2023), and underscores the necessity for research prioritization through an intersectional lens (Pérez-Stable and Webb Hooper, 2023), considering the interaction of racial and ethnic groups and SES with disparities in diabetes. Thus, the primary aim of this study was to examine the association of racial and ethnic groups and SES with the prevalence of diabetes using data from a large, nationally representative sample of U.S. adults. The secondary aim was to test whether age and sex moderate the association of racial and ethnic groups and SES-related disparities with the prevalence of diabetes. The last aim was to explore how racial and ethnic groups moderate these associations.

2. Subjects, materials and methods

2.1. Study participants

This study retrieved data from the 2007–2020 NHANES, utilizing the cross-sectional survey cycles from 2007 – 2008, 2009–2010, 2011–2012, 2013–2014, 2015–2016, and 2017–2020 (CDC, 2020). NHANES uses a stratified multistage sampling method to represent the U.S. population. The sampling frame encompassed 36,691 participants aged 20–79 years. The final analytical sample resulted in $n = 30{,}754$ participants drawn from the six NHANES cycles between 2007 and 2020 (details of the exclusion criteria are provided in eFig.1 in the Supplement). The NHANES protocol received approval from the National Center for Health Statistics research ethics review board and all participants provided written informed consent.

2.2. Measures

2.2.1. Outcomes

Diabetes was defined as the following self-reported survey items based on a previous physician's diagnosis. Participants were classified as having diabetes based on the following criteria: if they answered “yes” to the question, “Have you ever been told by a doctor or health professional that you have diabetes or sugar diabetes?”

2.2.2. Exposures

Self-identified racial and ethnic groups included non-Hispanic White, non-Hispanic Black, Mexican American, and other Hispanic adults, and non-Hispanic Other adults (e.g., non-Hispanic Asian and multi-racial adults). We further categorized as non-Hispanic White, non-Hispanic Black, Hispanic (including Mexican American and other Hispanic adults), and Other adults. Poverty-income ratio (PIR), serving as SES, was based on family income relative to poverty guidelines. PIR was calculated by the U.S. Census Bureau by dividing family income by the poverty threshold specific to family size and geographic location. SES based on PIR was classified into as low SES (PIR < 1.3), middle SES (PIR ≥ 1.3 and < 3.5), and SES high income (PIR ≥ 3.5) (Jackson et al., 2018).

2.2.3. Moderators

Self-reported sociodemographic variables included age (20–44, 45–64, 65–79), sex (male, female), and racial and ethnic groups (also used as a moderator in the association between PIR and diabetes for the third aim). Racial and ethnic groups were used as a moderator for the last aim.

2.2.4. Covariates

Education levels included: 1) high school or less, 2) some college/associate degree, and 3) bachelor and above. Participants' standing height was measured using a portable stadiometer, and their weight was recorded with a portable digital scale. Body Mass Index (BMI) was based on weight in kilograms divided by height in meters squared (kg/m^2). Weight status included normal weight (BMI = 18.5–24.9), overweight (BMI = 25.0–29.9), and obesity (BMI $\geq$ 30.0). The Global Physical Activity Questionnaire was used to collect respondent-level weekly physical activity. The weekly physical activity metabolic equivalent of task (MET) was computed using the MET scores of the daily physical activity duration, and the number of days per week being engaged. Subsequently, the physical activity level was classified into meeting the guidelines ($\geq$ 500 MET minutes/week) and not meeting the guidelines ($<$ 500 MET minutes/week) (Piercy et al., 2018). Survey years included six cycles.

2.3. Statistical analyses

Accounting for sampling weights, strata, and primary sampling units in the NHANES complex sampling design, survey analysis procedures were used to derive nationally representative estimates. For descriptive statistics, we estimated weighted means and standard deviation for continuous variables. Additionally, we provide a description of diabetes trends from 2007 to 2020, both overall and stratified by subgroups (age, sex, racial and ethnic groups, and SES). A survey-weighted Poisson regression model was used to evaluate the prevalence of diabetes trends.

To answer the first aim, we employed survey-weighted Poisson regression models to investigate the associations of racial and ethnic groups and SES with the prevalence of diabetes. The prevalence ratios (PRs) and corresponding 95 % CIs were calculated. The interaction between racial and ethnic groups, age, sex, and SES was examined using survey-weighted Poisson regression models. As the secondary aim, the analyses were stratified by age groups and sex, separately. Lastly, SES was stratified by race and ethnic groups. The interaction between racial and ethnic groups, age, sex, and SES was examined using survey-weighted Poisson regression models. Sensitivity analyses were conducted to include participants with diabetes at borderline (i.e., a condition that is at the threshold of a diagnosis but does not fully meet the diabetes criteria) and self-reported diabetes as the outcome to explore associations of racial and ethnic groups and SES with the prevalence of diabetes. All analyses were conducted using the R statistical software “Survey” package (e.g., “svymean” and “svyglm”), taking into account the complex sampling design (version 4.2.2; www. R-project.org).

3. Results

3.1. Participants' characteristics

The present study comprised data from 30,754 adults, over half identified as female (Table 1). The mean age of the participants was 47.4 years (SD $\pm$ 16.81). Approximately, 67.4 % identified as non-Hispanic White, 11.0 % as non-Hispanic Black, 13.9 % as Hispanic, and 7.7 % as other racial and ethnic categories. 42.9 % identified as high SES based on PIR, 35.3 % as middle SES, and 21.8 % as low SES. 33.3 % of participants were overweight, while 38 % were obese. Fig. 1 showed overall diabetes prevalence weighted proportions stratified by age, sex, racial and ethnic groups. The details of the diabetes prevalence trend from 2007 to 2020 are available in Supplementary eTable 1. Notably,

Table 1
Weighted descriptive characteristics of the study participants from the United States adults 2007–2020.

Demographics		Diabetes	
	Overall (n = 30,754)	No (n = 26,511 [89.9 %])	Yes (n = 4,243 [10.1 %])
Age group			
20–44	12,935 (44.8)	12,478 (48.5)	457 (13.2)
45–64	10,623 (36.7)	8,742 (35.5)	1,881 (47.0)
65–79	7,196 (18.5)	5,291 (16.0)	1,905 (39.8)
Sex			
Male	15,101 (48.8)	12,885 (48.5)	2,216 (51.7)
Female	15,653 (51.2)	13,626 (51.5)	2,027 (48.3)
Racial and ethnic groups			
Non-Hispanic White	12,811 (67.4)	11,333 (68.1)	1,478 (61.5)
Non-Hispanic Black	6,788 (11.0)	5,619 (10.5)	1,169 (15.1)
Hispanic	7,446 (13.9)	6,310 (13.8)	1,136 (14.7)
[a]Other race	3,709 (7.7)	3,249 (7.6)	460 (8.7)
SES based on [b]PIR			
High SES (PIR ≥ 3.5)	9,358 (42.9)	8,365 (43.9)	993 (34.0)
Middle SES (PIR =1.3–3.4)	11,513 (35.3)	9,816 (34.7)	1,697 (40.0)
Low SES (PIR < 1.3)	9,883 (21.8)	8,330 (21.4)	1,553 (26.0)
Education			
High school or less	14,155 (38.1)	11,778 (36.8)	2,377 (49.0)
Some college/associate degree	9,291 (31.5)	8,092 (31.5)	1,199 (31.6)
Bachelor or above	7,308 (30.4)	6,641 (31.7)	667 (19.4)
Weight status (kg/m^2)			
Normal 18.5–24.9	8,459 (28.7)	7,915 (30.6)	544 (11.1)
Overweight 25.0–29.9	10,171 (33.3)	8,972 (34.2)	1,199 (25.5)
Obese 30.0+	12,124 (38.0)	9,624 (35.1)	2,500 (63.4)
Physical activity guidelines (min/week)			
<500 [c]MET	11,805 (33.7)	9,510 (31.7)	2,295 (51.0)
≥500 MET	18,949 (66.3)	17,001 (68.3)	1,948 (49.0)

Note: Categorical variables are presented as frequency (weighted %).
[a] Other: adults include non-Hispanics, reported other or two or more racial and ethnic groups.
[b] PIR represents the Poverty Income Ratio and is determined by the US Census Bureau.
[c] Metabolic equivalent of task (MET).

those 65–79 years, males, non-Hispanic Black, Hispanic, and Other adults showed higher diabetes prevalence than the non-Hispanic White adults. Moreover, adults from low SES, high school or less, and physical activity <500 MET demonstrated the highest prevalence.

3.2. Overall association of racial and ethnic groups and SES with the prevalence of diabetes

Compared to non-Hispanic White adults, non-Hispanic Black adults, Hispanic, and Other adults had a 47 % (PR = 1.47 [95 % CI: 1.33–1.62]), 31 % (PR = 1.31 [95 % CI: 1.19–1.44]), and 76 % (PR = 1.76 [95 % CI: 1.54–2.00]) higher prevalence of diabetes, respectively (Table 2). Adults from low and middle SES had a 37 % (PR = 1.37, [95 % CI: 1.23–1.52]) and 22 % (PR = 1.22 [95 % CI: 1.10–1.35]) higher prevalence of diabetes than those from high SES, respectively. Further details on the results of other sociodemographic variables were provided in Supplementary eTable 2.

Table 2
Overall association of racial and ethnic groups and socioeconomic status with diabetes among the United States. adults, 2007–2020 (n = 30,754).

	Adjusted prevalence ratio (95 % CI)
Racial and ethnic groups	
Non-Hispanic White	1.00
Non-Hispanic Black	1.47 (1.33, 1.62)
Hispanic	1.31 (1.19, 1.44)
Other race	1.76 (1.54, 2.00)
SES based on PIR	
High SES (PIR ≥ 3.5)	1.00
Middle SES (PIR = 1.3–3.4)	1.22 (1.10, 1.35)
Low SES (PIR < 1.3)	1.37 (1.23, 1.52)

Note: Models were adjusted for age, sex, education, BMI, PA, and survey years.
Other races: Other racial and ethnic groups include non-Hispanics reporting to others.
or two or more racial and ethnic groups.
PIR represents the Poverty Income Ratio and is determined by the US Census Bureau.

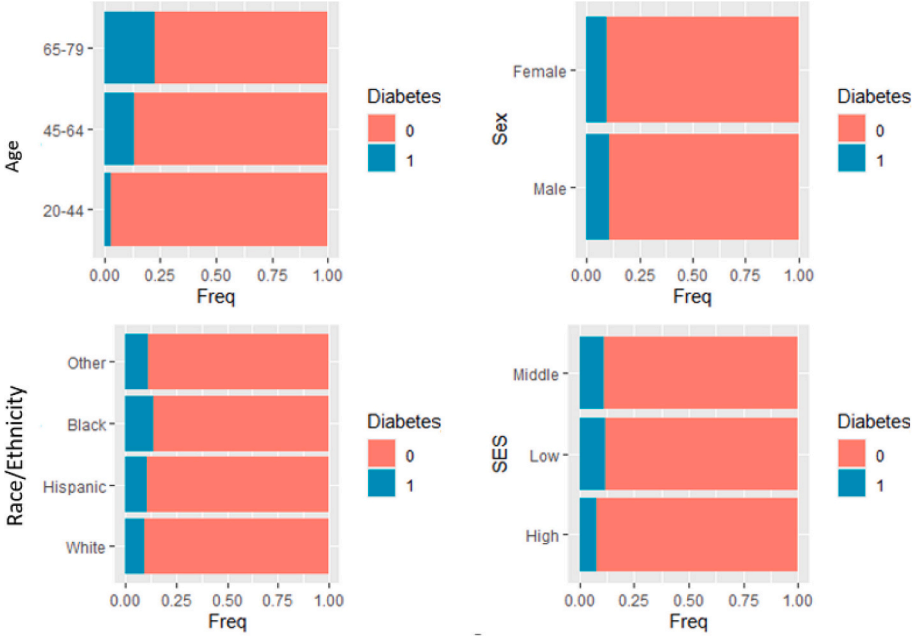

Fig 1. Weighted proportions in diabetes prevalence, stratified by age, sex, race/ethnicity, SES from 2007-2008 to 2017-2020
Note: Diabetes refers to diabetes cases categorized as a binary variable (Yes=1 and No=0).SES refers to socioeconomic status.

3.3. Associations stratified by age groups and sex

Overall, the interaction between racial and ethnic groups and age and the interaction between SES and sex were significant ($P < 0.05$). Among adults aged 20–44 years, no associations were observed for race and ethnic groups and SES (Table 3). Among adults aged 45–64 years, compared to non-Hispanic White adults, non-Hispanic Black, Hispanic, and other groups had a higher prevalence of diabetes, respectively (PR = 1.45 [95 % CI: 1.26–1.67]; PR = 1.34 [95 % CI: 1.17–1.55]; and PR = 1.78 [95 % CI: 1.46–2.18]). Compared to high SES, adults with low and middle SES also exhibited a higher prevalence of diabetes, respectively (PR = 1.57 [95 % CI: 1.33–1.84] and PR = 1.32 [95 % CI: 1.15–1.52]). Among adults aged 65–79 years, compared to non-Hispanic White adults, non-Hispanic Black, Hispanic, and other racial and ethnic groups had a higher prevalence of diabetes, respectively (PR = 1.56 [95 % CI: 1.41–1.72]; PR = 1.38 [95 % CI: 1.24–1.53]; and PR = 1.91 [95 % CI: 1.61–2.28]). Compared to high SES, adults from low and middle SES also exhibited a higher prevalence of diabetes, respectively (PR = 1.25 [95 % CI: 1.05–1.48] and PR = 1.20 [95 % CI: 1.03–1.40]).

Compared to non-Hispanic White males, non-Hispanic Black, Hispanic, and other race and ethnic males had a higher prevalence of diabetes, respectively (PR = 1.49 [95 % CI: 1.31–1.68]; PR = 1.35 [95 % CI: 1.19–1.53]; and PR = 1.62 [95 % CI: 1.38–1.90]) (Table 4). Males with low SES compared to high SES had a 20 % (PR = 1.20 [95 % CI: 1.03–1.40]) higher prevalence of diabetes. Similarly, compared to White females, non-Hispanic Black, Hispanic, and other racial and ethnic females had a higher prevalence of diabetes, respectively (PR = 1.42 [95 % CI: 1.25–1.62]); PR = 1.28 [95 % CI: 1.13–1.45]; and PR =1.91 [95 % CI, 1.59–2.29]). Compared to the high SES, females with low and middle SES had a higher prevalence of diabetes, respectively (PR = 1.49 [95 % CI: 1.28–1.74]; PR = 1.30 [95 % CI: 1.12–1.51]).

3.4. Associations stratified by SES

The interaction between racial and ethnic groups and SES was also significant ($P < 0.05$). Among non-Hispanic White adults, those with low and middle SES compared to high SES had a higher prevalence of diabetes, respectively (PR = 1.46 [95 % CI: 1.27–1.69]; and PR = 1.21 [95 % CI: 1.06–1.38]) (eTable 3). Similarly, non-Hispanic Black and Hispanic adults from low SES compared to high SES showed a 20 % (PR = 1.20 [95 % CI: 1.02–1.43]) and 25 % (PR = 1.25 [95 % CI: 1.04–1.51]) higher prevalence of diabetes, but no significant association was observed with middle SES among non-Hispanic Black and Hispanic groups. Lastly, other individuals from low and middle SES, compared to high SES, exhibited a higher prevalence of diabetes, respectively (PR = 1.48 [95 % CI: 1.14–1.92]; PR = 1.36 [95 % CI: 1.07–1.72]).

Table 3
Age-moderated associations of race and ethnicity and socioeconomic status with diabetes among the United States adults, 2007–2020.

	Aged 20–44 (n = 12,935)	Aged 45–64 (n = 10,623)	Aged 65–79 (n = 7,196)
	Adjusted prevalence ratio (95 % CI)	Adjusted prevalence ratio (95 % CI)	Adjusted prevalence ratio (95 % CI)
Racial and ethnic groups			
Non-Hispanic White	1.00	1.00	1.00
Non-Hispanic Black	1.24 (0.95, 1.63)	1.45 (1.26, 1.67)	1.56 (1.41, 1.72)
Hispanic	1.06 (0.80, 1.41)	1.34 (1.17, 1.55)	1.38 (1.24, 1.53)
Other race	1.25 (0.88, 1.78)	1.78 (1.46, 2.18)	1.91 (1.61, 2.28)
SES based on PIR			
High SES (PIR ≥ 3.5)	1.00	1.00	1.00
Middle SES (PIR = 1.3–3.4)	0.83 (0.58, 1.18)	1.32 (1.15, 1.52)	1.20 (1.03, 1.40)
Low SES (PIR < 1.3)	0.94 (0.66, 1.34)	1.57 (1.33, 1.84)	1.25 (1.05, 1.48)

Note: Models were adjusted for age, education, BMI, PA, and survey years.
Other races: Other races/ethnicities include non-Hispanics reporting other or two or more races/ethnicities.
PIR represents the Poverty Income Ratio, and is determined by the US Census Bureau.

Table 4
Sex-moderated associations of racial and ethnic groups and poverty with diabetes among the United States adults from 2007 to 2020.

	Male (n = 15,101)	Female (n = 15,653)
	Adjusted prevalence ratio (95 % CI)	Adjusted prevalence ratio (95 % CI)
Racial and ethnic groups		
Non-Hispanic White	1.00	1.00
Non-Hispanic Black	1.49 (1.31, 1.68)	1.42 (1.25, 1.62)
Hispanic	1.35 (1.19, 1.53)	1.28 (1.13, 1.45)
Other race	1.62 (1.38, 1.90)	1.91 (1.59, 2.29)
SES based on PIR		
High SES (PIR ≥ 3.5)	1.00	1.00
Middle SES (PIR = 1.3–3.4)	1.16 (1.00, 1.34)	1.30 (1.12, 1.51)
Low SES (PIR < 1.3)	1.20 (1.03, 1.40)	1.49 (1.28, 1.74)

Note: Models were adjusted for age, education, BMI, PA, and survey years.
Other races: Other races/ethnicities include non-Hispanics reporting other or two or more races/ethnicities.
PIR represents the Poverty Income Ratio, and is determined by the US Census Bureau.

4. Discussion

Our study investigated how race, ethnicity, and SES were associated with the prevalence of diabetes using a nationally representative sample of NHANES between 2007 and 2020. Our analysis revealed persistent disparities that non-Hispanic Black, Hispanic, and other racial and ethnic groups (compared to non-Hispanic White adults) and individuals from low and middle SES (compared to high SES) had a higher prevalence of diabetes. Furthermore, diabetes disparities were indicated in middle-aged minorities and individuals with low and middle SES with a higher prevalence of diabetes but not for those aged 20–44 years. Furthermore, sex-stratified models showed males among non-Hispanic Black, Hispanic, and other adults and females from low and middle SES families had a higher prevalence of diabetes. Lastly, racial and ethnic-stratified analyses demonstrated that a higher prevalence of diabetes persisted across all racial and ethnic groups in low SES groups. Future research should prioritize local efforts (e.g., including community, local organizations, and state government) and investments in racial and ethnic minorities and lower SES groups, which is crucial for reducing the prevalence of diabetes.

Consistent with the previous research, a higher prevalence of diabetes was observed among non-Hispanic Black and Hispanic adults and other racial and ethnic groups compared to non-Hispanic White counterparts (Hassan et al., 2023; Wright et al., 2020). For example, a study using 1999–2018 years NHANES indicated that non-Hispanic Black, Hispanic, and non-Hispanic Asian adults compared to non-Hispanic White adults had a higher prevalence total diabetes respectively (Liu et al., 2023). Using the most recent data, our study confirms the persistent disparities experienced by minority groups. A potential explanation may be that minority groups have limited access to quality healthcare and unequal distribution of neighborhood resources compared to non-Hispanic White adults (Hassan et al., 2023). In addition, our findings further indicated that low and middle SES had a higher prevalence of diabetes compared to their high SES counterparts, which

was consistent with previous research (Agardh et al., 2011; Bilal et al., 2018; Liu et al., 2023). For example, a similar study using the NHANES demonstrated that adults from middle and high SES (compared to low SES) had a lower prevalence of total diabetes, respectively (Liu et al., 2023). Moreover, a meta-analysis study found that, compared to high SES groups, lower SES groups had a 40 % prevalence of type 2 diabetes (Agardh et al., 2011). One plausible explanation for these consistent findings is that individuals in low and middle SES may reside in unfavorable environments (e.g., limited access to physical activity and healthy food) (Agardh et al., 2011; Bilal et al., 2018; Zhao et al., 2020). This lack of environmental support may impede healthy behaviors, contributing to the higher prevalence of diabetes among low SES groups (Bilal et al., 2018). Future interventions should prioritize improving access to affordable and quality healthcare and promoting activity-friendly neighborhood resources for minority and low and middle SES as crucial steps toward reducing disparities in the development of diabetes (American Diabetes Association Professional Practice, 2024a; Hassan et al., 2023).

Beyond the previous scope of studies (Cameron et al., 2021; Liu et al., 2023), this study investigated age-stratified analyses. Age-stratified analyses indicated that non-Hispanic Black, Hispanic, and other race and ethnic participants aged 65–79 had the highest prevalence of diabetes, followed by those aged 45–64. Previous studies supported our findings that type 2 diabetes most often develops in adults over age 45 (Cameron et al., 2021; CDC, 2024; Chen et al., 2021). Moreover, our findings align with previous research (Chen et al., 2021), indicating that middle-aged adults with low SES groups had a higher risk of diabetes compared to older age groups. Future strategies need to be tailored to specific age groups across the lifespan and aimed across specific race and ethnic groups (Hassan et al., 2023). For young adults, increasing diabetes screening is crucial for averting the onset of diabetes (Davidson et al., 2021).

Sex-stratified analyses revealed that males among non-Hispanic Black and Hispanic adults had a higher prevalence of diabetes. A previous NHANES study confirmed that diabetes is also common among non-Hispanic Black and Mexican American males (Fang et al., 2023). Males are slightly more likely to have diabetes than females, primarily due to higher amounts of abdominal fat (Delaney and Santosa, 2022). In addition, we found that females from low and middle-SES families had a higher prevalence of diabetes. Consistent with prior studies (Chen et al., 2021), our study also highlights that female adults with low SES have a higher prevalence of developing diabetes compared to those with high SES (Chen et al., 2021). For example, the previous study found that women from low SES families had the highest risk of developing diabetes compared to their male counterparts (Chen et al., 2021). Moreover, another study emphasized that women with declining SES, compared to women who maintained high SES, had an 18 % greater risk of diabetes (Lidfeldt et al., 2007). Taken together, females from low SES are particularly susceptible to diabetes due to psychological factors (e.g., chronic stress)(Harris et al., 2017) and other risk factors (e.g., lack of physical activity) associated with low SES groups (Dinca-Panaitescu et al., 2012). In light of these findings, future clinical and public health strategies should focus on developing targeted interventions to reduce diabetes risk among males from non-Hispanic Black and Hispanic populations and females from low SES, considering the unique psychological and socioeconomic challenges they face.

Racial and ethnic-stratified analyses demonstrated that the higher prevalence of diabetes persisted across all racial and ethnic groups, specifically in low SES groups. This aligns with prior research indicating that non-Hispanic Black adults and individuals with low-income groups had a higher prevalence of diabetes (Gaskin et al., 2014). Possible explanations are that people in low SES groups across all racial/ethnic groups were more likely to consume less healthy diets (e.g., nutritionally poor foods), lower physical activity, and lack access to quality healthcare (Seligman et al., 2010; Sigal et al., 2006). These insights underscore the urgent need for proactive interventions (e.g., implementing educational programs including diabetes management and healthy lifestyle choices (American Diabetes Association Professional Practice, 2024b) to address the disparities in diabetes prevalence and management among low SES populations. Stakeholders and policymakers should invest in certain initiatives to improve access to healthcare, promote healthy lifestyle behaviors, and address social determinants of health to combat the burden of diabetes in vulnerable communities (Gaskin et al., 2014; Hassan et al., 2023). Additionally, engaging communities and employing community-based participatory research are crucial steps in planning effective strategies to enhance the adoption of diabetes treatment interventions among low-income groups (Hassan et al., 2023; Hill-Briggs et al., 2020). Simultaneously, researchers must apply a health equity lens to ensure that these interventions are implemented to not only mitigate existing disparities but also prevent further exacerbating inequalities in diabetes (Brownson et al., 2021; Hassan et al., 2023).

4.1. Strengths and limitations

The strengths of this study included utilizing the most up-to-date available data from a nationally representative sample of adults from 2007 to 2020. Another strength is the large sample size, which provided sufficient statistical power to examine the intersectionality of racial and ethnic groups and SES. Moreover, our sensitivity analysis combined participants with borderline diabetes ($n = 724$) and self-reported diabetes generally showed similar results. Last, this study employed a rigorous multivariable survey-weighted data analysis and accounted for the key sociodemographic factors and survey cycles. This methodological approach significantly enhances the depth and reliability of the findings, strengthening the validity of the study's conclusion.

This study has several limitations. First, the NHANES data are based on repeated cross-sectional surveys, limiting our ability to establish causality. Second, our study was limited by an inability to distinguish type 1 and type 2 diabetes. Self-reported diabetes diagnoses can introduce biases and inaccuracies, potentially underestimating or overestimating the true prevalence of diabetes within the studied population (Fang et al., 2022), Future studies could benefit from incorporating clinical assessments and laboratory tests to confirm diabetes diagnoses in accordance with American Diabetes Association criteria, thereby enhancing the accuracy and reliability of the findings (ElSayed et al., 2024; Jagannathan et al., 2020; Jagannathana et al., 2021). Lastly, other racial and ethnic groups need to be disentangled into Asian and multiracial groups, including Asian American and Pacific Islander and Pacific Islander, multiple-race, and American Indian and Alaskan Native populations, to gain deeper insights into the dynamics of diabetes prevalence among diverse racial and ethnic groups on diabetes (Hassan et al., 2023).

5. Conclusions

Our study, exploring the intersectionality of racial and ethnic and SES-related disparities, highlighted that individuals who are racial and ethnic minorities with low SES had a higher risk of diabetes than their counterparts. Furthermore, age and sex-stratified analyses demonstrated that middle-aged adults and females from low SES groups were at the highest risk of diabetes. To address these disparities, prioritizing local efforts to invest in racial andethnic minority communities and lower SES areas is crucial for reducing the disparities in diabetes.

Disclaimer

The views expressed in this study are those of the authors and do not necessarily represent those of the NIMHD, the NIH, or the U.S. Department of Health and Human Services.

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CRediT authorship contribution statement

Yangyang Deng: Writing – review & editing, Writing – original draft, Formal analysis. **Mohammad Moniruzzaman:** Writing – review & editing. **Breanna Rogers:** Writing – review & editing. **Lu Hu:** Writing – review & editing. **Ram Jagannathan:** Writing – review & editing. **Kosuke Tamura:** Writing – review & editing, Supervision, Funding acquisition, 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

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2024.102957.

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