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Adverse childhood experiences, diabetes and associated conditions, preventive care practices and health care access: A population-based study

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ABSTRACT

Our objective was to examine how Adverse Childhood Experiences (ACEs) are associated with diabetes mellitus, diabetes-related conditions, and preventive care practices. We used data from the Behavioral Risk Factor Surveillance System (BRFSS) 2009–2012, a cross-sectional, population-based survey, to assess ACEs, diabetes, and health care access in 179,375 adults. In those with diabetes ($n = 21,007$), we assessed the association of ACEs with myocardial infarction, stroke, and five Healthy People 2020 (HP2020) diabetes-related preventive-care objectives ($n = 13,152$). Healthcare access indicators included lack of a regular health care provider, insurance, and difficulty affording health care. Regression analyses adjusted for age, sex, and race. The adjusted odds ratio (AOR) of diabetes increased in a stepwise fashion by ACE exposure, ranging from 1.2 (95% CI 1.1–1.3) for 1 ACE to 1.7 (95% CI 1.6–1.9) for ≥4 ACEs, versus having no ACEs. In persons with diabetes, those with ≥4 ACEs had an elevated adjusted odds of myocardial infarction (AOR = 1.6, 95% CI 1.2–2.0) and stroke (AOR = 1.8, 95% CI 1.3–2.4), versus having no ACEs. ACEs were also associated with a reduction in the adjusted percent of HP2020 diabetes objectives met: 72.9% (95% CI 71.3–74.5) for those with no ACEs versus only 66.5% (95% CI 63.8–69.3%) for those with ≥4 ACEs ($p = 0.0002$). Finally, ACEs predicted worse health care access in a stepwise fashion for all indicators. In conclusion, ACEs are associated with greater prevalence of diabetes and associated disease conditions, and with meeting fewer HP2020 prevention goals. Implementing ACE screening and trauma-informed health care practices are thus recommended.

1. Introduction

Diabetes mellitus (i.e., diabetes) is a worldwide health problem and the 7th leading cause of death in the United States (Centers for Disease Control and Prevention, 2015). Adverse Childhood Experiences (ACEs), such as abuse and neglect, affect more than 50% of Americans and are associated with increased risk for several serious mental and physical disorders (Felitti et al., 1998; Schüssler-Fiorenza Rose et al., 2014; Slavich, 2016) including diabetes (Deschênes et al., 2018; Huang et al., 2015; Huffhines et al., 2016; Shields et al., 2016; Widom et al., 2012). We are presently at a pivotal moment in the screening, prevention, and research of ACEs. For the first time in U.S. history, a majority of states are now screening for ACEs at the population level. In addition, the first surgeon general of California, Dr. Nadine Burke Harris, put this topic in the international spotlight, with several countries now developing public health policies geared toward fostering ACEs awareness and developing systems that support trauma- and resilience-informed care. Despite these efforts, it has remained unclear how ACEs impact diabetes-related preventive care practices and health care access, which is critical to know in order to develop policies that have the potential to reduce the negative impact that ACEs have on mental and physical health.

Despite research linking ACEs with increased risk of diabetes, there is a significant gap in our understanding of how ACEs impact preventive care practices in people with diabetes as well as whether ACEs also have an additional effect on conditions that are associated with diabetes such as myocardial infarction and stroke. In the present study, therefore, we investigated the association between ACEs and the receipt of preventive health care in individuals with diabetes in the context of a large population-based sample. We also evaluated how ACEs affect the risk of associated conditions in those with diabetes. Based on prior research, we

Abbreviations: ACE, Adverse Childhood Experience; AOR, Adjusted odds ratio; CI, Confidence interval; BRFSS, Behavioral Risk Factor Surveillance System; HP2020, Healthy People 2020; CDC, Centers for Disease Control and Prevention.

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hypothesized that greater ACE exposure would be associated with a higher prevalence of self-reported diabetes and associated conditions (i.e., myocardial infarction, stroke) and with meeting fewer health-promoting objectives from Healthy People 2020 (HP2020), a U.S. government initiative that identified national health improvement priorities and set measurable objectives for diabetes education and preventive self-care [Centers for Disease Control and Prevention (CDC), 2015; Diabetes | Healthy People, 2010; Healthy People 2020, 2010]. Because preventive care practices may be influenced by health care access, which we hypothesized may also be negatively affected by ACEs, we also investigated whether the associations we observed between ACEs and preventive care practices were accounted for by differences in health care access. Therefore, we also examined the association between ACEs and participants' (a) health care access, as indexed by having insurance; (b) having a regular health care provider; and (c) difficulty affording health care over the past year (CDC, 2009-2012).

2. Method

2.1. Participants

Data came from the Behavioral Risk Factor Surveillance System (BRFSS), an annual population-based survey of non-institutionalized American adults (18 years and older) that is administered by states in coordination with the Centers for Disease Control and Prevention (CDC). The BRFSS consists of a core survey used by all states and optional modules that only some states administer. We used data from 20 states and Washington D.C. that administered the complete ACE Module from 2009 to 2012 (n = 201,646). The BRFSS traditionally consisted of landline samples but added cellphone samples starting in 2011 to include participants that received over 90% of their calls on cellular telephones. The BRFSS uses disproportionate stratified sampling for the landline telephone samples. Data from 2011 and 2012 also contained a cellular telephone sample which consisted of random samples of cellular telephone numbers from cellular telephone sampling frames (CDC, 2013a). Of the states that administered the ACE module, the median response rate (i.e., survey completers as a proportion of estimated eligible) was 52.0% (range: 40.4%–68.8%), calculated according to the CASRO standard (2009 and 2010) and the American Association of Public Opinion Research Response Rate Formula #4 (2011 and 2012), which are considered equivalent (CDC, 2013b). The BRFSS uses weighting to adjust for noncoverage and nonresponse bias and to have the total number of cases for each state equal to the state's population. In the years 2009 and 2010, the BRFSS used a post-stratification method to develop weights (CDC, 2011); starting in 2011, the BRFSS used raking to adjust design weights (CDC, 2013a).

The ACE Module was administered to 186,026 individuals of whom 4,421 (2.4%) were missing answers to some ACE questions. Of the remaining individuals, 1,707 (0.9%) were missing race/ethnicity information and an additional 523 (0.3%) had missing diabetes, stroke, or cardiac disease/myocardial infarction status, leading to a final sample of 179,375 adults. We assessed the association between ACEs and associated diabetic conditions in individuals reporting diabetes (n = 21,007). A subset of the states administering the ACE Module also administered the Diabetes Module (15 states and D.C.), which assessed receipt of preventive care (n = 13,152) in participants with diabetes. Missing data for the HP2020 objectives varied by objective: eye exam (n = 10), diabetes class (n = 48), daily blood glucose (n = 206), annual foot exam (n = 362), and glycosylated hemoglobin checked twice in the past year (n = 1,417). Participants with no feet (n = 57) were included in the foot exam missing data count. The missing data of the glycosylated hemoglobin question consisted primarily of respondents who answered "Never Heard of 'A one C' test" (n = 564, weighted percent 3.6%) and "Don't Know" (n = 816, weighted percent 6.5%). For the purpose of variance calculation, missing values were treated as not missing completely at random. Results from complete cases are reported.

2.2. Measures

The ACE Module assessed eight childhood adversity categories: physical, emotional, and sexual abuse; domestic violence; parental divorce, separation or death; and family member incarceration, substance abuse or mental illness. These categories were summed to create an ACE score (Felitti et al., 1998; Ford et al., 2011). Based on prior research (Felitti et al., 1998), ACE scores of $\geq$4 were grouped for analyses.

The BRFSS core survey asked about diabetes, myocardial infarction, and stroke using the questions "Has a doctor, nurse, or other health professional EVER told you that you have the following: (Ever told) you have diabetes?; (Ever told) you that you had a heart attack also called a myocardial infarction?; (Ever told) you had a stroke?" Those who reported only having had gestational diabetes or having prediabetes were not included as having diabetes. The core survey assessed health care access by asking about healthcare coverage ("Do you have any kind of health care coverage, including health insurance, prepaid plans such as HMOs, government plans such as Medicare, or Indian Health Service?"), having a personal doctor or healthcare provider ("Do you have one person you think of as your personal doctor or health care provider?" and if the person answers "no," "Is there more than one, or is there no person who you think of as your personal doctor or health care provider) and whether "there was a time in the past 12 months when you needed to see a doctor but could not because of cost." The Diabetes Module was only administered to persons with diabetes and asked about five HP2020 diabetes objectives: annual eye exam, annual foot exam, obtain glycosylated hemoglobin at least twice a year, formal diabetes education, and self-blood glucose monitoring at least once daily (CDC, 2009).

2.3. Statistical analyses

We used the survey procedures in SAS 9.4 to account for the complex survey design and incorporated survey weights into all analyses. For states that contributed >1 year of data, survey weights were divided by the number of years that data were available to avoid overweighting those states. Because of the strong inverse relation between ACEs and age, combined with a strong positive association between diabetes and age (Table 1), we report the age-adjusted prevalences for diabetes and associated conditions. Age-adjustment was performed using the 2000 U.S. Population Standard (Klein and Schoenborn, 2001) and the age categories shown in Table 1. Logistic regression analyses were adjusted for age (as a continuous variable), sex, and race. For each HP2020 objective, we report the age-adjusted percentage meeting the objective by ACE score. We also used logistic regression to evaluate the adjusted odds of meeting each individual HP2020 objective by ACE score. We then calculated the percent of HP2020 objectives that each individual met and evaluated the relation with participants' ACE scores using linear regression while adjusting for age, sex, and race. Finally, we used logistic regression to examine the relation between ACEs and health care access indicators using two models: one that adjusted only for demographic variables (i.e., age, sex, and race), and a second that adjusted for demographic variables and income.

2.4. Data availability

The datasets analyzed for this study are available at the BRFSS website: https://www.cdc.gov/brfss/annual_data/annual_data.htm. We confirmed with the Stanford University Institutional Review Board that research with this publicly available data does not constitute human subjects research.

Table 1
Demographics, Adverse Childhood Experiences (ACEs), and diabetes estimated prevalence.

Characteristic	Raw *n*	Weighted (wt.) %	ACE ≥ 1 wt.% (95% cl)	ACE ≥ 4 wt.% (95% cl)	Diabetes wt.% (95% CI)
Overall	179,375	100.0	57.3 (56.8–57.8)	14.5 (14.1–14.9)	9.5 (9.1–9.8)
Age					
18–29 years	12,278	16.3	63.6 (62.0–65.3)	20.3 (19.0–21.6)	1.6 (1.2–1.9)
30–44 years	31,083	30.3	62.8 (61.6–63.9)	17.7 (16.8–18.6)	4.0 (3.6–4.5)
45–54 years	34,093	19.2	60.2 (59.2–61.3)	16.0 (15.2–16.8)	9.5 (8.8–10.1)
55–64 years	43,265	16.0	54.9 (53.9–55.8)	11.9 (11.3–12.5)	15.7 (15.0–16.5)
65–74 years	32,710	10.0	46.6 (45.5–47.7)	6.8 (6.2–7.3)	20.6 (19.7–21.6)
75+ years	25,946	8.2	35.5 (34.3–36.7)	2.5 (2.2–2.9)	19.8 (18.8–20.9)
Gender					
Male	70,504	48.4	56.2 (55.4–57.1)	12.5 (11.9–13.1)	10.2 (9.7–10.6)
Female	108,871	51.6	58.3 (57.7–59.0)	16.5 (16.0–17.0)	8.9 (8.6–9.2)
Race					
Non-Hispanic white	150,245	80.5	55.9 (55.3–56.5)	13.9 (13.5–14.3)	9.1 (8.8–9.4)
Non-Hispanic black	9,690	8.0	65.5 (63.8–67.2)	15.7 (14.3–17.1)	14.3 (13.2–15.5)
Hispanic	7,238	5.3	65.0 (62.9–67.0)	17.4 (15.7–19.0)	8.6 (7.4–9.7)
Asian	3,768	2.5	38.5 (35.0–42.1)	4.7 (3.4–6.0)	7.4 (6.0–8.8)
Native Hawaiian, Pacific islander	392	0.2	56.6 (46.6–66.5)	16.9 (10.8–23.0)	6.2 (3.6–8.9)
Native American/Alaska native	2,687	1.2	59.3 (53.7–64.9)	25.8 (21.9–29.7)	14.0 (11.8–16.2)
Multiracial, other	5,355	2.6	71.6 (69.0–74.1)	28.2 (25.4–31.0)	9.9 (8.4–11.4)

3. Results

Demographic characteristics are reported in Table 1. Over 57% of participants reported at least one ACE and 14.5% reported ≥4 ACEs. As age increased, the percentage of participants reporting having experienced ACEs decreased, particularly for those older than 45 years. More women than men reported experiencing at least one ACE and ≥4 ACEs. ACEs varied by race, with those self-identifying as multiracial (non-Hispanic) having the highest prevalence of experiencing at least one ACE and ≥4 ACEs, and those identifying as Asians having the lowest prevalence. The overall estimated prevalence of diabetes was 9.5%, and was highest for persons over 65 years old and for men and non-Hispanic Blacks, Native Americans, and Alaskan Natives (Table 1).

Of participants with diabetes, the age distribution was different than the whole population with almost two-thirds being over the age of 55 (65.2%). Notably, those under 55 years old had a very high rate of experiencing any ACE (>70%) as well as higher rates of experiencing ≥4 ACEs (20–35%). Overall, the prevalence of myocardial infarction and stroke were 14.4% and 9.3%, respectively, with rates of these associated disease conditions being much lower in the youngest versus oldest age groups (Table A.1).

As hypothesized and as shown in Fig. 1, the adjusted odds ratio (AOR) of diabetes increased in a stepwise fashion as a function of experiencing more ACEs. With respect to associated conditions in participants with diabetes, persons experiencing any ACEs had an increased odds of myocardial infarction (AOR = 1.4, 95% CI 1.2–1.6, $p < 0.0001$) versus those with no ACEs, although there was no clear stepwise effect. The odds of stroke increased substantially for adults experiencing ≥3 ACEs as compared to those with no ACEs (Fig. 1b).

The association between ACEs and individuals' likelihood of meeting HP2020 goals was strongest for those experiencing ≥4 ACEs. Indeed, individuals exposed to no ACEs met 4 out of 5 HP2020 targets as compared to those exposed to ≥4 ACEs, who (on average) met only one of the 5 HP2020 targets (Fig. 2a). For individual HP2020 objectives, the greatest differences were evident for the annual eye exam and foot exam, where adults with ≥4 ACEs versus 0 ACEs had an AOR of 0.61 (95% CI 0.46–0.81, $p = 0.0007$) for having an annual eye and an AOR of 0.68 (95% CI 0.52–0.88, $p = 0.0031$) for an annual foot exam. The AOR of those with ≥4 ACEs versus 0 ACEs for daily blood glucose checks (AOR = 0.79, 95% CI 0.63–0.99, $p = 0.044$) and checking hemoglobin A1C twice a year (AOR = 0.76, 95% CI 0.59–0.99, $p = 0.039$) were only marginally significant. In contrast, rates of checking blood glucose daily did not differ for those with high (≥4 ACEs) versus no ACE exposure (AOR = 0.80, 95% CI 0.63–1.02, $p = 0.071$). With regard to the percent of HP2020 objectives met, the adjusted percentage declined from 72.9% (95% CI 71.3–74.5) for those with 0 ACEs to 66.5% (95% CI 63.8–69.3) for those reporting ≥4 ACEs (Fig. 2b).

Finally, we examined whether ACEs were associated with three major health care access indicators: health care access (i.e., having insurance), having a regular health care provider, and difficulty affording health care over the past year (Table 2). As ACE exposure increased, the percentage of participants without health insurance increased, such that the adjusted odds of not having insurance for individuals with ≥4 ACEs was 1.81 (95% CI 1.64–1.99, $p < 0.0001$) relative to those with no ACEs. Similarly, the adjusted odds of not having a personal doctor was 1.54 (95% CI 1.40–1.69, $p < 0.0001$) for those with ≥4 ACEs as compared to no ACEs. ACEs were also related to difficulty affording medical care in a stepwise fashion, going from 8.3% for those with 0 ACEs to 29.4% for those with ≥4 ACEs (AOR = 3.83, 95% CI 3.48–4.22, $p < 0.0001$). The relation between ACEs and health care access was similar while controlling for income (Table 2). Moreover, including the health care access indicators as covariates in the model did not eliminate the significant association between high (≥4) ACEs and meeting fewer HP2020 preventive care practices. In the model adjusting for demographics (i.e., age, sex, and race) and all of the access to health care variables, the difference between the estimated mean percentage of goals met between ≥4 ACEs and no ACEs was −4.9% ($p = 0.0038$, two-sided *t*-test).

4. Discussion

Substantial research has examined associations between ACEs and health. The present study extends this body of work in a critical new direction by showing that in adults with diabetes, those with higher ACE exposure are also less likely to receive recommended diabetes preventive care, which likely compounds the chronic health difficulties experienced by this population. In addition, we found that experiencing childhood adversity was strongly related to a greater risk of developing diabetes, in addition to myocardial infarction and stroke for those with diabetes, as well as with engaging in fewer diabetes-related preventive care practices and having poorer health care access. Together, these data underscore the crucial importance of screening for ACEs in general, and especially in the context of diabetes care, as one way to help reduce ACE-assocaited health disparities in adulthood.

These findings are consistent with research showing that ACEs are related to the prevalence of diabetes and other chronic diseases (Bellis et al., 2019; Merrick et al., 2019) but extend this body of work by demonstrating that ACEs also increase the odds of associated disease conditions in those with diabetes. The novel finding that high ACE exposure relates to lower receipt of diabetes-related preventive care—in particular, eye and foot exams—could exacerbate the impact of diabetes

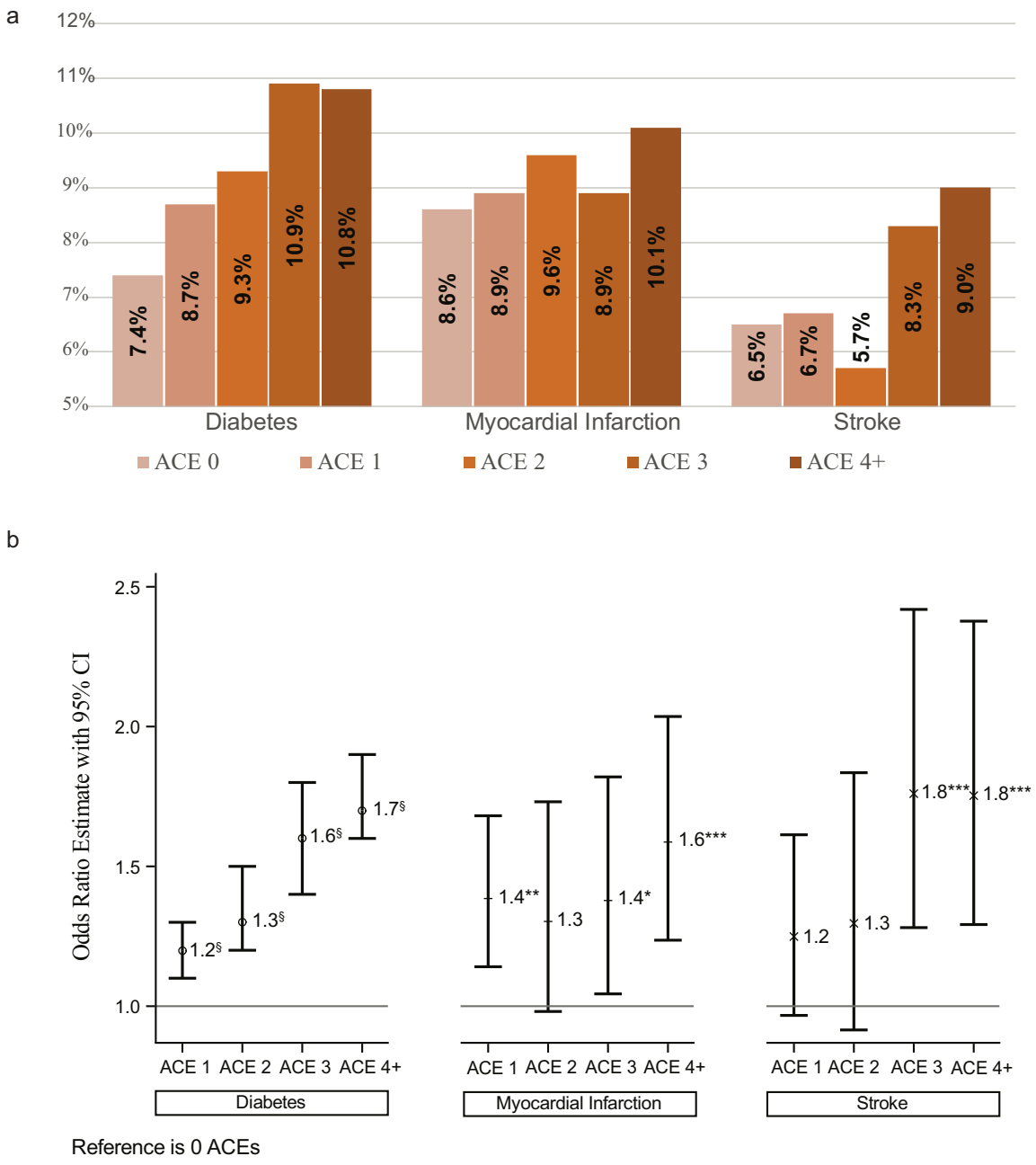

Fig. 1. Age-adjusted prevalence and adjusted odds ratios of diabetes and associated conditions by ACE score.
(**a**) Age adjusted prevalence of diabetes (all participants) and associated disease conditions (participants with diabetes only). The U.S. 2000 population standard was used for age adjustment using the age groups: 18–29, 30–44, 45–54, 55–64, 65–74 and 75 plus. (**b**) Adjusted odds ratios of diabetes and associated disease conditions for each ACE score as compared to having 0 ACEs. Analyses adjusted for age (continuous), sex, and race/ethnicity. $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$; $^{\S}p < 0.0001$.

and suggests a greater need for targeting this specific population to meet national preventative health care goals. Finally, we found that greater ACE exposure relates to worse health care access in a stepwise fashion, suggesting that addressing disparities in health care access may be necessary for reducing the effects of early life stress on risk for diabetes and likely other chronic diseases as well.

These data do not indicate exactly how early life stress leads to poorer health. However, a wealth of clinical and preclinical studies have shown that early adversity can lead to altered disease-relevant biological functioning in adulthood through epigenetic changes (Berens et al., 2017; McEwen, 2012). This research has particularly focused on the association of ACEs with increased inflammatory tone, altered hypothalamic-pituitary-adrenal axis responsiveness, and metabolic changes in adulthood (Coelho et al., 2014; Deighton et al., 2018; Furman et al., 2019; Slavich, 2020). ACEs also have been shown to have a strong impact on adult health risk behaviors such as smoking (Ford et al., 2011), which can lead to diabetes complications. In addition, ACEs can lead to negative psychosocial outcomes such as work disability (Laditka and Laditka, 2018; Schüssler-Fiorenza Rose et al., 2016), which may also affect access to care.

Some prior research has shown that ACEs are associated with decreased receipt of some preventive practices such as cancer screening (Alcalá et al., 2018). To our knowledge, though, no other study has examined the effect of ACEs on diabetes preventive care, which is particularly important given that it is possible for health care providers and public health policies to impact the preventive care people receive.

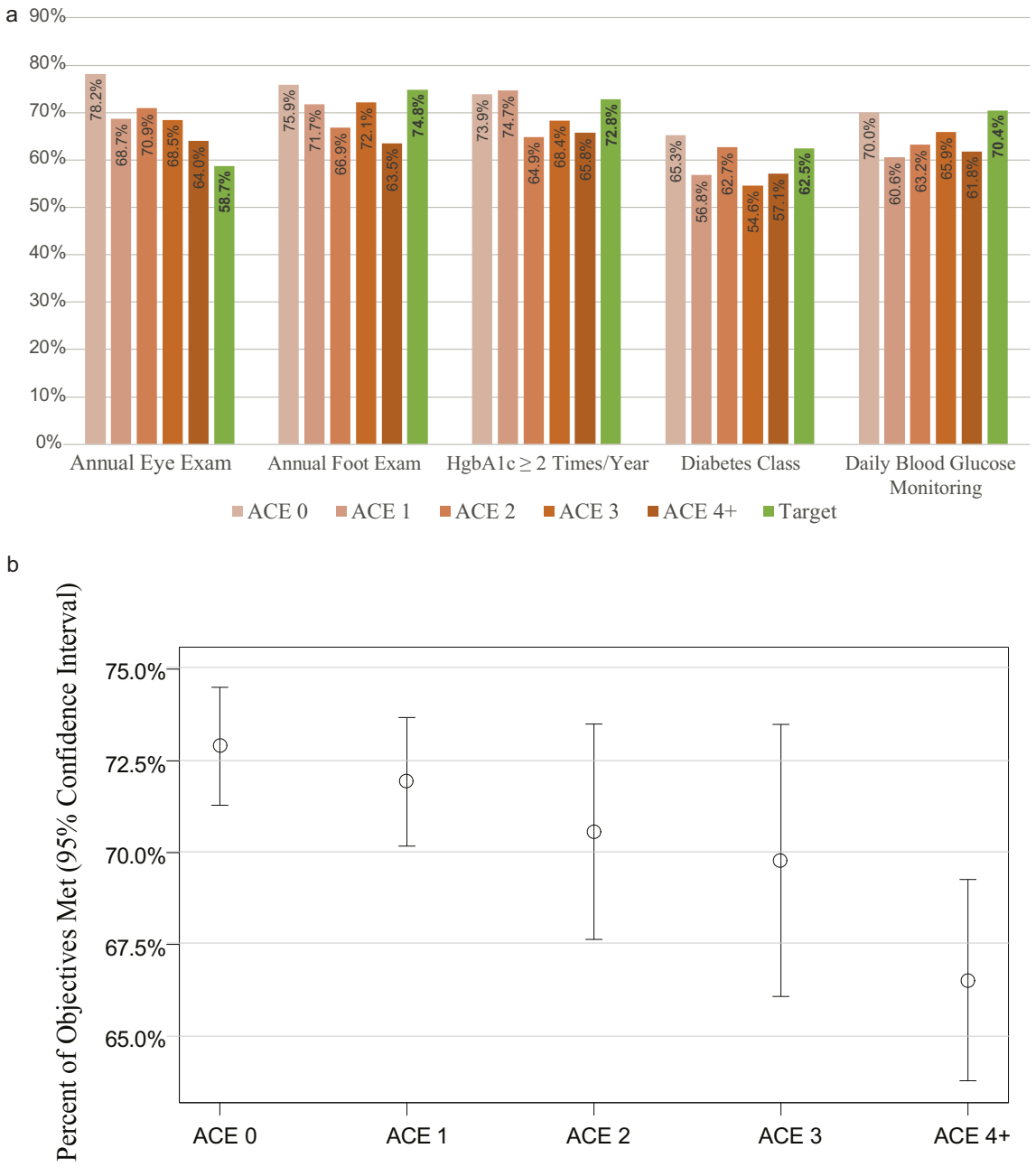

Fig. 2. ACE Score and Age-Adjusted Percent Meeting Healthy People 2020 Objectives.
(**a**) The age-adjusted percent of each ACE score meeting the specified Healthy People 2020 (HP2020) Diabetes Objective. The U.S. 2000 population standard was used for age adjustment using the age groups: 18–29, 30–44, 45–54, 55–64, 65–74, and 75+. The green bars show the target percentage specified in 2010 as the goal for the U.S. population. (**b**) The mean percent of the five HP2020 objectives met with 95% confidence intervals (CI), adjusted for age (continuous), sex, and race/ethnicity. (Test of ACE effect: $p = 0.0031$, $df = 404$, Wald F test).

Although additional research is required to understand which of the effects of ACEs underlie our finding of increased prevalence of diabetes-associated conditions in persons with high ACE burden, our finding that high ACE exposure is associated with decreased preventive care is a potential point of intervention for health care providers. Assessing and addressing the impact of ACEs on health risk behaviors may make interventions for reducing these behaviors more effective (Felitti et al., 2010; Goldstein et al., 2019), which is also important for diabetes care. Finally, understanding how ACEs affect health care access indicators will be important. We found that even when accounting for a lack of insurance and inability to afford health care, participants with a high ACE burden were less likely to report having a regular doctor. Given that ACEs can impact trust in the medical profession (Munoz et al., 2019), additional research is needed to understand how ACEs influence the clinician-patient relationship to facilitate the provision of trauma- and resilience-informed care.

4.1. Strengths and limitations

Several strengths and limitations of this study should be noted. In terms of strengths, we employed a large representative sample of adults, used one of the most common instruments for assessing early life stress exposure, and focused on a range of diabetes-related outcomes and preventive care practices that have direct clinical relevance. In terms of limitations, the BRFSS only includes community-dwelling American adults with telephones and not all states assessed ACEs, which may limit

Table 2
Access to health care by Adverse Childhood Experiences (ACEs) score.

# of ACE categories	Prevalence	Model 1: adjusted OR	Model 2: adjusted OR
No insurance (n = 179,249)			
ACE 0	11.0 (10.4–11.5)	Reference	Reference
ACE 1	14.4 (13.4–15.3)	**1.22 (1.11–1.34)*****	**1.19 (1.08–1.32)******
ACE 2	15.8 (14.7–16.9)	**1.31 (1.18–1.45)*****	**1.27 (1.14–1.41)******
ACE 3	19.8 (18.2–21.5)	**1.66 (1.47–1.88)*****	**1.49 (1.31–1.70)******
ACE 4+	22.3 (21.1–23.5)	**1.81 (1.64–1.99)*****	**1.43 (1.29–1.59)******
No personal health care provider (n = 179,291)			
ACE 0	14.3 (13.8–14.9)	Reference	Reference
ACE 1	18.4 (17.4–19.3)	**1.21 (1.11–1.31)*****	**1.19 (1.10–1.30)*****
ACE 2	18.4 (17.2–19.6)	**1.16 (1.05–1.28)****	**1.13 (1.03–1.25)***
ACE 3	20.6 (19.0–22.1)	**1.29 (1.15–1.44)*****	**1.20 (1.07–1.34)****
ACE 4+	24.4 (23.1–25.7)	**1.54 (1.40–1.69)*****	**1.35 (1.23–1.49)*****
Difficulty affording care (n = 179,330)			
ACE 0	8.3 (7.8–8.7)	Reference	Reference
ACE 1	12.2 (11.4–13.0)	**1.44 (1.31–1.59)*****	**1.42 (1.29–1.57)*****
ACE 2	15.2 (14.2–16.3)	**1.80 (1.62–2.00)*****	**1.77 (1.58–1.97)*****
ACE 3	20.7 (19.1–22.3)	**2.53 (2.25–2.86)*****	**2.36 (2.08–2.67)*****
ACE 4+	29.4 (28.0–30.8)	**3.83 (3.48–4.22)*****	**3.30 (2.98–3.65)*****

Model 1 adjusted for age, sex and race.
Model 2 adjusted for age, sex, race, and income.
OR = odds ratio; CI = Confidence Interval.
Boldface indicates statistically significant ($^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$; $^{****}p < 0.0001$).

the generalizability of these results to other states and countries. Second, the BRFSS is a retrospective survey, which may underestimate the prevalence of ACEs because of age- or trauma-related memory degradation (Brown et al., 2007; Dube et al., 2004; Hardt and Rutter, 2004) or social desirability bias. Adults over 65 years old in the present sample had a much lower prevalence of multiple ACEs, which is consistent with possible age-related differences in reporting. Multiple ACEs may also be under-reported in older individuals due to ACE-associated premature mortality (Brown et al., 2009). In this sample, the youngest participants with diabetes had a particularly high ACE burden with over a third reporting ≥4 ACEs; relevantly, earlier onset of diabetes is associated with earlier mortality (Huo et al., 2018). In addition, there may be a positivity bias in autobiographical memory for older adults (Mather and Carstensen, 2005). Finally, there may be cohort effects in the prevalence of certain ACEs (e.g., divorce) or in the self-recognition of having experienced ACEs, which may have impacted older adults' reporting. The potential underestimation of ACEs in older adults would bias our results toward the null and is thus of limited concern. In addition, though, for our assessment of the impact of ACEs on diabetes-associated conditions in participants with diabetes, the relatively lower prevalence of multiple ACEs in the older age groups combined with the much higher prevalence of these outcomes in the oldest age groups may have contributed to the wide confidence intervals and lack of precision of these estimates. Additional research is thus warranted.

Third, the assessment of ACEs was limited and did not include the severity, frequency, exposure timing, or duration of the experiences described, which are important for fully understanding stress effects (Shields and Slavich, 2017; Slavich, 2019; Slavich and Shields, 2018). In addition, the version of the ACEs scale used in the BRFSS did not assess neglect, which could have led us to underestimate the negative effects of stress on diabetes in this study. Fourth, the BRFSS does not allow one to distinguish between those with Type I and Type II diabetes. Based on other national prevalence estimates, we expect that at least 90% of our sample had Type II diabetes (Bullard et al., 2018). Although this may be relevant for our diabetes prevalence estimates, this would not affect the bulk of the analyses examining diabetes-associated conditions and preventive care, as these are similar for both Type I and Type II diabetes. Relatedly, the BRFSS relies on self-reports of diabetes, which may have led to underestimates of its prevalence. Moreover, these data do not contain any objective metrics, such as blood glucose values, anthropomorphic data, or data on potential confounders such as objective measures of blood pressure or medication use, all of which are topics for future research. Fifth, the survey did not include information about the severity of diabetes, which should be assessed in future studies.

Sixth, we did not adjust for demographic variables such as education because we view such factors not as confounds but rather as pathways linking ACEs with inequalities in human health and opportunity. Notably, however, a sensitivity analysis found that adjusting for education and income slightly attenuated the effects but did not alter the results (Table A.2). We also did not adjust for other variables that we considered intermediate variables on the causal pathway between ACEs and diabetes, such as smoking and obesity. Again, however, we did conduct a sensitivity analysis looking at smoking and obesity, and consistent with prior work, both variables were associated with ACEs in a stepwise fashion (Table A.3). Moreover, adding these variables to the main model slightly attenuated the odds ratios but, importantly, did not change the results (Table A.4), suggesting that what we are seeing is likely also driven by stress-induced changes in disease-relevant biology, not just stress-related effects on health risk behaviors. Given research showing that stress induces health-damaging biology but also promotes unhealthy coping behaviors (Felitti et al., 2010), effective interventions will ultimately need to focus on reducing both sources of risk to promote health and wellness.

4.2. Conclusion

In conclusion, this study extends existing research by showing that greater ACE exposure is related to a decrease in the receipt of diabetes-related preventive care. These data also demonstrate that ACEs are strongly associated with an increased risk of both diabetes mellitus and diabetes-associated disease conditions, as well as with a strong stepwise increase in barriers to health care access. Screening for ACEs in populations with diabetes, and increasing access to preventive diabetes care, are thus warranted, especially for high ACE-exposure populations (Polick et al., 2021; Valderhaug and Slavich, 2020).

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Prior presentation

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Author conflicts of interest

The authors report no conflicts of interest.

CRediT authorship contribution statement

Sophia Miryam Schüssler-Fiorenza Rose: Conceptualization, Methodology, Formal analysis, Validation, Visualization, Writing – original draft, Writing – review & editing. **Michael P. Snyder:** Writing – review & editing. **George M. Slavich:** Supervision, Methodology, Writing – review & editing.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2022.107044.

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