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Adverse Childhood Experiences are Associated with High-Intensity Binge Drinking Behavior in Adulthood and Mediated by Psychiatric Disorders

Jeesun Jung[†], Daniel B. Rosoff[†], Christine Muench, Audrey Luo, Martha Longley, Jisoo Lee, Katrin Charlet, and Falk W. Lohoff,[*]

Section on Clinical Genomics and Experimental Therapeutics, National Institute on Alcohol Abuse and Alcoholism, National Institutes of Health, 10 Center Drive (10CRC/2-2352), Bethesda, MD 20892-1540, USA.

*Corresponding author: Section on Clinical Genomics and Experimental Therapeutics (CGET), Lasker Clinical Research Scholar, National Institute on Alcohol Abuse and Alcoholism (NIAAA), National Institutes of Health, 10 Center Drive (10CRC/2-2352), Bethesda, MD 20892-1540, USA. Tel.: +301-827-1542; Fax: +301-402-1543; E-mail: falk.lohoff@nih.gov

[†]Contributed equally.

Abstract

Aim: High-intensity binge drinking (HIBD), defined as two or more times the gender-specific binge threshold, is rapidly increasing in the USA; however, the underlying contributing factors are poorly understood. This study investigated the relationship of adverse childhood experiences (ACEs) and HIBD.

Methods: Two independent, cross-sectional samples were analysed: (a) past 12-month drinkers in the National Epidemiological Survey on Alcohol and Related Conditions-III (NESARC-III; $n = 25,552$) and (b) the National Institute on Alcohol Abuse and Alcoholism (NIAAA) clinical sample ($n = 1303$). Multinomial logistic regressions were utilized to estimate adjusted odds ratios (AORs) of ACEs on HIBD. Mediation analysis was performed to examine the relationship between the past 12-month psychiatric disorders, ACEs, and HIBD.

Results: In the NESARC-III sample, prevalence of ACEs increased across all binge levels with the highest prevalence in extreme HIBD; ACEs were associated with higher odds for HIBD (level II, odds ratio (OR) = 1.2–1.4; $P = 0.03$–0.001; level III, OR = 1.3–1.9; $P < 0.001$). Prevalence of *DSM-5* diagnoses also increased across all binge levels. Substance use disorders (SUD), mood, personality and post-traumatic stress disorders (PTSD) conferred the highest odds with extreme HIBD (SUD: OR = 21.32; mood: 1.73; personality: 2.84; PTSD: 1.97; all *Ps* < 0.001). Mediation analyses showed that the association between ACEs and HIBD was fully mediated through SUD (proportion mediated: 70–90%) and partially through other psychiatric disorders (20–80%). In the NIAAA sample, ACEs were 2–5 times more prevalent in extreme HIBD with higher odds (ORs = 3–8, $P < 0.001$) compared with non-bingers.

Conclusion: ACEs were associated with significantly increased odds of HIBD and the relationship may be mediated by psychiatric disorders.

INTRODUCTION

Heavy alcohol consumption is a leading cause of alcohol-associated diseases and premature deaths in the USA (Midanik *et al*., 2004; Mokdad *et al*., 2005; Lucey *et al*., 2009). Approximately 36% of all adults in the US ages 18 and older report episodes of binge drinking (BD) within the past year. BD is defined as reaching a blood alcohol concentration (BAC) $\geq 0.08\%$, which results in a gender-specific threshold of consuming five or more standard drinks (containing 14 g pure alcohol) on one occasion for men and four or more for women (Hingson *et al*., 2017). BD is a major risk factor for many acute and long-term health conditions (Charlet and Heinz, 2017) and has also been used as an indicator of dangerous alcohol consumption (Rehm *et al*., 2009; World Health Organization. Management of Substance Abuse Team, 2011). However, defining BD in a dichotomous way using gender-specific thresholds may obscure important information regarding heavier or more dangerous drinking behaviors and may suggest that all BD confers identical risk, regardless of how far it exceeds the threshold and how severe the consequences of the high-quantity levels are (Fish *et al*., 2018; Patrick and Azar, 2018).

Drinking two or more times the BD threshold is defined as high-intensity binge drinking (HIBD) which confers significant health risks. Individuals BD three times the threshold have BACs of 0.20–0.30% and often suffer from blackouts, memory loss, or overdoses. Individuals with HIBD have been shown to be at substantially increased risk of alcohol-related and other health-related consequences. While HIBD is prevalent among young adults, particularly college students (White *et al*., 2006), recent data indicate that the prevalence of HIBD has also increased among the general population in the last decade (Hingson *et al*., 2017). Although it is evident that individuals who engage in HIBD are predisposed to major public health problems, little is known about the underlying risk factors, pathophysiology and neurobiology of HIBD.

One well-studied risk factor for alcohol misuse is exposure to adverse childhood experiences (ACEs) (Brady and Back, 2012). Child abuse is common in the USA: the US Child Protective Services documented 700,000 cases of childhood sexual abuse, physical abuse and neglect in 2014 (Bynum *et al*., 2011). When expanding the ACE definition to include categories of household dysfunction, such as having mentally ill or incarcerated family members, or observing violence toward a mother or stepmother, approximately half of the children in the USA have experienced at least one type of trauma (Felitti *et al*., 1998). To date, most studies examining the association between ACEs and alcohol consumption have focused primarily on BD (Loudermilk *et al*., 2018), not on HIBD which might lead to more severe health consequences (Felitti *et al*., 1998; Bynum *et al*., 2011). Retrospective studies have linked ACEs with increased susceptibility to BD and alcohol use disorder (AUD) later in life (Kauhanen *et al*., 2011; Schwandt *et al*., 2013). Additionally, adolescents and young adults with ACEs report having their first drink earlier and are at a higher risk of developing psychiatric disorders compared with their peers without ACEs (Vallejos *et al*., 2017). Exposure to ACEs is also linked to higher odds of adulthood alcohol, opioid, and nicotine dependence, as well as depression, anxiety, suicidal behaviors, and schizophrenia (Rothman *et al*., 2008; Cheong *et al*., 2017; Cawthorpe *et al*., 2018; Rokita *et al*., 2018; Lew and Xian, 2019). However, associations between ACEs and heavy drinking that exceeds the binge threshold, associations between ACEs and comorbid psychiatric disorders among HIBD, as well as the role of psychiatric disorders in the relationship between ACEs and HIBD

remain poorly understood (Regier *et al*., 1990; Kessler *et al*., 1996; Grant *et al*., 2004; Kessler *et al*., 2005; Nock *et al*., 2010).

In the present study, we aimed to investigate the relationship between ACEs and HIBD in a sample recruited in the National Epidemiologic Survey on Alcohol and Related Conditions-III (NESARC-III). Defining HIBD as two or more times the BD threshold and extreme HIBD as three or more times the BD threshold, we estimated prevalence and odds ratio (OR) of each category of ACE among HIBD. Furthermore, we examined the association between past 12-month psychiatric diagnoses and HIBD, and explored psychiatric disorders as a mediator of the relationship between ACEs and HIBD. Our second goal was to confirm our findings in a clinical sample collected at the National Institute on Alcohol Abuse and Alcoholism (NIAAA) which was predominantly comprised of individuals with AUD.

METHODS

Sources of data

NESARC-III sample. The NESARC-III is a nationally representative survey of the non-institutionalized civilian US adult population 18 years and older. The cross-sectional samples were collected from 2012 to 2013. The detailed methodological information of sampling in NESARC-III are available elsewhere (https://www.niaaa.nih.gov/research/nesarc-iii/methodology). The final sample consisted of 25,552 respondents who reported at least one drink within the previous 12 months (Table 1). The NESARC-III survey protocol was approved by the institutional review boards of the National Institutes of Health (NIH) and Westat.

NIAAA clinical sample. The NIAAA clinical sample consisted of 1,326 participants who were diagnosed using the Structured Clinical Interview for DSM-IV (First *et al*., 2002). Participants with alcohol dependence (AD) included both individuals seeking treatment for AD and non-treatment-seeking individuals. Detailed information is available in the Supplementary Material. All protocols were approved by the institutional review board. Informed consent was obtained in accordance with the Declaration of Helsinki.

Assessments

Adverse childhood experience

NESARC-III sample. NESARC-III used more comprehensive questions, namely ACEs, than the NIAAA clinical sample regarding childhood trauma experiences (CTEs). ACEs include categories for child abuse (sexual, physical, verbal abuse and physical and emotional neglect), as well as categories for household dysfunction consisting of witnessing a battered mother or stepmother, having a household member with a mental health or substance use disorder (SUD) or who was incarcerated, or who either attempted or committed suicide when respondents were younger than 18 years old. Detailed methodological description of ACEs and diagnoses of psychiatric disorders can be found in the Supplementary Material.

NIAAA clinical sample. The Childhood Trauma (CTQ) and Early Life Stress (ELSQ) Questionnaires were used to quantitatively assess CTEs in the NIAAA clinical sample. The CTQ is a 28-item, self-administered instrument for the retrospective assessment of childhood abuse and neglect (Bernstein *et al*., 2003). The five CTQ subscales comprise emotional abuse, physical abuse, sexual abuse, emotional neglect, and physical neglect. In the present study, average

Table 1. Frequency and prevalence of sociodemographic characteristics by alcohol binge levels[a]

NESARC-III	Alcohol binge level[b]				P-value
	Non-binge N = 14,030	Level I N = 7,190	Level II N = 2,599	Level III N = 1,733	
Weighted prevalence of N (%, SE)	55.0 (0.56)	27.6 (0.44)	10.6 (0.29)	6.8 (0.23)	
Age (years) (mean, SE)	49.44 (0.25)	40.54 (0.28)	36.57 (0.38)	33.85 (0.39)	<0.0001
Age at first drink (mean, SE)	20.93 (0.11)	18.45 (0.08)	17.68 (0.24)	16.97 (0.13)	<0.0001
Age at heaviest drinking (mean, SE)	32.78 (0.23)	28.33 (0.21)	25.98 (0.34)	24.80 (0.28)	<0.0001
Gender: male (%, SE)	45.1 (0.52)	49.9 (0.71)	69.4 (1.08)	68.2 (1.23)	<0.0001
Race					<0.0001
White, non-Hispanic	68.2 (0.83)	68.81 (0.90)	68.97 (1.11)	70.39 (1.38)	
Black, non-Hispanic	11.9 (0.65)	10.24 (0.64)	7.40 (0.62)	7.63 (0.89)	
American Indian	1.30 (0.13)	1.58 (0.20)	2.17 (0.44)	2.78 (0.56)	
Asian	5.95 (0.46)	3.75 (0.49)	3.76 (0.54)	2.86 (0.65)	
Hispanic	12.63 (0.60)	15.62 (0.77)	17.70 (1.14)	16.34 (1.06)	
Marital status (%, SE)					<0.0001
Married or cohabiting	62.84 (0.70)	56.01 (0.78)	50.57 (1.13)	42.51 (1.52)	
Widowed, separated or divorced	20.26 (0.45)	16.55 (0.53)	13.22 (0.84)	15.72 (1.12)	
Never married	16.90 (0.48)	27.44 (0.76)	36.21 (1.17)	41.76 (1.60)	
Educational attainment (%, SE)					<0.0001
Some high school	9.20 (0.38)	9.45 (0.46)	11.18 (0.80)	16.13 (1.19)	
High school graduate	23.25 (0.67)	22.52 (0.64)	27.11 (1.18)	31.94 (1.26)	
Some college or higher	67.55 (0.84)	68.03 (0.85)	61.71 (1.37)	51.93 (1.57)	
Family income, $ (%, SE)					<0.0001
0–19,999	17.99 (0.54)	19.79 (0.59)	24.65 (1.20)	30.14 (1.50)	
20,000–34,999	17.96 (0.42)	17.46 (0.57)	17.00 (0.81)	19.99 (1.18)	
35,000–69,999	27.74 (0.53)	26.68 (0.69)	26.56 (0.91)	29.18 (1.40)	
≥70,000	36.31 (0.88)	36.07 (0.97)	31.80 (1.29)	20.69 (1.32)	
NIAAA	N = 199	N = 319	N = 196	N = 589	
Frequency (%, SE) of N	15.3 (1.0)	24.5 (1.19)	15.0 (0.99)	45.2 (1.38)	
Age (years) (mean, SE)	35.81 (0.91)	33.81 (0.66)	38.95 (0.91)	41.99 (0.46)	<0.0001
Gender: male (%, SE)	55.28 (3.53)	57.05 (2.78)	64.29 (3.43)	72.16 (1.85)	<0.0001
Race					0.01
White, non-Hispanic	44.22 (3.53)	54.86 (2.79)	49.49 (3.58)	47.20 (2.06)	
Black, non-Hispanic	47.24 (3.55)	34.80 (2.67)	44.39 (3.56)	47.20 (2.06)	
Asian	5.03 (1.55)	5.96 (1.33)	3.06 (1.23)	2.86 (0.65)	
Hispanic	1.51 (0.87)	1.57 (0.70)	1.53 (0.88)	2.21 (0.61)	
Treatment-seeking AD (%, SE)	2.51 (1.11)	8.78 (1.59)	38.27 (3.48)	75.55 (1.77)	<0.0001
Non-treatment-seeking AD (%, SE)	1.01 (0.71)	13.79 (1.93)	28.06 (3.22)	17.83 (1.58)	<0.0001
Healthy volunteer (no AD) (%, SE)	96.48 (1.31)	76.80 (2.37)	33.67 (3.38)	6.62 (1.03)	<0.0001

Abbreviation: AD, DSM-IV diagnosis of current alcohol dependence in NIAAA sample.
[a]Frequency or prevalence % and standard error (in parentheses) reported except where otherwise noted.
[b]Alcohol binge levels are gender-specific: for women, non-binge = 1–3; level I = 4–7; level II = 8–11; level III ≥ 12 drinks; for men, non-binge = 1–4; level L = 5–9; level II = 10–14; level III ≥ 15 drinks.

scores for each subscale were categorized into a binary outcome, such that a mean score of 2 or above indicates CTE exposure and a mean score below 2 indicates no exposure. The ELSQ is an 18-item assessment of exposure to specific traumatic events before age 18 (Sanders and Becker-Lausen, 1995). Subjects scoring above 2 on a CTQ subscale or endorsing the corresponding ELSQ item were considered to have a history of CTE. To be consistent with NESARC-III, CTEs were referred to as ACEs in the NIAAA clinical sample.

Alcohol binge levels. Alcohol consumption for the 90 days prior to screening or admission was assessed for the NIAAA clinical sample using the Timeline Followback (Sobell and Sobell, 1992). NESARC-III respondents reported the maximum number of drinks in a single day during the past 12 months. Consistent with current literature on high-intensity alcohol consumption (Hingson *et al.*, 2017), four gender-specific binge levels were generated based on the maximum number of standard drinks (defined as 14 g alcohol) consumed on any single day in the survey-specified time period. For women, 4 categorized BD levels were defined as 1–3 drinks (non-binge), 4–7 drinks (level I), 8–11 drinks (level II), and 12 drinks or more (level III) in a single day. For men, the BD levels were categorized as 1–4 drinks (non-binge), 5–9 drinks (level I), 10–14 drinks (level II), and 15 drinks or more (level III). Levels I, II, and III thus correspond to one, two, and three or more times the gender-specific binary BD thresholds utilizing standard drinks ≥4 for women and ≥5 for men. HIBD was defined as two or more times the BD threshold, and extreme HIBD was defined as three or more times the BD threshold.

Statistical analysis
The NESARC-III and NIAAA samples were analysed separately due to differences in study design. The data analysis proceeded in two steps: first, the NESARC-III data was analysed to identify associations between each category of ACEs and binge levels. The NIAAA clinical data was then used to confirm the findings observed in the NESARC-III sample.

NESARC-III sample. Weighted cross-tabulations estimated the prevalence of sociodemographic characteristics and the 10 ACEs for each binge level. We also estimated the prevalence rates of past 12-month SUD and psychiatric disorders at the given binge level to describe prevalence of comorbidities. The weighted prevalence was compared across four binge groups using Rao-Scott Chi-Square Test and the weighted mean of age, age at onset of drinking, and age at the heaviest drinking across binge levels were also tested using a weighted regression model that was equivalent to a weighted analysis of variance. Adjusted odds ratios (AORs) were derived from multivariable multinomial logistic regression models that tested for associations between each ACE as an explanatory variable (e.g. sexual abuse) and BD levels as a response variable after controlling for age, gender, race, marital status, education attainment, and family income listed in Table 1. Consistent with the analyses for BD levels, multivariable logistic regression models were utilized for the relationship between each ACE and psychiatric disorders (e.g. AUD). The weights derived from the complex design of NESARC-III were incorporated into all analyses using SUDAAN, version 11.0.

Mediation analysis. As an exploratory analysis, mediation analysis was performed to test if an explanatory variable (X, e.g. sexual abuse) is associated with a response variable (Y, e.g. BD levels), indirectly through a third mediating variable (M, e.g. SUD). Based on a single mediator approach with three separate multinomial logistic regression models (Fig. 1), we defined a as an effect of an explanatory variable (X) on a mediating variable (M), b as an effect of a mediating variable (M) to a response variable (Y), c as a total effect of an explanatory variable X to a response variable Y, and c' (cprime) as a direct effect of an explanatory variable (X) to a response variable Y adjusted for a mediating variable, M. First, we used Baron and Kenny's four steps to identify the indirect effect of mediation analysis (1986). Detailed statistical procedures are described in the Supplementary Material. When all four conditions were met, a psychiatric diagnosis fully or partially mediated the relationship between ACE and binge levels. We then used the Sobel approach (MacKinnon *et al.*, 2002) to test if the mediation effect (ab), quantified by the product of the a and b from the three models, was statistically significant. Furthermore, as another measure of mediation, a proportion of the mediated effect was calculated to quantify the magnitude of the indirect effect divided by the total effect of ACE on BD levels (MacKinnon *et al.*, 2007). We explored SUD, mood disorder, anxiety disorder, post-traumatic stress disorders (PTSD), and personality disorder (PD) individually as a mediator and subsequently investigated three specific SUDs, AUD, nicotine use disorder (NUD), and drug use disorder (DUD). All mediation analyses incorporated weights using SUDAAN, version 11.0 and SAS (version 9.4; SAS Institute Inc., Cary, NC).

NIAAA clinical sample. Frequencies of ACEs were estimated and compared for each binge level using chi-squared test for gender, race, and treatment-seeking AD. Mean differences of age across binge levels were tested by Kruskal–Wallis test due to non-normality. Multinomial logistic regression models controlling for age, gender, and race were employed to test the relationships between each ACE and each binge level. AORs were reported with the *P*-value to describe associations of each ACE on HIBD. All NIAAA analyses were performed using SAS (version 9.4; SAS Institute Inc., Cary, NC).

RESULTS

Sociodemographic characteristics across high-intensity binge levels
In the NESARC-III sample, 17.0% reported HIBD who were disproportionately white, younger overall, younger at age of the first drink, and younger at age of heaviest drinking ($P < 0.0001$). Prevalence of low to mid-level socioeconomic status increased across binge levels with *P*-values <0.0001 (Table 1).

Prevalence and association of ACEs with HIBD
In the NESARC-III sample, ACE prevalence increased across binge levels, ranging from 1.3 to 1.5 times among extreme HIBD compared with non-bingers (sexual abuse: 5.71–7.44%; physical abuse: 18.68–26.26%; verbal abuse: 26.57–38.59%; physical neglect: 18.87–29.04%; emotional neglect: 29.16–34.17%) (Table 2). Prevalence of household dysfunction also increased by 1.6–2.4 times across binge levels with the exception of family history of mental illness, which was not significantly different across any binge groups ($P = 0.12$). ACE prevalence of child abuse (sexual, physical, verbal abuse, and physical and emotional neglect) increased across binge levels ($P < 0.001$; Fig. 2) and ACE overall was the most prevalent at the extreme HIBD ($P < 0.0001$).

Adjusted for sociodemographics but not psychiatric disorders, each ACE except family history of mental illness was associated with
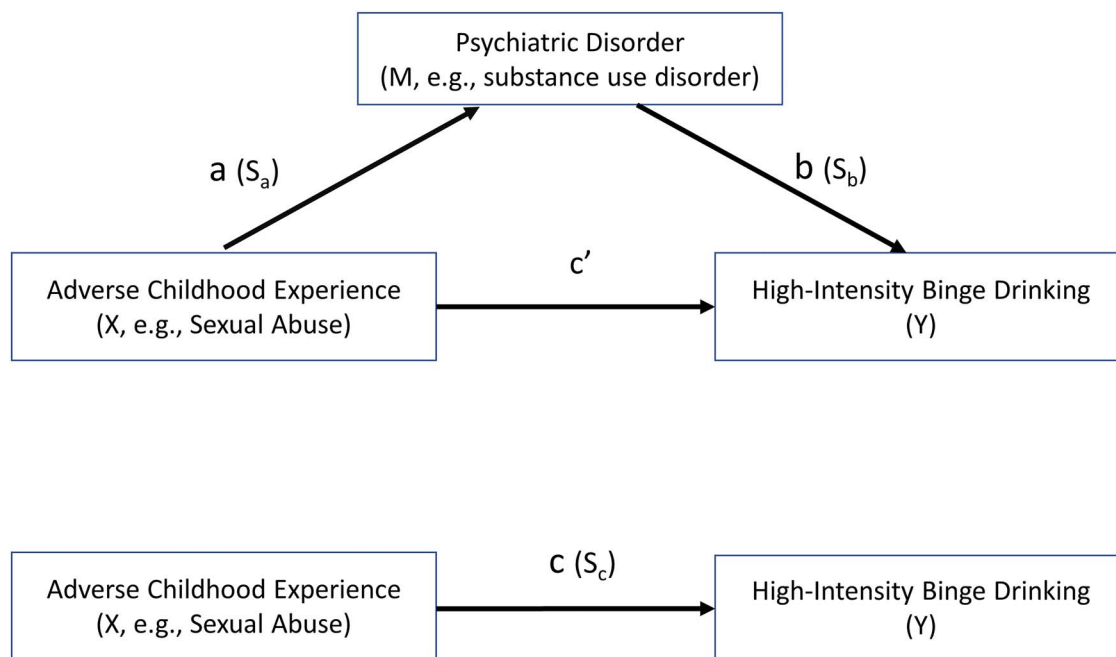
Fig. 1. Standard tri-variate mediation: X = explanatory variable (ACE, e.g. sexual abuse), M = mediator (psychiatric disorder, e.g. SUD), Y = response variable (HIBD), S_a is the standard error of a, S_b is the standard error of b and S_c is the standard error of c.

significantly higher odds of HIBD compared with non-binge drinkers, with the largest odds for level III ($P < 0.001$; Table 3). Among child abuse ACEs, verbal abuse conferred the highest ORs, and emotional neglect had the lowest ORs (verbal abuse for level III, 1.90, 95% CI, 1.65–2.18; level II, 1.23, 95% CI, 1.09–1.38; emotional neglect for level III, 1.27, 95% CI, 1.11–1.43; level II, 1.15, 95% CI, 1.02–1.29). Three of five household dysfunction ACEs, available only in NESARC-III, were significantly associated with HIBD and had increased odds across binge levels relative to the non-binging group. Having family members with substance abuse constituted the highest OR (level III: 1.90, 95% CI, 1.64–2.21; level II, 1.40, 95% CI, 1.23–1.58), and having a family member with suicide attempt or commission had the lowest ORs (level III, 1.58, 95% CI, 1.19–2.11; level II,1.35, 95% CI, 1.04–1.76).

Prevalence and association of psychiatric disorders with HIBD

The prevalence of each psychiatric disorder in NESARC-III increased across binge levels, ranging from 1.3 to 5 times among individuals with extreme HIBD compared with non-bingers (SUD: 18.00–85.82%; any mood disorder: 12.18–22. 21%; any anxiety disorder: 12.54–16.39%; PTSD: 4.06–8.62%; any PD: 11.88–33.84%) (Table 4). Overall, the prevalence of psychiatric disorders was significantly different across binge levels ($Ps < 0.0001$) except that specific phobia and generalized anxiety disorder were not differently distributed at any binge levels ($Ps > 0.05$). The separate analysis for comorbid psychiatric disorders showed that, adjusted for sociodemographics, SUD was significantly associated with increasingly higher odds across all binging levels (level III OR, 21.32, 95% CI, 17.49–25.98), while at lesser magnitudes, mood, personality, and anxiety disorders were also significant (Table 5). Other subcategories of psychiatric disorders, with the exception of agoraphobia and social phobia, were also significantly associated with HIBD, especially extreme HIBD ($Ps < 0.001$).

Mediation analysis of psychiatric disorders on the relationship between ACE and HIBD

As all four requirements of Baron and Kenny's approach were satisfied with level III (the extreme HIBD), we found that each psychiatric disorder either fully or partially mediated the relationship between ACE and extreme HIBD. Table 6 shows the results of Sobel's test statistics and the proportion mediated, which is the amount of reduction in the direct effect of ACE on HIBD due to each psychiatric disorder. SUD and any PD had the most significant mediating effect ($P < 1.0E-10$, Table 6), while any anxiety disorder had a significant, but weaker indirect effect ($0.001 < P < 0.02$). Mood disorder and PTSD also significantly mediated the association of ACE and HIBD ($1.0E-10 < P < 1.0E-5$). Consistent with the Sobel's test, the proportion mediated by each psychiatric disorder varied across ACEs. We defined that over 80% of the proportion mediated was considered as full mediation. SUD, consisting of AUD, NUD, and DUD, accounted for 70–90% of the mediating effect on the relationship between ACEs and HIBD except family history of mental illness, which did not show significant associations with any binge levels (Supplementary Table S1). The proportions mediated by PD and PTSD were 60–80 and 30–50%, respectively, while mood and anxiety disorders had small mediating effects (mood, 20–30%; anxiety, <20%). Among categories of ACEs, the association of emotional neglect and HIBD was fully mediated by SUD or PD (proportion > 90%), which explained no direct association of emotional neglect on HIBD. The contribution of sexual abuse, family history of incarceration, and suicidal behavior to HIBD were also fully mediated through SUD and AUD (proportion > 80%, Supplementary Table S1). All detailed associated effects, a, b, c values, and Sobel's t statistic were listed in Supplementary Table S2. The results of the mediation analyses suggested that SUD or AUD fully mediated the relationship between ACE and extreme HIBD, while other psychiatric disorders were partial mediators.

Table 2. Weighted prevalence of ACEs by alcohol binge consumption levels in NIAAA and NESARC-III (%, SE)[a]

| | Alcohol binge level[b] | | | | |
NESARC-III	Non-binge N = 14,030	Level I N = 7,190	Level II N = 2,599	Level III N = 1,733	*P*-value
Child abuse and neglect					
Sexual abuse	5.71 (0.25)	5.86 (0.30)	4.81 (0.53)	7.44 (0.71)	0.02
Physical abuse	18.68 (0.50)	18.93 (0.63)	19.48 (0.97)	26.26 (1.48)	<0.0001
Verbal abuse	26.57 (0.61)	28.03 (0.67)	28.55 (1.14)	38.59 (1.33)	<0.0001
Physical neglect	18.87(0.54)	20.08 (0.58)	22.07 (0.91)	29.04 (1.39)	<0.0001
Emotional neglect	29.16 (0.58)	29.89 (0.68)	30.64 (1.09)	34.17 (1.34)	0.004
Household dysfunction ACE					
Battered mother/stepmother	10.10 (0.38)	10.74 (0.47)	12.12 (0.82)	16.11 (1.22)	<0.0001
Substance abuse	22.93 (0.50)	26.73 (0.71)	29.04 (1.17)	36.99 (1.54)	<0.0001
Mental illness	5.30 (0.20)	6.01 (0.40)	5.65 (0.45)	6.71 (0.86)	0.12
Incarceration	6.38 (0.28)	8.87 (0.39)	9.80 (0.68)	15.41 (0.96)	<0.0001
Suicide/suicide attempts	2.84 (0.18)	4.14 (0.28)	4.26 (0.47)	5.48 (0.68)	<0.0001
NIAAA	N = 199	N = 319	N = 196	N = 589	
Child abuse and neglect					
Sexual abuse	5.03 (1.55)	6.58 (1.39)	13.27 (2.43)	19.19 (1.62)	<0.0001
Physical abuse	5.53 (1.62)	9.72 (1.66)	17.35 (2.71)	28.69 (1.87)	<0.0001
Emotional abuse	16.08 (2.61)	16.61 (2.09)	26.53 (3.16)	39.73 (2.02)	<0.0001
Physical neglect	3.54 (1.32)	6.98 (1.44)	8.81 (2.05)	18.40 (1.60)	<0.0001
Emotional neglect	19.19 (2.81)	24.13 (2.41)	29.02 (3.28)	42.69 (2.04)	<0.0001

[a]Weighted prevalence % (SE) reported.
[b]Alcohol binge levels are gender-specific: for women, non-binge = 1–3; level I = 4–7; level II = 8–11; level III ≥ 12 drinks; for men, non-binge = 1–4; level L = 5–9; level II = 10–14; level III ≥ 15 drinks.

Prevalence and association of ACEs with HIBD in the NIAAA sample

In the NIAAA sample, Table 1 shows that 60.2% reported HIBD, which combined level II (15%) and III (45.2%) by the definition. HIBD were predominantly male, generally older, and equally non-Hispanic whites and non-Hispanic black (P < 0.05). Unsurprisingly, HIBD was seen predominantly in treatment-seeking AD individuals due to clinically based sample recruitment (P < 0.0001). ACE frequencies similarly increased across binge levels, ranging from 2 to 5 times in extreme HIBD (sexual abuse: 5.03–19.19%; physical abuse: 5.53–28.69%; emotional abuse: 16.08–39.73%; physical neglect: 3.54–18.40%; emotional neglect: 19.19–42.69%) (P < 0.0001; Table 2, Fig. 2). Table 3 illustrates that physical abuse among extreme HIBD conferred the highest odds (OR, 7.95; 95% CI, 4.06–15.57) and emotional neglect had the lowest odds (2.90, 95% CI, 1.95–4.32) with all odds larger than those of the NESARC-III. The ORs of each ACE for HIBD were significant (P < 0.001).

DISCUSSION

Using two independent phenotypic samples, our study comprehensively investigated the relationship between ACEs, comorbid psychiatric disorders, and HIBD. Initial analyses examined a large nationally representative survey sample with individuals who had consumed alcohol in the past 12 months (NESARC-III, n = 22,552). Next, analyses were replicated in the NIAAA sample (n = 1,326) that contained a clinically severe alcohol -dependent phenotype. ACE prevalence overall (excluding household dysfunction ACEs) increased across binge levels in both samples. In the NESARC-III sample, among child abuse ACEs, verbal and sexual abuse showed the most significant associations with extreme HIBD. The effect sizes of household dysfunction ACEs were similar to child abuse ACEs, which supports the importance and utility of all types of ACEs as risk factors for HIBD. In addition, the prevalence of psychiatric diagnoses, with the exceptions of social anxiety and specific phobia, were higher in each BD level than estimates of the general US population (Kessler *et al*., 2005). For example, the past 12-month prevalence of major depressive disorder in each BD level (level I: 11.49%, level II: 11.79% and level III: 14.18%) was almost double the 6.7% 12-month prevalence reported in the 2016 National Survey on Drug Use and Health (Rebecca Ahrnsbrak *et al*., 2017). Similarly, PTSD was more than twice as prevalent in level III (8.62%) than estimates for US adults (3.6%). In general, AUD was the strongest risk factor across BD levels with increased odds of 70.1 for extreme HIBD among all psychiatric diagnoses. Given that these comorbid psychiatric disorders constitute risk factors for BD, the NESARC-III sample suggests that all psychiatric disorders may contribute directly or indirectly to the association between ACEs and HIBD with various magnitudes. Moreover, the full mediation effect of AUD
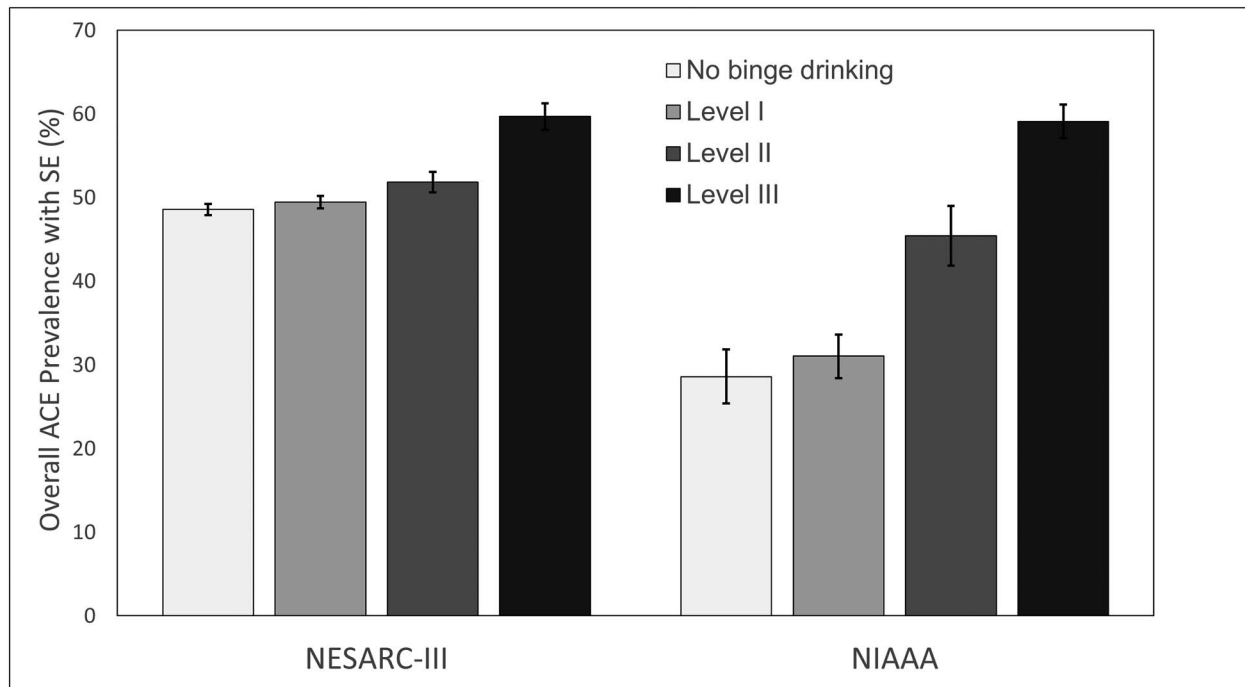
Fig. 2. Prevalence of child abuse ACE by alcohol binge levels in the NESARC-III and NIAAA samples. Child abuse ACE includes five childhood abuse and neglect experiences: physical abuse, sexual abuse, emotional or verbal abuse, emotional neglect, and physical neglect. Prevalence difference *P*-values <0.001 for all levels in both NESARC-III (*n* = 25552) and NIAAA (*n* = 1303) samples.

Table 3. AORs of ACEs on alcohol binge levels, adjusted for sociodemographic characteristics[a]

	Alcohol binge level[b]			
NESARC-III	Non-binge N = 14,030	Level I N = 7,190	Level II N = 2,599	Level III N = 1,733
Sexual abuse	1 (ref)	1.10 (0.96–1.27)	1.23 (0.94–1.62)	**1.86 (1.45–2.39)***
Physical abuse	1 (ref)	**1.10 (1.0–1.21)***	**1.23 (1.08–1.41)****	**1.83 (1.54–2.18)***
Verbal abuse	1 (ref)	**1.11 (1.02–1.21)***	**1.23 (1.09–1.38)****	**1.90 (1.65–2.18)***
Physical neglect	1 (ref)	**1.12 (1.02–1.24)***	**1.27 (1.10–1.47)****	**1.80 (1.52–2.14)***
Emotional neglect	1(ref)	**1.09 (1.01–1.18)***	**1.15 (1.02–1.29)***	**1.27 (1.11–1.43)****
Household dysfunction ACE				
Mother abused	1(ref)	1.09 (0.97–1.22)	**1.38 (1.18–1.61)***	**1.77 (1.43–2.19)***
Substance abuse	1(ref)	**1.18 (1.08–1.28)****	**1.40 (1.23–1.58)***	**1.90 (1.64–2.21)***
Mental Illness	1(ref)	1.10 (0.94–1.28)	1.09 (0.91–1.29)	1.23 (0.93–1.64)
Incarceration	1(ref)	**1.16 (1.02–1.31)***	1.19 (0.99–1.44)	**1.71 (1.45–2.03)***
Suicide/suicide attempt	1(ref)	**1.31 (1.06–1.61)***	**1.35 (1.04–1.76)***	**1.58 (1.19–2.11)****
NIAAA	N = 199	N = 319	N = 196	N = 589
Child abuse and neglect				
Sexual abuse	1 (ref)	1.58 (0.71–3.50)	**3.32 (1.52–7.28)****	**5.86 (2.92–11.75)***
Physical abuse	1 (ref)	**2.35 (1.11–4.93)***	**4.08 (1.94–8.59)****	**7.95 (4.06–15.57)***
Emotional abuse	1 (ref)	1.18 (0.72–1.93)	**1.97 (1.19–3.27)****	**3.70 (2.41–5.69)***
Physical neglect	1 (ref)	2.31 (0.96–5.56)	**2.49 (1.00–6.20)***	**5.48 (2.49–12.10)***
Emotional neglect	1 (ref)	1.45 (0.93–2.26)	**1.64 (1.02–2.64)***	**2.90 (1.95–4.32)***

[a]AORs are reported with 95% CI in parentheses; AORs were generated from multinomial logistics regression adjusted for age, gender, race, marital status, education attainment, and family income for NESARC-III sample and age, gender, race for NIAAA sample; *$P < 0.05$ **$P < 0.01$ ***$P < 0.001$ (significant AORs in boldface).

[b]Alcohol binge levels are gender-specific: for women, non-binge = 1–3; level I = 4–7; level II = 8–11; level III ≥ 12 drinks; for men, non-binge = 1–4; level L = 5–9; level II = 10–14; level III ≥ 15 drinks.

Table 4. Weighted prevalence of psychiatric disorders by alcohol binge consumption levels in NESARC-III (%, SE)[a]

	Alcohol binge level[b]				
	Non-binge (N = 14,030)	Level I (N = 7,190)	Level II (N = 2,599)	Level III (N = 1,733)	*P*-value
Past-year psychiatric disorders					
SUD	18.00 (0.50)	42.01 (0.81)	66.79 (1.16)	85.82 (1.10)	<0.0001
AUD	3.36 (0.18)	23.80 (0.68)	50.72 (1.21)	74.42 (1.33)	<0.0001
NUD	14.68 (0.47)	24.62 (0.73)	37.91 (1.31)	53.46 (1.61)	<0.0001
Any DUD	2.11 (0.14)	5.19 (0.35)	9.39 (0.76)	17.37 (1.09)	<0.0001
Mood disorder	12.18 (0.39)	15.05 (0.53)	16.25 (0.98)	22.21 (1.20)	<0.0001
Major depressive disorder	9.91 (0.36)	11.49 (0.49)	11.79 (0.84)	14.18 (1.05)	<0.0001
Bipolar I disorder	0.91 (0.10)	1.83 (0.21)	2.39 (0.41)	5.19 (0.66)	<0.0001
Anxiety disorder	12.54 (0.40)	14.52 (0.56)	14.60 (0.92)	16.39 (1.11)	0.0003
Agoraphobia	1.18 (0.11)	1.79 (0.21)	2.16 (0.39)	2.16 (0.41)	0.0006
Social phobia	2.47 (0.18)	3.28 (0.28)	3.37 (0.43)	3.90 (0.58)	0.003
Specific phobia	5.51 (0.23)	6.20 (0.40)	5.83 (0.56)	7.42 (0.79)	0.06
Generalized anxiety disorder	5.21 (0.26)	5.63 (0.34)	6.13 (0.68)	6.83 (0.67)	0.09
Panic disorder	2.46 (0.16)	3.77 (0.26)	4.36 (0.53)	5.21 (0.74)	<0.0001
PTSD	4.06 (0.22)	5.23 (0.34)	5.45 (0.57)	8.62 (0.68)	<0.0001
Personality disorder	11.88 (0.43)	16.97 (0.63)	23.43 (1.23)	33.84 (1.39)	<0.0001
Schizotypal PD	2.17 (0.30)	6.77 (0.38)	9.05 (0.73)	13.62 (1.0)	<0.0001
Borderline PD	8.58 (0.34)	12.77 (0.52)	17.63 (1.04)	25.81 (1.30)	<0.0001
Antisocial (adult)	16.49 (0.51)	24.79 (0.63)	33.37 (1.37)	43.72 (1.39)	<0.0001

Abbreviations: DSM-5, Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition.
[a]Weighted prevalence % (SE) reported.
[b]Alcohol binge levels are gender-specific: for women, non-binge = 1–3; level I = 4–7; level II = 8–11; level III ≥ 12 drinks; for men, non-binge = 1–4; level L = 5–9; level II = 10–14; level III ≥ 15 drinks.

on the relationship between ACEs and HIBD indicates that ACE may be associated with HIBD predominantly through AUD. We confirmed our findings in the NIAAA clinical sample with clinically severe phenotypes of ACEs and alcohol consumption that there were significant increases in all ACE prevalence rates across BD levels with the highest being a 2–5-fold increased ACE prevalence in the extreme HIBD group. Among individuals with extreme HIBD in the NIAAA sample, 95% were individuals with AD. The greater magnitude of odds of ACE on extreme HIBD in the NIAAA sample confirmed the results of the mediation analysis in NESARC-III, where ACEs were associated with extreme HIBD through AUD.

Our findings in the present study aligned with those in studies identifying a relationship between ACEs and alcohol consumption. A recent study conducted by Loudermilk *et al*. (2018) showed adults with household abuse had a 30% increased risk for BD and a 21% increased risk for AD compared with adults without household abuse. In addition to examining a mediating role of psychiatric disorders, our study differs from the previous studies which focused on only BD, not HIBD that has been shown to be associated with more severe alcohol-related health problems (Rosoff *et al*., 2019). Given the substantially more severe health consequences of heavy drinking that exceeds the binge threshold (i.e. HIBD), which might be missed in studies using binary BD as their main outcome, improving our ability to identify individuals at high risk for HIBD is crucial for improving public health outcomes. Our findings might have important implications for the identification and diagnostic assessment of individuals at risk for HIBD, as well as the development and implementation of treatment plans. Screening for recent HIBD is recommended, given

the associations between binge level I, II, and III and broad health-related risks. The present study's findings indicate that health-care providers should include questions about early childhood experiences of trauma and psychiatric disorders when assessing cases of HIBD behavior, regardless of AD diagnosis. At the public health level, there is evidence that BD rates respond to population level alcohol policies. As such, policy changes may reduce BD rates and prevent the consequences of harmful BD. Another recommendation at the public health level resulting from these findings is that the first stage that seems to contribute to HIBD and SUD, namely ACEs, should be minimized through adequate policies and child protection services.

There are several limitations to this study. First, the cross-sectional design does not allow to conclude any causality. Although our study provides potential evidence that psychiatric disorders may fully or partially mediate the relationship between ACE and HIBD, longitudinal research is needed to confirm the causal relationship. Moreover, mediation analyses with multiple mediators could be a more suitable approach to explain the underlying mechanism of the relationship due to comorbidity among psychiatric disorders. Second, recall bias for ACEs may lead to an underestimation of the impact of these events on HIBD (Kauhanen *et al*., 2011). Retrospective reports of ACEs, obtained in adulthood, may be biased regarding their severity compared with adolescent reports of ACEs (Femina *et al*., 1990; Williams, 1995). Further, previous research suggests that ACEs, in particular sexual abuse, are associated with an inability to remember details of the event(s) (Freyd *et al*., 2005). For BD outcomes, recall and social desirability biases may affect self-reported alcohol consumption, especially among HIBD (Hingson *et al*., 2017).

Table 5. AORs of past-year substance use and other psychiatric disorders on alcohol binge levels, adjusted for sociodemographic characteristics in NESARC-III[a]

Past-year psychiatric disorders	OR, 95% CI Alcohol binge level[b]			
	Non-binge (n = 14,030)	Level I (n = 7,190)	Level II (n = 2,599)	Level III (n = 1,733)
SUD	1 (ref)	**3.05(2.80–3.33)*** **	**7.99 (7.17–8.91)*** **	**21.32(17.49–25.98)*** **
AUD	1 (ref)	**7.96 (6.94–9.11)*** **	**25.25 (22.27–28.64)*** **	**70.10(58.41–84.13)*** **
NUD	1 (ref)	**1.76 (1.60–1.95)*** **	**3.11 (2.72–3.54)*** **	**5.11 (4.41–5.91)*** **
Any DUD	1 (ref)	**1.92 (1.59–2.32)*** **	**2.95 (2.33–3.75)*** **	**5.15 (4.13–6.42)*** **
Mood disorder	1 (ref)	**1.14 (1.03–1.26)* **	**1.32 (1.14–1.54) ** **	**1.73 (1.46–2.04)*** **
Major depressive disorder	1 (ref)	1.07 (0.95–1.21)	**1.21 (1.01–1.44)* **	**1.33 (1.08–1.63)** **
Bipolar I disorder	1 (ref)	**1.69 (1.31–2.19)*** **	**2.04 (1.31–3.18)** **	**3.97 (2.67–5.91)*** **
Anxiety disorder	1 (ref)	**1.15 (1.02–1.30)* **	**1.30 (1.10–1.53)** **	**1.37 (1.15–1.63)** **
Agoraphobia	1 (ref)	**1.37 (1.01–1.84)* **	**1.81 (1.20–2.74)** **	1.54 (0.97–2.45)
Social phobia	1 (ref)	1.17 (0.94–1.46)	1.18 (0.85–1.65)	1.17 (0.83–1.64)
Specific phobia	1 (ref)	1.13 (0.96–1.32)	1.20 (0.96–1.50)	**1.45 (1.14–1.84)** **
Generalized anxiety	1 (ref)	1.09 (0.92–1.28)	**1.31 (1.02–1.68)* **	**1.38 (1.09–1.76)** **
Panic disorder	1 (ref)	**1.35 (1.12–1.63)** **	**1.81 (1.35–2.42)*** **	**1.97 (1.40–2.77)*** **
PTSD	1 (ref)	1.16 (0.99–1.36)	**1.36 (1.08–1.71)* **	**1.97 (1.56–2.47)*** **
Personality disorder	1 (ref)	**1.35 (1.21–1.51)*** **	**1.91 (1.64–2.22)*** **	**2.84 (2.48–3.26)*** **
Schizotypal PD	1 (ref)	1.15 (0.98–1.35)	**1.42 (1.15–1.77)** **	**1.95 (1.54–2.45)*** **
Borderline PD	1 (ref)	**1.40 (1.24–1.57)*** **	**2.02 (1.71–2.40)*** **	**2.89 (2.44–3.42)*** **
Antisocial (adult) personality	1 (ref)	**1.51 (1.39–1.64)*** **	**2.08 (1.80–2.39)*** **	**3.00 (2.58–3.49)*** **

[a]AORs are reported with 95% CI in parentheses; AORs were generated from multinomial logistics regression adjusted for age, gender, race, marital status, education attainment, and family income for NESARC-III sample, and age, gender, race for NIAAA sample; $P < 0.05$ ** $P < 0.01$ *** $P < 0.001$ (significant AORs in boldface).

[b]Alcohol binge levels are gender-specific: for women, non-binge = 1–3; level I = 4–7; level II = 8–11; level III ≥ 12 drinks; for men, non-binge = 1–4; level L = 5–9; level II = 10–14; level III ≥ 15 drinks.

Table 6. Mediation analyses of each psychiatric disorder in the relationship between ACE and level III (extreme HIBD) in NESARC-III

	Any SUD		Any mood disorder		Any anxiety disorder		PTSD		Any PD	
	Sobel test[a]	Proportion mediated	Sobel test	Proportion mediated	Sobel test	Proportion mediated	Sobel test	Proportion mediated	Sobel test	Proportion mediated
Sexual abuse	9.99***	0.86	5.80***	0.33	2.74**	0.18	4.29***	0.49	11.31***	0.69
Physical abuse	13.11***	0.77	5.36***	0.27	2.87**	0.14	4.49***	0.37	11.99***	0.62
Verbal abuse	15.16***	0.76	4.87***	0.26	2.34*	0.13	4.05***	0.36	11.59***	0.62
Physical neglect	12.44***	0.72	5.41***	0.26	2.74**	0.16	4.39***	0.39	12.59***	0.60
Emotional neglect	8.65***	0.92	6.00***	0.52	3.31**	0.30	5.04***	0.63	12.51***	0.93
Household dysfunction ACE										
Mother abused	11.02***	0.76	5.41***	0.27	3.02**	0.16	4.65***	0.40	11.94***	0.60
Substance abuse	13.20***	0.74	5.16***	0.22	2.52*	0.11	4.34***	0.29	11.47***	0.50
Incarceration	10.17***	0.82	5.44***	0.27	3.17**	0.17	4.8***	0.41	11.77***	0.67
Suicide/suicide attempt	5.76***	0.82	5.37***	0.38	3.35**	0.27	4.75***	0.49	10.14***	0.78

[a]Sobel test statistics presented a mediation effect driven by three multinomial logistics regression adjusted for sociodemographic status; P value of the Sobel test statistic was calculated by a normal (Z) distribution with large sample size, *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$).

The definition of HIBD was developed in previous studies, however, the categories preclude distinction between individuals consuming alcohol throughout the day and individuals' binging that occurs rapidly enough for BAC to reach 0.08 g/dL within 2 hours, as is the NIAAA definition of BD. Third, certain populations were not covered in the NESARC-III, which may underestimate our findings. Simi-larly, AUDADIS interviews determining past 12-month substance, mood, anxiety, trauma-related and PDs were not conducted by clinicians, although NESARC-III psychiatric diagnoses have reported good accordance with clinical reappraisal procedure (Grant *et al.*, 2017). Furthermore, it has been known that exposure or responses to ACEs differ by gender, and higher prevalences of AUD and more

extreme alcohol consumption are associated with males compared with females (Erol and Karpyak, 2015; Liu *et al.*, 2015). Future studies on a mediating role of specific psychiatric disorders (e.g. anxiety or eating disorders) on the relationship between ACEs and HIBD might consider focusing on gender differences.

In conclusion, our study shows that ACEs and comorbid psychiatric disorders are significant risk factors for HIBD in adulthood and that psychiatric disorders play a full or partial mediating role in the relationship between ACEs and HIBD. These findings suggest that health-care providers may consider including questions about early childhood experiences/trauma and psychiatric disorders when assessing cases of extreme BD behavior.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Alcohol and Alcoholism* online.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ADDITIONAL INFORMATION

The original data set for the National Epidemiologic Survey on Alcohol and Related Conditions II (NESARC-III) is available from the NIAAA (http://www.niaaa.nih.gov).

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