



HIV testing and risk behaviors associated with depression in the United States

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ABSTRACT

Given the high correlation between depression and HIV infection rates, our objective was to assess national rates for HIV testing and HIV risk behaviors among U.S. adults stratified by self-reports of depression. We conducted a cross-sectional study using data from the 2018–2020 Behavioral Risk Factor Surveillance System (BRFSS). We included respondents aged 18 years old and above with self-reported depression status (Sample size = 1,228,405). The primary outcomes included HIV testing and HIV-related risk behaviors. For respondents with prior HIV testing experience, we estimated the duration since the last HIV test. We applied a multivariable logistic regression model to analyze the correlation between depression and HIV testing or risk behaviors. The results showed people with depression had 51% higher odds of receiving HIV testing [adjusted odds ratio (AOR) = 1.51, 95% CI = 1.48, 1.55] and 51% higher odds of involvement in HIV risk behaviors [AOR = 1.51, 95% CI = 1.44, 1.58] after adjusting for covariates. Various socio-demographics and healthcare access variables were significantly associated with HIV testing and HIV risk behaviors. When comparing the average time from the last HIV test, people with depression had a shorter period compared to those without depression [Median time in months: 27.1 ± 0.45 vs. 29.3 ± 0.34]. Even though people with depression had higher rates of HIV testing, they still experienced long time periods (median = 2 + years) between HIV testing, which exceeded the recommended annual HIV testing for people at high risk from the Centers for Disease Control and Prevention.

1. Introduction

The prevalence of depression has increased over time. (Moreno-Agostino et al., 2021) In 2019, approximately 18.5% of adults had symptoms of depression in the U.S., (Villaruel and Terlizzi, 2020) and the prevalence was projected to be higher after the COVID-19 pandemic. (Ettman et al., 2020) People with depression are more likely to be involved in behaviors that put them at risk for acquiring the human immunodeficiency virus (HIV), such as injection drug use or unprotected sexual encounters. (Ahaneku et al., 2016; Carney et al., 2019; Marshall et al., 2013; Kim et al., 2019) In this regard, it is believed that the prevalence of depression was highly correlated with HIV infection. (Angelino, 2008) A previous study from a nationally representative survey demonstrated that around half of people with HIV screened positive for psychiatric disorders, including minor and major depression. (Bing et al., 2001; Yu et al., 2022)

Given the high correlation between depression and HIV infection

rates, it is important to encourage the uptake of routine HIV testing among these high-risk populations. Therefore, the Centers for Disease Control and Prevention (CDC) recommend annual testing for those at higher risk of HIV. (Branson et al., 2006) Routine HIV testing may benefit individuals and the general population through early virus detection and disease intervention. Routine HIV testing could enable identification of unknown HIV infection, early access to antiretroviral therapy (ART), and better prognostic outcomes for people with HIV. (Lundgren et al., 2015) From the public health perspective, this early intervention in people with HIV could more effectively suppress viral load and further reduce the risk for HIV transmission. (Cohen et al., 2016).

With the benefits of routine HIV testing, barriers influencing people's routine HIV testing behaviors like sociological, psychological, or structural barriers must be considered. (Dieffenbach and Fauci, 2009) More specifically, previous studies indicated common barriers to receiving HIV testing, including cost, stigma, lack of privacy, limited/no access, or

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low perceived needs. (Parchem and Molock, 2022; Zhang et al., 2021; Wise et al., 2019) Other studies identified that demographic characteristics (e.g., age, sex, race/ethnicity, and educational status) might be associated with the HIV testing behaviors. (Qiao et al., 2018) Much of the prior literature focused on HIV testing behaviors among specific populations, such as men who have sex with men, (Bien-Gund et al., 2022) transgender, (Tordoff et al., 2022; Pitasi et al., 2020) Black racial groups, (Uzoeghelu et al., 2021) youth, (Haney-Caron et al., 2021; Phillips et al., 2020) or populations from a specific region in the U.S. (Marshall et al., 2020; Daniel et al., 2022) In addition to these populations, prior studies also focused on people with mental illnesses like depression, demonstrating the potential influence of depression status on HIV testing. (Senn and Carey, 2009; Yehia et al., 2014) Our study adds to existing literature by focusing on a nationally representative sample of adults with self-reported depression across all demographic factors. Additional benefits include the ability to produce U.S. population-based estimates while ensuring the protection and privacy of the population when responding to sensitive questions about HIV testing and risk behaviors.

Our objective was to assess national rates for HIV testing and HIV risk behaviors among U.S. adults stratified by self-reports of depression. We evaluated the correlation between depression and HIV testing/risk behaviors after adjusting for potential confounding factors in the literature. Lastly, we focused on the population with depression to examine how HIV testing and risk behaviors were associated with socio-demographic characteristics and other healthcare access factors.

2. Methods

2.1. Study design and data source

We conducted a cross-sectional study using data from the 2018–2020 Behavioral Risk Factor Surveillance System (BRFSS). The BRFSS is a nationally representative telephone survey administered by the CDC (Centers of Disease Control and Prevention (CDC), 2022). Each year, the BRFSS interviewed U.S. adults from all 50 states, the District of Columbia, and sovereign territories regarding their health-related risk behaviors and chronic health conditions (Centers of Disease Control and Prevention (CDC), 2022). To ensure a nationally representative sample, we only examined variables accessible from the core questions collected from all survey participants included in the BRFSS. The Institutional Review Board at the authors' institution approved the study through an exempt application.

2.2. Study population

We included respondents aged 18 years old and above with answers of "Yes/No" to the following question: "(Ever told) you had a depressive disorder (including depression, major depression, dysthymia, or minor depression)?" (Centers of Disease Control and Prevention (CDC), 2022) Respondents who answered "Don't know / Not sure," refused to answer, or skipped the question were considered missing data and excluded from the study. In addition, we unified the depression conditions listed in the survey question (i.e., depression, major depression, dysthymia, and minor depression) as "depression" hereafter based on the definition from the National Institute of Mental Health (NIMH). (Institute, 2021).

2.3. Outcome measures

The primary outcomes included HIV testing and risk behaviors. HIV testing was assessed by the question: "Including fluid testing from your mouth, but not including tests you may have had for blood donation, have you ever been tested for HIV?" (Centers of Disease Control and Prevention (CDC), 2022) HIV risk behaviors were assessed by the question: "Do any of these situations (list of risk behaviors) apply to you?" The HIV risk behaviors are listed in Table 1. For respondents with

Table 1

List of HIV Risk Behaviors from the Behavioral Risk Factor Surveillance System.

HIV risk behavior*	Response options
"You have injected any drug other than those prescribed for you in the past year."	"Yes" "No"
"You have been treated for a sexually transmitted disease or STD in the past year."	"Don't know / Not sure" or "Refused"
"You have given or received money or drugs in exchange for sex in the past year."	
"You had anal sex without a condom in the past year."	
"You had four or more sex partners in the past year."	

*The BRFSS asks about HIV risk behaviors using the following question: "I am going to read you a list. When I am done, please tell me if any of the situations apply to you. You do not need to tell me which one." (Centers of Disease Control and Prevention (CDC), 2022).

HIV testing experience, we further estimated the duration since the last HIV test by calculating the period between the interview date and the last time of HIV testing. The last time of HIV testing was based on the question: "In what month and year was your last HIV test?" (Centers of Disease Control and Prevention (CDC), 2022) Respondents could reply test year and month or only reply test year without indicating the testing month. For the latter case, we coded January as the test month. For the above outcome variables, respondents who answered "Don't know / Not sure" or skipped/refused to answer were coded as missing data and excluded from the data analysis.

2.4. Covariates

The covariates included socio-demographic variables (age, sex, race, ethnicity, marital status, education, income, general health status, and geographic region of residence), healthcare access variables (health insurance coverage, having a personal healthcare provider, financial limitations seeking care, and time since routine checkup), and interview year. We categorized geographic region of residence following the U.S. Census Bureau's Census Regions and Divisions. (United States Census Bureau. Geographic Levels. <https://www.census.gov/programs-surveys/economic-census/guidance-geographies/levels.html>. Accessed August, 11, 2022) In addition, we included a covariate representing the mental distress level. We conceptualized the mental distress level using the self-reported number of poor mental health days from the following question: "(Including stress, depression, and problems with emotions), for how many days during the past 30 days was your mental health not good?" (Centers of Disease Control and Prevention (CDC), 2022) We categorized the number of poor mental health days into three categories of mental distress: "no distress" (0 days), "minor distress" (<14 days), and "major distress" (≥ 14 days). (Cree et al., 2020) We included the mental distress level as a covariate based on prior findings for a high correlation between major distress and adverse behaviors, chronic diseases, and depression. (Cree et al., 2020) All questions for covariates with "Don't know / Not sure," "Refused," or "Missing" responses were all categorized as "unknown" and remained in the data analysis. We chose to retain the "unknown" category to avoid inducing potential bias from deleting these respondents and to maintain the nationally representative estimates from weights placed on this category.

2.5. Statistical analysis

We first calculated the prevalence of depression from the proportion of respondents with self-reported depression divided by the total number of survey respondents each year. After the prevalence calculation, we applied the previous selection criteria under Section 2.2 for the subsequent analyses. Demographic characteristics were presented as unadjusted sample sizes and weighted percentages, stratified by people with and without depression. Similarly, an identical approach was used to present HIV testing and risk behaviors, and data were stratified by

each interview year and all years combined (all years: 2018 to 2020). To evaluate the average duration since the last HIV test, we first calculated each individual's duration from those with prior HIV testing. Then, we estimated the mean and median duration since the last HIV test among people with and without depression. Where applicable, chi-square and student's t-tests were used to compare people with and without depression.

We applied multivariable logistic regression models to analyze the correlation between depression and HIV testing or risk behaviors. Results from the adjusted analyses were reported as adjusted odds ratios (AOR) and 95% confidence intervals (CI). Among people with self-reported depression, we applied simple logistic regression models to examine correlations between covariates and HIV testing or HIV risk behaviors. The reference group for each categorical covariate used in the logistic regression models was chosen based on the category with the largest weighted percentage. Comparisons or coefficients were considered significant at the alpha level of 0.05 for the two-sided tests. The statistical analyses considered the complex sampling design of BRFSS, and percentages were weighted to the U.S. population. All data were analyzed using SAS, version 9.4 (SAS Institute, Cary, NC).

3. Results

3.1. Prevalence of depression among people sampled through 2018–2020 BRFSS

The prevalence of depression ranged from approximately 18% to 19% in the U.S. from 2018 to 2020. There were 18.23% (95% CI = 17.99, 18.46) of respondents with self-reported depression in 2018, 18.69% (95% CI = 18.45, 18.92) in 2019, and 18.23% (95% CI = 17.96, 18.50) in 2020. No statistically significant difference in prevalence among these three years was found (Rao-Scott Chi-Square = 9.12, *P* = 0.06; data were not presented in tables).

3.2. Characteristics stratified by people with versus without depression

A total of 1,228,405 adults were retained in the study population. People with depression were most often female (64.65%), White race (76.48%), and non-Hispanic/Latino/Spanish ethnicity (85.18%) (Table 2). Compared to the 22.03% (95% CI = 21.67, 22.39) of people with depression reporting financial limitations to seek care, 10.12% (95% CI = 9.98, 10.26) of those without depression had such concerns. Major mental distress was more common among people with depression (39.18%, 95% CI = 38.77, 39.59) than people without depression (7.02%, 95% CI = 6.91, 7.14). Statistically significant differences between populations with and without depression were found for the following socio-demographic and healthcare access factors: age, sex, race, ethnicity, marital status, education, income, general health, geographic region, insurance, personal healthcare provider, financial limitations to seek care, time since routine checkup, level of mental distress, and interview year (Table 2; *P* < 0.001 for all variables).

3.3. HIV testing behaviors

Compared to those without depression, people with depression reported a higher rate of HIV testing (46.85% (95% CI = 46.43, 47.27) vs. 32.70% (95% CI = 32.49, 32.90); *P* < 0.001). When comparing the average time from the last HIV test, people with depression had a shorter period compared to those without depression [Mean in months = 71.35 (SD = 0.62) vs. 75.13 (SD = 0.42), *P* < 0.001; Median in months = 27.05 (SD = 0.45) vs. 29.34 (SD = 0.34)]. In 2020, people had a longer HIV testing period regardless of depression status compared with the previous two years (Table 3). After adjusting for covariates, people with depression had 51% higher odds of receiving HIV testing (AOR = 1.51, 95% CI = 1.48, 1.55) than those without depression. Covariates in the multivariable logistic regression model for HIV testing were statistically

Table 2
Characteristics among U.S. adults sampled in the 2018–2020 Behavioral Risk Factor Surveillance System (BRFSS), stratified by depression status.

Characteristics*	People with depression (N = 234,544)		People without depression (N = 993,861)	
	N	Weighted % (95% CI)	N	Weighted % (95% CI)
Age				
18–29	30,790	23.04 (22.65, 23.43)	108,996	20.04 (19.85, 20.23)
30–49	64,845	33.64 (33.25, 34.04)	237,760	32.47 (32.26, 32.68)
50–69	98,116	32.83 (32.45, 33.21)	381,789	31.71 (31.51, 31.91)
70+	40,793	10.49 (10.27, 10.72)	265,316	15.79 (15.65, 15.92)
Sex				
Male	77,871	35.28 (34.88, 35.67)	480,939	51.75 (51.53, 51.97)
Female	156,506	64.65 (64.25, 65.04)	512,322	48.19 (47.97, 48.41)
Unknown [†]	167	0.08 (0.05, 0.10)	600	0.05 (0.04, 0.06)
Race				
White	192,116	76.48 (76.08, 76.87)	782,893	69.35 (69.13, 69.57)
Black or African American	16,218	10.84 (10.54, 11.14)	84,425	12.88 (12.73, 13.04)
American Indian/Alaskan Native	5353	1.86 (1.75, 1.97)	19,282	1.58 (1.53, 1.64)
Asian	2506	2.24 (2.07, 2.41)	26,884	6.16 (6.01, 6.32)
Native Hawaiian/Pacific Islander	1044	0.29 (0.24, 0.34)	6564	0.35 (0.32, 0.37)
Other	5882	3.48 (3.30, 3.67)	29,383	4.76 (4.65, 4.88)
Multirace	7312	2.42 (2.29, 2.54)	20,642	1.49 (1.44, 1.53)
Unknown [†]	4113	2.39 (2.24, 2.54)	23,788	3.42 (3.33, 3.51)
Ethnicity				
Not Hispanic/Latino/Spanish	214,194	85.18 (84.80, 85.56)	893,952	80.79 (80.58, 81.00)
Hispanic/Latino/Spanish	18,285	13.91 (13.53, 14.29)	90,855	18.27 (18.06, 18.47)
Unknown [†]	2065	0.91 (0.82, 0.99)	9054	0.95 (0.90, 0.99)
Marital status				
Married	94,127	38.70 (38.29, 39.10)	536,369	52.52 (52.30, 52.74)
Divorced	45,788	15.32 (15.04, 15.60)	119,342	9.51 (9.40, 9.63)
Widowed	25,536	7.02 (6.83, 7.21)	117,309	6.78 (6.69, 6.88)
Separated	8197	3.86 (3.70, 4.01)	17,444	2.20 (2.13, 2.27)
Never married	48,772	28.39 (28.00, 28.79)	164,230	23.74 (23.54, 23.94)
Unmarried couple	11,000	6.19 (5.97, 6.40)	33,578	4.61 (4.51, 4.71)
Unknown [†]	1124	0.53 (0.46, 0.59)	5589	0.63 (0.59, 0.67)
Education status				
Did not graduate high school	20,570	14.97 (14.61, 15.33)	66,874	12.46 (12.28, 12.63)
Graduated high school	63,511	27.29 (26.92, 27.66)	268,036	27.92 (27.72, 28.11)
Attended college/technical school	73,461	34.60 (34.20, 35.00)	267,247	29.80 (29.60, 30.01)
Graduated college/technical school	76,564	22.98 (22.68, 23.28)	388,930	29.50 (29.32, 29.68)
Unknown [†]	438	0.16 (0.14, 0.19)	2774	0.32 (0.29, 0.35)
Income status				
Less than \$15,000	31,812	13.19 (12.91, 13.48)	60,152	6.96 (6.84, 7.09)

(continued on next page)

Table 2 (continued)

Characteristics*	People with depression (N = 234,544)		People without depression (N = 993,861)	
	N	Weighted % (95% CI)	N	Weighted % (95% CI)
\$15,000 to less than \$25,000	40,894	17.10 (16.79, 17.41)	117,206	11.83 (11.68, 11.97)
\$25,000 to less than \$35,000	21,758	8.83 (8.60, 9.07)	80,725	7.77 (7.65, 7.89)
\$35,000 to less than \$50,000	26,233	10.44 (10.19, 10.69)	112,041	10.36 (10.23, 10.49)
\$50,000 or more	76,696	33.51 (33.12, 33.91)	441,213	44.23 (44.01, 44.44)
Unknown [^]	37,151	16.92 (16.60, 17.24)	182,524	18.85 (18.67, 19.02)
General health status				
Excellent	18,727	9.02 (8.76, 9.27)	195,308	21.36 (21.17, 21.54)
Very good	58,346	24.91 (24.56, 25.26)	348,800	33.54 (33.33, 33.74)
Good	76,987	32.90 (32.51, 33.30)	304,946	31.12 (30.91, 31.33)
Fair	53,020	22.20 (21.86, 22.54)	110,190	10.94 (10.80, 11.07)
Poor	26,784	10.72 (10.45, 10.99)	32,467	2.84 (2.77, 2.92)
Unknown [^]	680	0.26 (0.22, 0.29)	2150	0.20 (0.18, 0.22)
Geographic region				
South	74,022	39.21 (38.81, 39.61)	297,279	37.76 (37.59, 37.92)
Northeast	43,172	15.47 (15.21, 15.73)	185,099	16.54 (16.44, 16.65)
Midwest	60,938	22.11 (21.83, 23.39)	270,244	20.41 (20.31, 20.51)
West	52,884	22.16 (21.81, 22.52)	222,909	24.14 (23.98, 24.30)
U.S. territories	3528	1.04 (0.99, 1.09)	18,330	1.14 (1.12, 1.16)
Insurance coverage				
Yes	19,922	11.55 (11.25, 11.85)	83,039	12.68 (12.52, 12.85)
No	213,762	87.89 (87.58, 88.20)	906,446	86.72 (86.55, 86.89)
Unknown [^]	860	0.56 (0.47, 0.65)	4376	0.59 (0.56, 0.63)
Personal healthcare provider				
Yes, only one	32,904	18.97 (18.62, 19.32)	175,748	23.84 (23.65, 24.04)
Yes, more than one	179,465	71.65 (71.26, 72.04)	741,945	68.85 (68.64, 69.06)
No	21,176	8.90 (8.66, 9.13)	71,037	6.66 (6.56, 6.77)
Unknown [^]	999	0.48 (0.43, 0.54)	5131	0.64 (0.61, 0.68)
Financial limitations seeking care				
No	190,033	77.62 (77.26, 77.98)	913,268	89.52 (89.38, 89.67)
Yes	43,679	22.03 (21.67, 22.39)	77,374	10.12 (9.98, 10.26)
Unknown [^]	832	0.35 (0.30, 0.40)	3219	0.36 (0.33, 0.38)
Time since routine checkup				
Never	806	0.42 (0.36, 0.47)	5888	0.80 (0.76, 0.85)
Within past year	191,261	78.32 (77.97, 78.67)	778,148	74.24 (74.04, 74.44)
Within past 2 years	21,255	10.24 (9.98, 10.50)	101,110	12.08 (11.92, 12.23)
Within past 5 years	10,411	5.52 (5.33, 5.72)	50,026	6.29 (6.18, 6.41)
More than 5 years ago	8151	4.34 (4.16, 4.52)	46,981	5.32 (5.22, 5.42)

Table 2 (continued)

Characteristics*	People with depression (N = 234,544)		People without depression (N = 993,861)	
	N	Weighted % (95% CI)	N	Weighted % (95% CI)
Unknown [^]	2660	1.16 (1.08, 1.25)	11,708	1.27 (1.23, 1.32)
Level of mental distress				
No (0 days)	63,308	23.89 (23.54, 24.25)	729,667	70.19 (68.98, 70.39)
Minor (<14 days)	79,782	34.45 (34.05, 34.84)	189,565	21.18 (21.00, 21.36)
Major (14–30 days)	85,313	39.18 (38.77, 39.59)	58,953	7.02 (6.91, 7.14)
Unknown [^]	6141	2.48 (2.35, 2.61)	15,676	1.61 (1.55, 1.67)
Interview year				
2018	80,972	34.69 (34.29, 35.08)	346,063	35.01 (34.82, 35.21)
2019	78,537	33.26 (32.88, 33.64)	330,963	32.66 (32.47, 32.86)
2020	75,035	32.05 (31.64, 32.46)	316,835	32.32 (32.11, 32.53)

*All comparisons of characteristics between people with and without depression were statistically significant, $P < 0.001$.

[^]Unknown indicates missing responses or responses of “Don’t know / Not sure” and “Refused.”.

significant (Table 4). For example, the odds of HIV testing were lower for males vs. females (AOR = 0.90, 95% CI = 0.89, 0.92), Asian race vs. White race (AOR = 0.61, 95% CI = 0.57, 0.65), uninsured vs. insured (AOR = 0.90, 95% CI = 0.87, 0.94), and people with longer time since routine checkup (e.g., ≥ 5 years ago vs. within past year; AOR = 0.61, 95% CI = 0.58, 0.63). The odds of HIV testing were higher for Black or African American race vs. White race (AOR = 2.88, 95% CI = 2.79, 2.97), Hispanic/Latino/Spanish ethnicity vs. non-Hispanic/Latino/Spanish ethnicity (AOR = 1.27, 95% CI = 1.22, 1.31), divorced vs. married (AOR = 1.69, 95% CI = 1.64, 1.74), and people with HIV risk behaviors vs. people without (AOR = 2.50, 95% CI = 2.40, 2.61).

3.4. HIV risk behaviors

Compared to those without depression, people with depression reported a higher rate of involvement in HIV risk behaviors (9.87% (95% CI = 9.61, 10.14) vs. 4.63% (95% CI = 4.53, 4.73); $P < 0.001$) (Table 3). After adjusting for covariates, people with depression had 51% higher odds of engaging in HIV risk behaviors (AOR = 1.51, 95% CI = 1.44, 1.58) than people without depression. Various covariates were significantly associated with HIV risk behaviors (Table 4). The odds of involvement in HIV risk behaviors were lower for Asian race vs. White race (AOR = 0.77, 95% CI = 0.68, 0.89) and lower income status (e.g., $< \$15,000$ vs. $\geq \$50,000$; AOR = 0.82, 95% CI = 0.76, 0.88). The odds of involvement in HIV risk behaviors were higher for people aged 18–29 years old vs. 30–49 years old (AOR = 1.99, 95% CI = 1.90, 2.09), Black or African American race vs. White race (AOR = 1.17, 95% CI = 1.10, 1.23), Hispanic/Latino/Spanish ethnicity vs. non-Hispanic/Latino/Spanish ethnicity (AOR = 1.09, 95% CI = 1.02, 1.16), non-married people (e.g., separated vs. married; AOR = 2.76, 95% CI = 2.48, 3.08), and people testing for HIV vs. people not testing for HIV (AOR = 2.66, 95% CI = 2.55, 2.78).

3.5. Subgroup results among people with self-reported depression

Among people with depression, age, race, ethnicity, education level, income, general health status, geographic region, access to healthcare, and level of mental distress were each significantly associated with HIV testing and risk behaviors, individually (Table 5). Sex was significantly

Table 3
Comparison of HIV testing and risk behaviors among U.S. adults with versus without depression from the 2018–2020 BRFSS.

	People with depression		People without depression		P-value*
	N	Weighted % (95% CI)	N	Weighted % (95% CI)	
2018					
HIV testing behavior					
Yes	35,004	46.78 (46.09, 47.48)	96,715	33.07 (32.73, 33.41)	<0.001
No	39,279	43.30 (42.61, 43.98)	218,452	55.08 (54.72, 55.43)	
Unknown	7,526	9.92 (9.49, 10.35)	38,307	11.86 (11.61, 12.10)	
HIV risk behavior					
Yes	5,688	9.98 (9.54, 10.43)	10,824	4.74 (4.58, 4.90)	<0.001
No	71,250	82.98 (82.43, 83.53)	314,955	85.70 (85.42, 85.97)	
Unknown	4,871	7.04 (6.67, 7.41)	27,695	9.56 (9.33, 9.80)	
Last time HIV test (Month)					
Mean ± SD	26,280	69.44 ± 0.67	71,359	72.88 ± 1.00	0.004
Median ± SD		26.32 ± 0.53		28.30 ± 0.53	
2019					
HIV testing behavior					
Yes	33,857	47.69 (47.01, 48.37)	92,113	33.65 (33.31, 33.98)	<0.001
No	36,274	39.52 (38.87, 40.17)	197,740	50.36 (50.01, 50.70)	
Unknown	9,050	12.79 (12.28, 13.30)	46,951	15.99 (15.72, 16.27)	
HIV risk behavior					
Yes	5,647	10.07 (9.64, 10.49)	10,216	4.86 (4.69, 5.04)	<0.001
No	66,855	79.51 (78.90, 80.11)	289,702	81.63 (81.33, 81.92)	
Unknown	6,679	10.43 (9.93, 10.92)	36,886	13.51 (13.25, 13.77)	
Last time HIV test (Month)					
Mean ± SD	26,009	70.79 ± 0.95	69,054	73.62 ± 0.62	0.013
Median ± SD		25.93 ± 0.70		28.46 ± 0.44	
2020					
HIV testing behavior					
Yes	31,481	45.73 (44.94, 46.53)	84,933	30.78 (30.39, 31.17)	<0.001
No	35,965	42.75 (41.97, 43.52)	195,137	54.88 (54.46, 55.30)	
Unknown	8,374	11.52 (10.99, 12.06)	43,965	14.33 (14.02, 14.65)	
HIV risk behavior					

Table 3 (continued)

	People with depression		People without depression		P-value*
	N	Weighted % (95% CI)	N	Weighted % (95% CI)	
Yes	5,214	9.43 (8.93, 9.92)	9,204	4.09 (3.93, 4.26)	<0.001
No	65,052	81.89 (81.22, 82.56)	282,828	84.42 (84.09, 84.76)	
Unknown	5,554	8.68 (8.17, 9.20)	32,003	11.49 (11.18, 11.79)	
Last time HIV test (Month)					
Mean ± SD	23,160	74.14 ± 0.67	60,250	79.58 ± 0.67	<0.001
Median ± SD		29.02 ± 0.87		31.75 ± 0.69	
All years (2018–2020)					
HIV testing behavior					
Yes	99,611	46.85 (46.43, 47.27)	269,571	32.70 (32.49, 32.90)	<0.001
No	110,539	41.93 (41.52, 42.34)	600,825	53.59 (53.38, 53.81)	
Unknown	24,394	11.22 (10.94, 11.50)	123,465	13.71 (13.55, 13.87)	
HIV risk behavior					
Yes	16,464	9.87 (9.61, 10.14)	29,998	4.63 (4.53, 4.73)	<0.001
No	201,447	81.62 (81.27, 81.96)	872,316	84.18 (84.01, 84.36)	
Unknown	16,633	8.51 (8.25, 8.77)	91,547	11.19 (11.03, 11.35)	
Last time HIV test (Month)					
Mean ± SD	75,290	71.35 ± 0.62	199,688	75.13 ± 0.42	<0.001
Median ± SD		27.05 ± 0.45		29.34 ± 0.34	

*Statistical analyses included chi-square or student's t-tests.

associated with HIV risk behaviors but not associated with HIV testing. Compared with women, men were more likely to engage in HIV risk behaviors (OR = 1.60, 95% CI = 1.51, 1.70). Furthermore, most socio-demographic characteristics with higher odds of receiving HIV testing also had higher odds of being involved in HIV risk behaviors, but a few exceptions existed. Compared to people aged 30–49, those aged 18–29 had 2.24 times the odds (OR = 2.24, 95% CI = 2.09, 2.39) of involvement in HIV risk behaviors but were 60% less likely to receive HIV testing (OR = 0.40, 95% CI = 0.38, 0.43). Regarding the correlation between healthcare access and HIV testing and risk behaviors, people with no insurance coverage, people with no personal healthcare provider, and people having financial concerns to seek care had higher odds of HIV testing and risk behaviors. Finally, higher mental distress levels were associated with higher odds of HIV testing (minor mental distress OR = 1.25, 95% CI = 1.19, 1.31; major mental distress OR = 1.51, 95% CI = 1.44, 1.58) and HIV risk behaviors (minor mental distress OR = 1.87, 95% CI = 1.70, 2.06; major mental distress OR = 2.56, 95% CI = 2.34, 2.80) compared to no mental distress.

4. Discussion

Approximately 18–19% of respondents self-reported depression from 2018 to 2020. Populations experiencing the highest rates of depression

Table 4
Multivariable logistic regression models for HIV testing and risk behaviors among U.S. adults sampled in the 2018–2020 BRFSS.

Characteristics	HIV testing behaviors (Ref. = no test behavior)		HIV risk behaviors (Ref. = no risk behaviors)	
	AOR	95% CI	AOR	95% CI
Depression status				
No (Ref.)	–	–	–	–
Yes	1.51	(1.48, 1.55)*	1.51	(1.44, 1.58)*
Age				
18–29	0.41	(0.40, 0.42)*	1.99	(1.90, 2.09)*
30–49 (Ref.)	–	–	–	–
50–69	0.45	(0.43, 0.46)*	0.39	(0.37, 0.41)*
70+	0.15	(0.14, 0.15)*	0.18	(0.16, 0.21)*
Sex				
Female (Ref.)	–	–	–	–
Male	0.90	(0.89, 0.92)*	1.83	(1.76, 1.90)*
Unknown [^]	0.97	(0.69, 1.36)*	3.44	(2.06, 5.76)*
Race				
White (Ref.)	–	–	–	–
Black or African American	2.88	(2.79, 2.97)*	1.17	(1.10, 1.23)*
American Indian/Alaskan Native	1.35	(1.25, 1.45)*	0.95	(0.83, 1.08)*
Asian	0.61	(0.57, 0.65)*	0.77	(0.68, 0.89)*
Native Hawaiian/Pacific Islander	1.13	(0.98, 1.29)*	1.38	(1.09, 1.74)*
Multi-race	1.16	(1.09, 1.23)*	0.90	(0.81, 1.01)*
Other	1.73	(1.63, 1.83)*	1.11	(1.00, 1.24)*
Unknown [^]	1.10	(1.03, 1.18)*	0.95	(0.83, 1.08)*
Ethnicity				
Non-Hispanic/Latino/Spanish (Ref.)	–	–	–	–
Hispanic/Latino/Spanish	1.27	(1.22, 1.31)*	1.09	(1.02, 1.16)*
Unknown [^]	1.30	(1.17, 1.44)*	1.12	(0.91, 1.39)*
Marital status				
Married (Ref.)	–	–	–	–
Divorced	1.69	(1.64, 1.74)*	2.83	(2.65, 3.02)*
Widowed	0.89	(0.86, 0.93)*	2.32	(2.04, 2.65)*
Separated	1.56	(1.46, 1.66)*	2.76	(2.48, 3.08)*
Never married	1.13	(1.10, 1.17)*	2.79	(2.64, 2.95)*
Unmarried couple	1.60	(1.52, 1.67)*	2.48	(2.30, 2.68)*
Unknown [^]	1.20	(1.05, 1.38)*	1.73	(1.35, 2.20)*
Education status				
Did not graduate high school	0.74	(0.71, 0.77)*	1.04	(0.96, 1.12)*
Graduated high school	0.79	(0.77, 0.81)*	0.98	(0.93, 1.03)*
Attended college/technical school (Ref.)	–	–	–	–
Graduated college/technical school	1.07	(1.04, 1.09)*	0.91	(0.87, 0.96)*
Unknown [^]	0.82	(0.65, 1.04)*	1.10	(0.66, 1.83)*
Income status				
Less than \$15,000	1.07	(1.03, 1.12)*	0.82	(0.76, 0.88)*

Table 4 (continued)

Characteristics	HIV testing behaviors (Ref. = no test behavior)		HIV risk behaviors (Ref. = no risk behaviors)	
	AOR	95% CI	AOR	95% CI
\$15,000 to less than \$25,000	1.06	(1.03, 1.20)*	0.86	(0.80, 0.91)*
\$25,000 to less than \$35,000	1.05	(1.01, 1.09)*	0.89	(0.83, 0.95)*
\$35,000 to less than \$50,000	0.99	(0.96, 1.03)*	0.90	(0.84, 0.95)*
\$50,000 or more (Ref.)	–	–	–	–
Unknown [^]	0.80	(0.77, 0.82)*	0.72	(0.68, 0.77)*
General health status				
Excellent	1.05	(1.02, 1.08)*	1.07	(1.01, 1.14)*
Very good	1.00	(0.97, 1.02)*	1.06	(1.01, 1.11)*
Good (Ref.)	–	–	–	–
Fair	1.07	(1.04, 1.11)*	0.95	(0.90, 1.02)*
Poor	1.24	(1.17, 1.30)*	0.83	(0.74, 0.92)*
Unknown [^]	1.04	(0.81, 1.33)*	0.67	(0.44, 1.01)*
Geographic region				
South (Ref.)	–	–	–	–
Northeast	1.09	(1.06, 1.12)*	1.00	(0.95, 1.06)*
Midwest	0.72	(0.71, 0.74)*	0.97	(0.92, 1.01)*
West	0.99	(0.97, 1.02)*	1.06	(1.01, 1.12)*
U.S. territories	1.49	(1.40, 1.59)*	1.01	(0.89, 1.14)*
Insurance coverage				
Yes (Ref.)	–	–	–	–
No	0.90	(0.87, 0.94)*	1.03	(0.97, 1.09)*
Unknown [^]	0.68	(0.58, 0.80)*	1.02	(0.78, 1.33)*
Personal healthcare provider				
Yes, only one (Ref.)	–	–	–	–
Yes, more than one	1.04	(1.01, 1.07)*	1.09	(1.01, 1.17)*
No	1.14	(1.10, 1.18)*	1.06	(1.01, 1.11)*
Unknown [^]	1.00	(0.84, 1.14)*	0.88	(0.68, 1.12)*
Financial limitations seeking care				
No (Ref.)	–	–	–	–
Yes	1.28	(1.24, 1.32)*	1.27	(1.21, 1.34)*
Unknown [^]	1.04	(0.86, 1.27)*	1.09	(0.74, 1.61)*
Time since routine checkup				
Within past year (Ref.)	–	–	–	–
Within past 2 years	0.83	(0.80, 0.85)*	1.00	(0.95, 1.06)*
Within past 5 years	0.74	(0.71, 0.78)*	1.12	(1.04, 1.20)*
More than 5 years ago	0.61	(0.58, 0.63)*	1.22	(1.13, 1.32)*
Never	0.44	(0.38, 0.50)*	1.37	(1.10, 1.71)*
Unknown [^]	0.67	(0.61, 0.73)*	1.11	(0.97, 1.27)*
Level of Mental distress				
No (0 days) (Ref.)	–	–	–	–
Minor (<14 days)	1.04	(1.02, 1.07)*	1.55	(1.48, 1.63)*
Major (14–30 days)	1.19	(1.16, 1.23)*	1.99	(1.88, 2.11)*
Unknown [^]	1.10	(1.01, 1.19)*	1.29	(1.11, 1.50)*
Interview Year				
2018 (Ref.)	–	–	–	–

(continued on next page)

Table 4 (continued)

Characteristics	HIV testing behaviors (Ref. = no test behavior)		HIV risk behaviors (Ref. = no risk behaviors)	
	AOR	95% CI	AOR	95% CI
2019	1.15	(1.12, 1.17) *	1.04	(1.00, 1.09)
2020	0.95	(0.93, 0.98) *	0.91	(0.87, 0.95) *
HIV risk behaviors				
No (Ref.)	–	–	–	–
Yes	2.50	(2.40, 2.61) *	–	–
Unknown [^]	1.36	(1.23, 1.51) *	–	–
HIV testing				
No (Ref.)	–	–	–	–
Yes	–	–	2.66	(2.55, 2.78) *
Unknown [^]	–	–	1.38	(1.23, 1.55) *

*p-value < 0.05. The reference group was chosen based on largest weighted percentage.

[^]Unknown indicates missing responses or responses of “Don’t know / Not sure” and “Refused.”.

AOR = adjusted odds ratio, CI = confidence interval.

included those identifying as non-Hispanic ethnicity, White race, and female sex. Compared to people without depression, those with depression had about a 14% higher rate of HIV testing, but they also had more than two times the rate of engaging in HIV risk behaviors. After adjusting for covariates, having depression seemed to have a similar effect on HIV testing and HIV risk behaviors. People with depression were 51% more likely to test for HIV and engage in HIV risk behaviors. Among people with depression, HIV testing and risk behaviors were associated with socio-demographic factors, the severity of mental distress, and healthcare access factors. The younger population (aged 18–29) was more likely to be involved in HIV risk behaviors but less likely to receive HIV testing. Men were more likely to be involved in HIV risk behaviors than women. Also, the results showed longer duration since the last HIV test in 2020 compared to 2018 and 2019, which might imply an influence from the COVID-19 pandemic due to national lockdowns. (Hoover et al., 2022).

Our study results complemented and addressed some limitations of the prior literature. (Senn and Carey, 2009) As mentioned earlier, unlike most studies with a specific focus on certain populations or regions, our study utilized a nationally representative survey that allowed us to identify population-based estimates generalizable to the overall U.S. population. Our study provided additional information for the correlation between depression and HIV testing/risk behaviors stratified by socio-demographic factors and mental distress levels, where mixed findings were reported from previous research. (Senn and Carey, 2009) So far, we are only aware of one study using a nationally representative dataset that discussed the correlation between mental health and HIV testing behavior, (Yehia et al., 2014) but the authors did not further discuss socio-demographic factors or HIV risk behaviors among the population with depression.

The low rates of HIV testing and long testing periods might have policy implications for future strategies to promote HIV testing. Our results found that people with depression had a higher chance of receiving HIV testing than those without depression. Still, only about half of adults with depression ever received HIV testing. Even though the time from the last HIV test was significantly shorter among people with depression compared with those without, the median time from the last HIV test was around 27 months (Table 3, all years). This time between HIV testing was still longer than the CDC’s recommendation for annual HIV testing for people at high risk. (Branson et al., 2006) Since the

Table 5

Simple logistic regression models for HIV testing and risk behaviors among U.S. adults sampled in the 2018–2020 BRFSS, sub-group analysis among people with self-reported depression.

Characteristics among the subgroup of people with self-reported depression	HIV testing behaviors		HIV risk behaviors	
	OR	95% CI	OR	95% CI
Age				
18–29	0.40	(0.38, 0.43) *	2.24	(2.09, 2.39) *
30–49 (Ref.)	–	–	–	–
50–69	0.43	(0.41, 0.45) *	0.26	(0.24, 0.29) *
70+	0.13	(0.12, 0.14) *	0.08	(0.06, 0.09) *
Sex				
Female (Ref.)	–	–	–	–
Male	0.98	(0.94, 1.01)	1.60	(1.51, 1.70) *
Unknown [^]	1.33	(0.67, 2.64)	5.19	(2.06, 13.26) *
Race				
White (Ref.)	–	–	–	–
Black or African American	2.77	(2.58, 2.98) *	1.57	(1.42, 1.74) *
American Indian/Alaskan Native	1.58	(1.58, 1.81) *	1.30	(1.07, 1.58) *
Asian	0.84	(0.71, 0.99) *	1.22	(0.89, 1.66)
Native Hawaiian/Pacific Islander	1.67	(1.18, 2.36) *	1.86	(1.76, 4.64) *
Multi-race	1.39	(1.23, 1.56) *	1.21	(1.03, 1.44) *
Other	2.04	(1.83, 2.28) *	1.65	(1.42, 1.93) *
Unknown [^]	1.29	(1.12, 1.49) *	0.99	(0.78, 1.26)
Ethnicity				
Non-Hispanic/Latino/Spanish (Ref.)	–	–	–	–
Hispanic/Latino/Spanish	1.27	(1.19, 1.36) *	1.37	(1.24, 1.51) *
Unknown [^]	1.26	(1.02, 1.56) *	0.98	(0.70, 1.37)
Marital status				
Married (Ref.)	–	–	–	–
Divorced	1.75	(1.66, 1.84) *	2.09	(1.90, 2.30) *
Widowed	0.55	(0.52, 0.59) *	0.69	(0.57, 0.84) *
Separated	1.99	(1.81, 2.20) *	2.91	(2.55, 3.33) *
Never married	1.32	(1.26, 1.38) *	4.99	(4.60, 5.41) *
Unmarried couple	1.92	(1.77, 2.08) *	4.91	(4.39, 5.49) *
Unknown [^]	1.20	(0.89, 1.60) *	2.34	(1.57, 3.49) *
Education status				
Did not graduate high school	0.95	(0.89, 1.02)	0.92	(0.83, 1.02)
Graduated high school	0.77	(0.74, 0.81) *	0.97	(0.90, 1.05)
Attended college/technical school (Ref.)	–	–	–	–
Graduated college/technical school	0.94	(0.90, 0.98) *	0.69	(0.65, 0.75) *
Unknown [^]	0.65	(0.45, 0.95) *	0.72	(0.37, 1.40)
Income status				
Less than \$15,000	1.41	(1.34, 1.50) *	1.23	(1.21, 1.36) *
\$15,000 to less than \$25,000	1.17	(1.11, 1.23) *	1.27	(1.16, 1.38) *
\$25,000 to less than \$35,000	1.05	(0.98, 1.12)	1.24	(1.11, 1.38) *
\$35,000 to less than \$50,000	1.01	(0.96, 1.07)	1.15	(1.04, 1.27) *

(continued on next page)

Table 5 (continued)

Characteristics among the subgroup of people with self-reported depression	HIV testing behaviors		HIV risk behaviors	
	OR	95% CI	OR	95% CI
\$50,000 or more (Ref.)	–	–	–	–
Unknown [^]	0.77	(0.73, 0.81) *	1.03	(0.93, 1.13)
General health status				
Excellent	1.04	(0.97, 1.12)	1.38	(1.23, 1.54) *
Very good	0.94	(0.90, 0.98) *	1.08	(1.00, 1.61) *
Good (Ref.)	–	–	–	–
Fair	1.13	(1.08, 1.19) *	0.92	(0.84, 0.92) *
Poor	1.15	(1.07, 1.22) *	0.69	(0.60, 0.79) *
Unknown [^]	0.92	(0.67, 1.26)	0.60	(0.37, 0.97) *
Geographic region				
South (Ref.)	–	–	–	–
Northeast	1.06	(1.01, 1.12) *	1.03	(0.95, 1.12)
Midwest	0.77	(0.73, 0.80) *	0.98	(0.91, 1.05)
West	0.99	(0.94, 1.04)	1.05	(0.97, 1.15)
U.S. territories	1.21	(1.09, 1.35) *	0.69	(0.55, 0.85) *
Insurance coverage				
Yes (Ref.)	–	–	–	–
No	1.21	(1.14, 1.29) *	1.66	(1.52, 1.80) *
Unknown [^]	0.82	(0.57, 1.18)	2.09	(1.05, 4.15) *
Personal healthcare provider				
Yes, only one (Ref.)	–	–	–	–
Yes, more than one	1.10	(1.03, 1.17) *	1.06	(0.95, 1.18)
No	1.20	(1.15, 1.27) *	2.09	(1.96, 2.24) *
Unknown [^]	0.83	(0.64, 1.07)	1.46	(0.99, 2.13)
Financial limitations seeking care				
No (Ref.)	–	–	–	–
Yes	1.46	(1.40, 1.53) *	1.71	(1.60, 1.82) *
Unknown [^]	0.80	(0.59, 1.09)	0.87	(0.53, 1.43)
Time since routine checkup				
Within past year (Ref.)	–	–	–	–
Within past 2 years	1.05	(0.99, 1.11)	1.49	(1.37, 1.64) *
Within past 5 years	1.12	(1.03, 1.21) *	1.98	(1.79, 2.19) *
More than 5 years ago	1.03	(0.94, 1.13)	1.99	(1.77, 2.24) *
Never	0.69	(0.51, 0.94) *	1.09	(0.78, 1.52)
Unknown [^]	0.80	(0.68, 0.94) *	1.70	(1.32, 2.18) *
Level of mental distress				
No (0 days) (Ref.)	–	–	–	–
Minor (<14 days)	1.25	(1.19, 1.31) *	1.87	(1.70, 2.06) *
Major (14–30 days)	1.51	(1.44, 1.58) *	2.56	(2.34, 2.80) *
Unknown [^]	1.14	(1.01, 1.28) *	1.36	(1.05, 1.76) *
Interview Year				
2018 (Ref.)	–	–	–	–
2019	1.12	(1.07, 1.16) *	1.05	(0.98, 1.13)
2020	0.99	(0.95, 1.04)	0.96	(0.89, 1.04)
HIV risk behaviors				
No (Ref.)	–	–	–	–

Table 5 (continued)

Characteristics among the subgroup of people with self-reported depression	HIV testing behaviors		HIV risk behaviors	
	OR	95% CI	OR	95% CI
Yes	2.74	(2.57, 2.92) *	–	–
Unknown [^]	1.78	(1.41, 2.25)	–	–
HIV testing				
No (Ref.)	–	–	–	–
Yes	–	–	2.74	(2.57, 2.92) *
Unknown [^]	–	–	0.98	(0.83, 1.17)

*p-value < 0.05. The reference group was chosen based on the largest weighted percentage.

[^]Unknown indicates missing responses or responses of “Don’t know / Not sure” and “Refused.”

OR = unadjusted odds ratio, CI = confidence interval.

results showed a higher chance of involvement in risky behaviors among people with depression, future HIV-related policies could focus on addressing the low testing rates and long testing periods among this high-risk group. Our results could also further support the need for continuous efforts and for future research among populations with severe mental health (including depression), (Senn and Carey, 2009) especially for interventions to promote HIV testing among people engaged in HIV risk behaviors.

According to our results, except for the sex factor, several socio-demographic characteristics, such as Black or African American races, Hispanic/Latino ethnicities, or people living in the U.S. territories, demonstrated higher odds of receiving HIV testing compared with their reference group, regardless of mental health status. These findings might be attributed to national policy efforts. For instance, the current national HIV strategy, *the National HIV/AIDS Strategy* (NHAS) first published in 2010 (an updated version was published in 2015), aimed to reduce new infections, improve access to care, and reduce health disparities. (Yehia and Frank, 2011; Holtgrave, 2014) Most implementation strategies were largely focused on populations more likely to be involved in HIV risk behaviors. The target populations included gay, bisexual men regardless of race or ethnicity, African American and Hispanic/Latino populations, injection drug users, and people residing in geographic hot spots (e.g., the U.S. southern and northern regions, along with other U.S. territories).

Our results for HIV testing behaviors among men highlighted the need for further work and attention to meet the targets that the national HIV strategy intended to achieve. We observed that men were more likely to be involved in HIV risk behaviors but less likely to receive HIV testing than women. Even among the population with depression, a high-risk population that policies have focused on, men were still more likely to be involved in HIV risk behaviors but had no significant difference in HIV testing compared with women. A previous study indicated that men receiving higher social support could result in lower odds of involvement in HIV risk behaviors. (Fang et al., 2019) Another study also concluded that social support was associated with HIV testing uptake. (Senn and Carey, 2009) In this regard, our study may indicate a potential policy implementation gap because the desired effects were not seen for social supports that the strategy intended to provide among the male population.

At the end of 2021, the *NHAS 2022–2025* was published by the White House. (The White House, 2021) This updated version retained three original goals but included more strategy implementation details. The strategy expanded its scope for reducing health disparities to include more racial minorities and aimed to address social determinants of health. Our study also contributes to identifying HIV-related disparities in social determinants of health, especially focusing on one of the most

vulnerable groups: people with depression.

4.1. Limitations

Some study limitations should be acknowledged. For this study, we could not conclude any causal relationships between the outcomes and depression status due to the cross-sectional nature of the BRFSS data source. As opposed to inferring causality, this study was intended to identify associations between HIV-related behaviors and depression by using a robust approach through consideration of potential confounding factors. Also, the responses for all questions from the BRFSS dataset were self-reported, and the self-reported data may suffer from recall bias or social desirability bias. To address the potential biases mentioned, future research may consider using more objective records, such as medical claims or electronic health records if applicable. Sexual orientation and gender identities are two demographic factors that might have influence on depression or HIV testing and risk behaviors in the literature. However, we could not include these factors in our study because the data for sexual orientation and gender identity from BRFSS are not available from a nationally representative sample. Future studies could investigate these factors by selecting states that include data for sexual orientation and gender identities.

5. Conclusion

Depression was associated with higher odds of HIV testing and higher odds of engagement in HIV risk behaviors. People with depression still demonstrated a disproportionately higher rate of HIV risk behaviors than those without depression, which could increase their risk for contracting HIV. Even though people with depression had higher rates of HIV testing, they still experienced long time periods between HIV testing, with a median time of over two years since the last HIV test. More targeted efforts are needed to focus on people with depression, especially young adult males (aged 18–29).

CRedit authorship contribution statement

Cassidi C. McDaniel: Conceptualization, Investigation, Methodology, Formal analysis, Validation, Writing – review & editing. **Tim C. Lai:** Conceptualization, Investigation, Methodology, Formal analysis, Validation, Visualization, Writing – original draft, Writing – review & editing. **Chiahung Chou:** Conceptualization, Methodology, Project administration, Resources, Supervision, Validation, Writing – review & editing.

Declaration of Competing Interest

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Data availability

Data from the 2018–2020 Behavioral Risk Factor Surveillance System (BRFSS) are publicly available from the Centers for Disease Control and Prevention.

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Database linking

BRFSS: https://www.cdc.gov/brfss/data_documentation/index.htm.

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