Letters

RESEARCH LETTER

Trends in Prediabetes Among Youths in the US From 1999 Through 2018

The US Preventive Services Task Force recently released a recommendation on screening for prediabetes and type 2 diabetes among adults,[1] but no recommendation has been issued for youths to date. A recent study[2] estimated that among youths aged 12 to 19 years, approximately 1 in 5 had prediabetes, with large variations across sociodemographic characteristics. However, trends in the prevalence of prediabetes among youths and associated disparities by population subgroups over the past 2 decades have not been reported to our knowledge, and such information is important for future diabetes prevention. In this

Table 1. Characteristics of US Youths Included in the Study by NHANES Cycles From 1999 Through 2018

	1999-2002 (n = 1862)		2003-2006 (n = 1788)		2007-2010 (n = 998)		2011-2014 (n = 1064)		2015-2018 (n = 886)	
Characteristic	No.	% (95% CI)[a]	No.	% (95% CI)[a]	No.	% (95% CI)[a]	No.	% (95% CI)[a]	No.	% (95% CI)[a]
Age, y										
12-15	938	49.9 (46.7-53.1)	882	48.7 (44.5-52.8)	485	50.5 (46.4-54.6)	544	50.5 (46.5-54.5)	440	48.8 (44.4-53.3)
16-19	924	50.1 (46.9-53.3)	906	51.3 (47.2-55.5)	513	49.5 (45.4-53.6)	520	49.5 (45.5-53.5)	446	51.2 (46.7-55.6)
Sex										
Female	903	48.8 (45.4-52.2)	843	48.4 (44.8-52.0)	450	49.0 (44.2-53.7)	539	48.8 (44.9-52.8)	451	49.2 (44.9-53.4)
Male	959	51.2 (47.8-54.6)	945	51.6 (48.0-55.2)	548	51.0 (46.3-55.8)	525	51.2 (47.2-55.1)	435	50.9 (46.6-55.1)
Race and ethnicity										
Hispanic	774	16.9 (13.0-21.8)	623	15.7 (12.3-19.7)	397	18.7 (14.0-24.4)	325	21.9 (17.4-27.1)	276	23.5 (17.9-30.2)
Non-Hispanic										
Asian	NA	NA	NA	NA	NA	NA	129	4.70 (3.23-6.78)	93	5.01 (3.32-7.50)
Black	515	13.8 (10.5-18.1)	628	14.8 (11.5-18.8)	215	14.8 (11.9-18.4)	295	15.1 (11.5-19.7)	194	13.4 (10.1-17.7)
White	490	61.4 (56.4-66.2)	461	63.8 (57.8-69.4)	331	60.2 (53.4-66.7)	269	54.4 (47.7-60.9)	268	52.3 (45.7-58.9)
Other[b]	83	NC	76	NC	55	NC	46	NC	55	NC
Parental educational level[c]										
<High school	706	21.3 (18.3-24.8)	566	18.0 (15.3-21.0)	287	18.2 (14.9-21.9)	284	21.7 (18.2-25.8)	186	18.4 (13.6-24.6)
High school	824	53.9 (48.4-59.3)	918	59.3 (54.8-63.7)	506	51.0 (46.1-55.8)	556	53.1 (47.7-58.4)	509	55.4 (48.6-62.0)
≥Some college	236	20.9 (16.5-26.3)	225	18.5 (14.7-23.2)	179	27.7 (21.1-35.5)	200	23.2 (18.7-28.3)	139	20.6 (15.1-27.5)
Ratio of family income to poverty level[d]										
<1.3	700	28.2 (23.9-33.0)	698	28.5 (24.4-33.0)	385	26.9 (23.4-30.8)	478	34.4 (28.4-41.0)	306	24.8 (20.4-29.8)
1.3 to <3.0	518	27.7 (24.6-30.9)	538	27.8 (24.5-31.0)	284	27.2 (22.4-32.7)	275	28.2 (22.8-34.3)	289	32.0 (26.6-37.9)
≥3.0	472	37.6 (33.2-42.1)	466	39.5 (34.9-44.3)	251	40.2 (34.1-46.7)	234	31.4 (26.0-37.3)	195	34.9 (29.7-40.3)
Food security[e]										
Very low	142	5.87 (4.20-8.15)	147	6.17 (4.69-8.08)	76	4.70 (3.41-6.43)	88	6.72 (4.51-9.90)	95	8.80 (6.73-11.4)
Low	285	9.81 (7.88-12.1)	273	9.66 (8.13-11.4)	177	12.5 (10.3-15.1)	179	13.9 (11.1-17.3)	161	12.9 (10.5-15.7)
Marginal	153	5.82 (4.22-7.97)	169	6.49 (4.87-8.58)	136	9.08 (6.68-12.2)	187	15.3 (12.4-18.6)	118	11.0 (8.50-14.1)
Full	1207	74.6 (70.8-78.1)	1143	74.4 (71.0-77.5)	601	72.8 (67.9-77.3)	604	62.8 (57.7-67.6)	481	64.7 (59.7-69.4)
BMI category[f]										
Underweight or normal weight	1202	70.3 (67.5-73.0)	1134	66.4 (62.4-70.2)	614	65.5 (62.3-68.5)	650	64.8 (60.2-69.0)	512	60.1 (56.3-63.9)
Overweight	291	13.3 (11.2-15.9)	291	15.5 (13.5-17.7)	173	16.1 (13.3-19.5)	160	14.2 (11.2-17.8)	148	18.4 (15.6-21.6)
Obese	354	16.4 (14.3-18.6)	350	18.1 (14.5-22.5)	193	18.4 (15.3-21.9)	226	21.0 (17.2-25.4)	211	21.5 (18.4-24.9)

Abbreviations: BMI, body mass index; NA, not available; NC, not calculated; NHANES, National Health and Nutrition Examination Survey.

[a] Percentages were adjusted for NHANES survey weight.

[b] Owing to the small sample size, other racial and ethnic groups were not included in the analysis. "Other" included groups indicated as "other" in NHANES, including multiracial.

[c] Data missing for 277 individuals.

[d] Data missing for 509 individuals.

[e] Data missing for 176 individuals.

[f] Data missing for 89 individuals.

Table 2. Trends in Weighted Prevalence of Prediabetes Overall and by Population Subgroups Among Youths by NHANES Cycles From 1999 Through 2018

Subgroup	Survey-weighted % (95% CI)[a]					*P* value	
	1999-2002 (n = 1862)	2003-2006 (n = 1788)	2007-2010 (n = 998)	2011-2014 (n = 1064)	2015-2018 (n = 886)	Trend	Interaction
Overall	11.6 (9.49-14.1)	15.4 (12.7-18.5)	23.4 (20.0-27.4)	22.7 (19.7-25.9)	28.2 (23.3-33.6)	<.001	NA
Age, y							
12-15	13.1 (10.2-16.8)	17.5 (13.8-22.1)	24.6 (19.2-30.9)	23.3 (19.3-27.9)	30.8 (24.9-37.4)	<.001	.65
16-19	10.0 (7.7-13.0)	13.4 (10.3-17.2)	22.2 (19.1-25.6)	21.9 (17.3-27.4)	25.6 (20.8-31.2)	<.001	
Sex							
Female	7.1 (5.1-9.9)	8.7 (6.6-11.4)	16.7 (13.1-21.0)	14.3 (11.5-17.8)	19.6 (14.7-25.7)	<.001	.84
Male	15.8 (12.3-20.1)	21.7 (18.2-25.7)	29.8 (25.5-34.5)	30.6 (25.4-36.3)	36.4 (30.1-43.1)	<.001	
Race and ethnicity							
Hispanic	13.4 (10.6-16.9)	16.0 (11.8-21.4)	30.6 (24.2-37.8)	26.7 (22.5-31.2)	28.6 (23.0-34.9)	<.001	.56[b]
Non-Hispanic							
Asian	NA	NA	NA	23.5 (15.8-33.6)	26.0 (15.5-40.2)	.75	
Black	11.7 (9.1-14.8)	14.7 (11.9-18.0)	26.8 (21.2-33.3)	23.2 (17.2-30.6)	32.3 (24.9-40.8)	<.001	
White	11.5 (8.4-15.5)	15.3 (11.6-20.1)	19.8 (15.2-25.4)	20.6 (16.2-25.8)	26.8 (19.1-36.2)	<.001	
Parental educational level							
<High school	15.6 (12.8-18.9)	15.9 (11.7-21.4)	24.2 (17.6-32.2)	29.9 (23.6-37.1)	29.1 (23.9-34.9)	<.001	.28
High school	10.0 (8.0-12.4)	14.7 (12.3-17.4)	24.0 (19.8-28.6)	20.5 (17.0-24.6)	29.2 (23.7-35.4)	<.001	
≥Some college	11.1 (6.3-18.8)	17.0 (10.9-25.7)	19.4 (12.6-28.7)	20.4 (13.8-29.0)	26.8 (15.7-42.0)	.03	
Ratio of family income to poverty level							
<1.3	12.5 (8.5-17.9)	12.7 (9.1-17.3)	29.4 (23.9-35.6)	26.6 (22.3-31.4)	31.2 (25.6-37.3)	<.001	.54
1.3 to <3.0	9.3 (6.4-13.3)	19.8 (15.2-25.4)	23.0 (17.1-30.0)	20.6 (15.6-26.7)	30.0 (23.2-37.7)	<.001	
≥3.0	11.8 (8.8-15.7)	13.8 (9.7-19.4)	18.5 (13.0-25.7)	20.8 (14.9-28.3)	24.5 (15.2-37.0)	<.006	
Food security							
Very low	18.4 (11.0-29.1)	13.3 (6.83-24.2)	40.7 (32.0-50.1)	20.1 (12.1-31.7)	26.3 (16.3-39.6)	.20	.24
Low	12.0 (8.0-17.6)	15.2 (10.5-21.6)	26.0 (20.1-33.1)	27.6 (19.4-37.7)	29.6 (22.2-38.2)	<.001	
Marginal	11.4 (6.9-18.3)	20.5 (13.9-29.3)	24.9 (15.8-36.9)	20.4 (13.8-29.1)	45.5 (31.6-60.2)	<.001	
Full	10.8 (8.3-13.9)	15.5 (12.2-19.4)	21.7 (17.4-26.7)	22.4 (18.2-27.3)	25.6 (19.7-32.5)	<.001	
BMI category							
Underweight or normal weight	9.41 (7.50-11.8)	13.3 (10.3-17.0)	23.0 (18.1-28.8)	18.3 (15.5-21.4)	24.3 (18.9-30.7)	<.001	.94
Overweight	15.3 (9.45-23.8)	14.4 (9.02-22.3)	17.7 (12.4-24.6)	26.7 (18.7-36.6)	27.5 (19.7-36.9)	<.005	
Obese	18.2 (12.8-25.2)	24.1 (16.0-34.6)	29.5 (22.8-37.3)	34.2 (24.5-45.4)	40.4 (30.2-51.5)	<.001	

Abbreviations: BMI, body mass index; NA, not applicable; NHANES, National Health and Nutrition Examination Survey.

[a] Percentages were adjusted for NHANES survey weight.

[b] The *P* value for interaction did not include data for Asian participants owing to inconsistent data across cycles.

study, we assessed trends in prediabetes among US youths from 1999 through 2018.

Methods | This survey study used data from 10 cycles of the National Health and Nutrition Examination Survey (NHANES) from 1999-2000 through 2017-2018 and combined every 2 consecutive cycles to obtain sufficient sample sizes. We included youths aged 12 to 19 years who completed the interview and examination. NHANES is a series of cross-sectional surveys using a complex, multistage probability design to sample the civilian, noninstitutionalized population. The NHANES protocol was approved by the US Centers for Disease Control and Prevention National Center for Health Statistics Ethics Review Board, and all participants provided written informed consent, or assent was obtained from participants or their guardians, respectively. This study was exempt from the Mount Sinai institutional review board review because it used publicly deidentified data sets. Details on NHANES survey methods and analytic methods are documented elsewhere.[3] This study followed the American Association for Public Opinion Research (AAPOR) reporting guideline.

Sociodemographic variables included sex, age, race and ethnicity (Hispanic, non-Hispanic Asian, non-Hispanic Black, and non-Hispanic White), parental educational level (less than high school, high school, and some college and above), income level (family income to poverty ratio <1.3, 1.3 to <3.0, and ≥3.0; adjusted for household size and based on poverty guidelines specific to the survey year), household food-security status (full, marginal, low, and very low; categorized based on the US Household Food Security Survey Module developed by the US Department of Agriculture[4]), and body mass index category (underweight or normal weight, overweight, and

obesity; age- and sex-specific body mass index *z* scores were calculated using US Centers for Disease Control and Prevention reference data[5]). Information on race and ethnicity was collected by trained NHANES interviewers according to the fixed categories provided by the National Center for Health Statistics. Blood samples were obtained by trained phlebotomists according to a standardized protocol, and data were recorded directly into a computerized database. Prediabetes was defined as no recorded diagnosis of diabetes but a hemoglobin A_{1c} level of 5.7% to 6.4% (to convert to proportion of total hemoglobin, multiply by 0.01) or a fasting plasma glucose level of 100 mg/dL to 125 mg/dL (to convert to millimoles per liter, multiply by 0.02586).[2]

Survey analysis procedures were used to account for sampling weights, stratification, and clustering in the NHANES complex sampling design to derive nationally representative estimates. Logistic regression was used to estimate trends by treating the survey cycle as a continuous variable. A survey-weighted Wald *F* statistic was used to test for the interaction. All analyses were performed using Stata, version 14 (StataCorp LLC). Significance was set at 2-sided $P = .05$. Data were analyzed from August to September 2021.

Results | A total of 6598 youths (mean [SD] age, 15.5 [2.76] years; 3412 [51.2% weighted] male) were included in this analysis (**Table 1**). The mean response rate was 79.2% (range, 59.3%-86.4%). Overall, the prevalence of prediabetes among US youths increased significantly from 11.6% (95% CI, 9.49%-14.1%) in 1999-2002 to 28.2% (95% CI, 23.3%-33.6%) in 2015-2018 (**Table 2**). The increasing trend was observed across population subgroups. Disparities in prevalence of prediabetes remained stable and were most pronounced in subgroup analyses of sex and body mass index category. For example, from 1999-2002 to 2015-2018, the prevalence of prediabetes increased from 15.8% (95% CI, 12.3%-20.1%) to 36.4% (95% CI, 30.1%-43.1%) among male youths and from 7.1% (95% CI, 5.1%-9.9%) to 19.6% (95% CI, 14.7%-25.7%) among female youths ($P < .001$ for trend). During the same period, the prevalence increased from 9.41% (95% CI, 7.50%-11.8%) to 24.3% (95% CI, 18.9%-30.7%) among youths with underweight or normal weight ($P < .001$ for trend), from 15.3% (95% CI, 9.45%-23.8%) to 27.5% (95% CI, 19.7%-36.9%) among youths with overweight ($P = .005$ for trend), and from 18.2% (95% CI, 12.8%-25.2%) to 40.4% (95% CI, 30.2%-51.5%) among youths with obesity ($P < .001$ for trend).

Discussion | In this survey study, the prevalence of prediabetes increased significantly among US youths from 1999 to 2018. Several limitations should be noted. First, there was only 1 measure of blood biomarkers for prediabetes, and thus, seasonal variations were not accounted for in the analysis. Second, we did not use the oral glucose tolerance test to define prediabetes because the information was not available in some of the NHANES cycles; thus, our results may have underestimated the prevalence of prediabetes. Third, owing to the small sample sizes, the statistical power might not have been sufficient to detect an interaction.

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