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Associations between adverse childhood experiences and acquired brain injury, including traumatic brain injuries, among adults: 2014 BRFSS North Carolina

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Abstract

Adverse childhood experiences (ACEs) can negatively affect lifelong health and opportunity. Acquired brain injury (ABI), which includes traumatic brain injury (TBI) as well as other causes of brain injury, is a health condition that affects millions annually. The present study uses data from the 2014 North Carolina Behavioral Risk Factor Surveillance System to examine the relationship between ACEs and ABI. The study sample included 3454 participants who completed questions on both ABI and ACEs. Multivariable logistic regression models were used to determine the relationship between ACEs and ABI as well as ACEs and TBI. Sexual abuse, emotional abuse, physical abuse, household mental illness and household substance abuse were significantly associated with ABI after adjusting for age, race/ethnicity, gender and employment. Compared with those reporting no ACEs, individuals reporting three ACEs had 2.55 times the odds of having experienced an ABI; individuals reporting four or more ACEs had 3.51 times the odds of having experienced an ABI. Examining TBI separately, those who experienced sexual abuse, physical abuse, household mental illness and had incarcerated household members in childhood had greater odds of reported TBI, after adjusting for age, race/ethnicity, gender and income. Respondents reporting three ACEs (AOR=4.16, 95% CI (1.47 to 11.76)) and four or more ACEs (AOR=3.39, 95% CI (1.45 to 7.90)) had significantly greater odds of reporting TBI than respondents with zero ACEs. Prevention of early adversity may reduce the incidence of ABI; however, additional research is required to elucidate the potential pathways from ACEs to ABI, and vice versa.

Early experiences in childhood lay the foundation for health and well-being throughout life. Adverse experiences, including child abuse and neglect and other violence, can negatively affect this foundation, increasing the risk of experiencing devastating consequences on

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lifelong health and opportunity.[1–3] Adverse childhood experiences (ACEs) are frequently defined as child maltreatment (ie, physical, emotional and sexual abuse and physical and emotional neglect) and household challenges (witnessing intimate partner violence, household substance abuse, incarcerated household member, household mental illness, parental divorce or separation) experienced during the first 18 years of life.[1] Research from the CDC-Kaiser ACE study[1] and replication studies[45] find that ACEs are common—61.6% to 63.9% of individuals report exposure to at least one ACE. Furthermore, ACE studies[4–6] repeatedly demonstrate a dose– response relationship between ACEs and several health risk behaviours and outcomes in adults. As the number of ACEs increase, so too does the risk for experiencing negative outcomes in adulthood such as chronic health conditions,[7] health risk behaviors,[89] mental health,[1011] victimisation and perpetration,[1213] fewer life opportunities (eg, low educational attainment and low income)[3] and decreased life expectancy.[14]

Research has highlighted pathways between ACEs and long-term changes in the physiological development of the nervous, endocrine and immune systems which can result in emotional and cognitive challenges.[15] Exposure to ACEs may result in toxic stress responses, defined as strong, frequent and prolonged activation of the body's stress response systems, that can cause permanent changes in gene expression[16] brain connectivity[17] and immune function.[18] Additionally, unhealthy behaviours used as coping strategies may become persistent over time.[19] While many coping strategies are healthy and help to reduce acute stress in the short-term, some strategies present long-term risks to health and well-being (eg, substance use, risky sexual behaviour). As such, exposure to ACEs can increase risk of later chronic and infectious health conditions through changes in physiological mechanisms, as well as increased engagement in risky health behaviours, ultimately resulting in premature death.[314] Many relationships between ACEs and health outcomes are well established; however, less is known about the relationship between ACEs and acquired brain injury (ABI). Although the impact of toxic stress on brain health and later impairment has been identified, the association between early adversity and risk of ABI, specifically traumatic brain injury (TBI), has not been extensively explored.

ABI includes TBI, as well as other causes of brain injury (eg, stroke, strangulation, near drowning, tumours) that are not congenital, perinatal or related to a degenerative disease. TBIs are the most common type of ABI, defined as a bump, blow, or jolt to the head, or penetrating head injury that disrupts the normal function of the brain.[20] In 2013, an estimated 2.8 million TBI-related emergency department visits, hospitalisations and deaths occurred in the USA.[21] TBIs contribute to approximately 30% of all injury-related deaths, with rates highest among the elderly (75 years and older) and young children (0–4 years).[22] Depending on the severity, both ABI and TBI can result in a wide range of short-term or long-term functional changes impairing emotion (personality changes, impulsivity, anxiety and depression), thinking, decision making and reasoning, concentration, memory, movement, sensation (ie, hearing or vision), language and epilepsy. Annually, TBIs cost an estimated $76 billion in direct and indirect medical expenses. An estimated 5.3 million Americans live with TBI-related disabilities, affecting the quality of life for the individual and their families.[23] ACEs may represent a step along a pathway that increases risk for ABI, for instance, via neglect by a parent that could lead to drowning or a bicycle crash, physical

abuse by a parent or intimate partner by strangulation and health risk behaviours, such as substance use, which may cause a stroke, drug overdose or heart attack/failure.

Ma and colleagues[24] conducted a review of the existing literature between ACEs and subsequent TBI in adulthood and found a possible relationship between ACEs and TBI; however, the six studies included in the review were limited to incarcerated or homeless samples and individuals at high risk of or with mental illnesses. Individual studies and systematic reviews continue to reveal significant associations between ACEs and health conditions, further underscoring the need to prevent ACEs. Further exploration of the interplay between ACEs and major ABIs within the general population may identify an additional risk factor for serious ABI (ie, brain injuries that limited activities from more than a week). The present study aims to: (1) identify the relationship between ACE score and ABI, as well as ACE score and TBI more specifically and 2) examine the relationship between each individual ACE and both ABI and TBI.

METHOD

Data from the 2014 North Carolina Behavioral Risk Factor Surveillance System (BRFSS), an annual representative telephone survey of non-institutionalised adults 18 years and older regarding their health-related conditions and risk behaviours, were used.[25] Trained survey administrators identified respondents using random-digit-dialling methods, conducting surveys via landline and cell phone interviews. The BRFSS employs a complex sampling design adjusting respondent data to known proportions of age, race, ethnicity and sex within the state. The overall response rate was 37.5%; calculated using standards set by the American Association of Public Opinion Research Response Rate formula.[2627] All respondents completed the core BRFSS items. In 2014, North Carolina employed two survey versions that included optional and state-added modules. ABI and ACE modules were state-added questions in 2014, the most recent survey year with both modules of interest. Therefore, the cross-sectional study sample comprised 3454 participants who completed questionnaire Version 1, which included both ABI and ACEs modules.

MEASURES

Adverse childhood experiences

The BRFSS ACE module consists of 11 questions adapted from the CDC-Kaiser ACE Study[1] that assess exposure to child abuse and household challenges experienced during their first 18 years of life. The questions are collapsed into eight ACE categories that include experiencing emotional, physical and sexual abuse and household challenges, (ie, mental illness, substance use, parental separation/divorce, witnessing intimate partner violence and incarcerated household member). Responses to ACE items were dichotomised based on exposure. An affirmative response to one or more ACE questions was designated as exposure to childhood adversity. These dichotomous items were also summed to create a total score with values ranging from 0 to 8. This score was subsequently used to construct a 5-level categorical variable, ACE score, corresponding to the overall number of ACEs each respondent reported experiencing – 0, 1, 2, 3 and 4 or more ACEs.

Acquired brain injury

In 2014, North Carolina included two ABI questions. At the beginning of the module, all respondents receive the following prompt: “A brain injury can result from a blow or jolt to the head caused by a fall, a motor vehicle accident, a sports injury, or an assault. A brain injury can also occur from a health problem like a tumor or a stroke.” followed by “Have you ever had a brain injury that limited you in any way for more than a week in any activities?” Responses were dichotomised (yes/no) based on self-reported injury.

Traumatic brain injury

Respondents who confirmed a history of ABI were given the question, “What was the cause of the brain injury?” where individuals freely responded to the cause of the ABI. If the respondent stated their ABI was caused by an assault, bicycle crash, equestrian accident, fall, motor vehicle crash or a sports-related event, the cause of the injury was recorded as a TBI (table 1).

DATA ANALYSIS

Descriptive statistics and prevalence estimates for ACEs, ABI and TBI were individually calculated. Weighted frequencies of demographic characteristics among participants who reported an ABI and those who did not report an ABI were examined; percentages and 95% CI are reported. Four sets of multivariable logistic regression models were used to first determine the relationship between ACEs and ABI, and second, to determine the relationship between ACEs and TBI. In the first set of regression models, self-reported ABI was the outcome variable, and cumulative ACE score was the predictor of interest after controlling for gender, age, race/ethnicity and self-reported employment. The second models were similar, except with TBI as the outcome variable controlling for gender, age, race/ethnicity and self-reported income. In the third set of models, multivariable logistic regression assessed the bivariate associations between each of the eight ACE types and cumulative ACE score with ABI as the outcome variable, controlling for the same sociodemographic variables. The final set of models were similarly constructed, except with TBI as the outcome. All models were specified using the appropriate survey weights to account for the complex sampling design used by the BRFSS. Adjusted ORs with 95% CIs are reported. Analyses were conducted using SAS, V.9.4.[28]

RESULTS

Among the 3454 adult respondents, 201 individuals reported an ABI and 107 (52%) individuals reported a TBI that limited their activities for more than a week. Approximately 25.37% were caused by a motor vehicle crash, and 22.53% were caused by a health problem (table 1). The weighted distribution among the sample who reported experiencing an ABI was mostly male (57.22%), 45 years or older (62.39%), white (77.00%) and had an income less than US$25 000 (55.93%). Around 50.90% of respondents reporting an ABI had at least some college education, and 38.28% were employed. Demographic characteristics by ABI status are provided in table 2.

ACEs and ABI

The prevalence of individual ACEs as well as the associations between each ACE type and ABI are shown in table 3. Sexual, emotional and physical abuse and household mental illness and substance abuse were significantly associated with ABI after adjusting for age, race/ethnicity, gender and employment. For example, individuals who reported experiencing sexual abuse had 3.00 (95% CI (1.81 to 4.97)) times the odds of reporting an ABI compared with those who did not report sexual abuse in childhood. Having an incarcerated household member, witnessing intimate partner violence and parental separation/divorce were not statistically significant predictors of ABI. Respondents reporting three ACEs (adjusted odds ratio (AOR)=2.55, 95% CI (1.12 to 5.77)) and four or more ACEs (AOR=3.51, 95% CI (1.95 to 6.32)) were at significantly greater odds of reporting ABI than respondents with zero ACEs.

ACEs and TBI

Four of the eight ACE types, as well as cumulative ACE score, were significantly associated with TBI after adjusting for age, race/ethnicity, gender and self-reported income (table 4). Sexual abuse, physical abuse, household mental illness and an incarcerated household member were significantly associated with TBI. For example, individuals who reported having an incarcerated household member had 3.41 (95% CI (1.36 to 8.52)) times the odds of reporting a TBI compared with those who did not report having an incarcerated household member. Emotional abuse, witnessing intimate partner violence, household substance use and parental separation/divorce were not statistically significant predictors of TBI. Respondents reporting three ACEs (AOR=4.16, 95% CI (1.47 to 11.76)) and four or more ACEs (AOR=3.39, 95% CI (1.45 to 7.90)) were at significantly greater odds of reporting TBI than respondents with zero ACEs.

DISCUSSION

This study examined the relationship between ACEs and ABI that limited a respondent's activities for more than a week. Data from the 2014 North Carolina BRFSS revealed that ACEs were prevalent, and many ACEs were significantly associated with ABI and TBI. Over half of respondents reporting an ABI stated it was caused by a health problem (ie, tumour, stroke) or a motor vehicle crash, followed by falls, sports-related event and other/multiple causes. Our findings are similar to other statistics using TBI-related emergency department visits that report an elevated risk of TBI among men, persons age 75 and older and TBIs caused by a fall or motor vehicle crash.[21]

Compared with respondents with zero ACEs, the odds of reporting ABI by individuals with three or more ACEs increased by 255%, while individuals with four or more ACEs had an odds increase by 351%. In addition, associations between TBI and ACE score showed similar effects; compared with respondents with zero ACEs, the odds of reporting a TBI by individuals with three or more ACEs increased by 416%, while individuals with four or more ACEs had an odds increase by 339%. Although these results are novel in relation to ABI/TBI within a general population, these findings align with previous studies in female children, adults with severe mental illness and adult homeless population linking ACEs to

risk for brain injury.[29–31] Data on individual ACEs and their association with ABI and TBI were provided. Findings revealed that five out of the eight ACEs examined were significantly associated with ABI, while four out of the eight ACEs (ie, sexual abuse, physical abuse, household mental illness and an incarcerated household member) were significantly associated with TBI. ACEs that were significantly associated with ABI, but not TBI, had a similar effect size (emotional abuse: AOR=1.64 for ABI, AOR=1.80 for TBI; household substance abuse : AOR=1.86 for ABI, AOR=1.74 for TBI). However, the 95% CI around TBI for all associations are wider due to a higher incidence of ABIs than TBIs that may account for non-significance for these individual ACEs, despite similar effect sizes.

It is important for healthcare providers to consider the relationship between early adversity and the risk of experiencing ABI or TBI. Although many causes of TBI are due to accidental events such as falls and health-related problems, additional causes are due to risk behaviours, motor vehicle crashes and violence. Studies suggest that maltreated children can experience reduced executive functioning and demonstrate hypervigilant responses to perceived threats.[19] Altered brain architecture in response to toxic stress explains in part the associations between ACEs and impulse control, emotional regulation and other cognitive challenges which may contribute to an increased risk of certain causes of TBI (ie, mother vehicle crashes, intentional self-harm).[17–19] Early adversity in childhood increases engagement in substance use[8] that may increase the risk for TBI as a significant proportion of those that sustain a TBI (25%) test positive for alcohol or illicit drugs.[832] Additionally, multiple studies have identified a strong link between early adversity and later victimisation[1213] that may result in an injury such as a TBI. As such, comprehensive TBI prevention could include efforts to reduce exposure to early adversity, a known risk factor for these precursors to TBI.

While this analysis has focused on the relationship between ACEs and brain injury, the experience of a brain injury in childhood could be conceptualised as an additional, unmeasured ACE. Beyond the potential psychological trauma due to the circumstances of experiencing a brain injury, a brain injury in childhood can significantly alter the developmental trajectory of a child, particularly when it occurs during critical periods of brain development.[33] Often the effects of a brain injury are not immediately apparent and manifest at a later age when a new developmental challenge is impacted by a previously unknown deficit.[34] Beyond the potential for lifelong disability, brain injuries have been shown to affect key cognitive (eg, self-regulation, executive function), academic (eg, lower grades and educational attainment) and social-behavioural (social information processing, social adjustment) skills that can lead to difficulties in adulthood.[34] These difficulties can range from subtle to significant, depending on the severity of the brain injury, and can include underemployment, legal problems and incarceration.[35] While there is a robust literature on the short-term and intermediate-term health impacts of childhood TBI, there is a need for more longitudinal research establishing that brain injury experienced in childhood is associated with longer-term adult morbidity and mortality.[35]

This study has several limitations. First, a clear definition of ABI or TBI was not stated before respondents were given the module, relying on an individual’s awareness about the full range of signs and symptoms indicative of a brain injury. For example, many individuals

believe a loss of consciousness (occuring in less than 25% of brain injuries) needs to happen to have a brain injury.[36] Studies have found that providing a definition that lists all symptoms of ABI or concussion increases estimates significantly,[36] therefore, ABI among the sample could be an underestimate. Second, the ABI questions may be biassed toward more severe brain injuries due to: (1) asking about lifetime ABIs which could increase the likelihood of forgetting less severe brain injuries and (2) inclusion of the phrase "that limited their activities for more than a week," as this likely led respondents to exclude many mild ABIs they experienced. Third, some respondents who reported an ABI did not report a cause, therefore whether it was a TBI could not be determined. Consequently, some number of TBIs were not classified as such in the TBI-specific analyses. Fourth, due to the nature of telephone surveys, the results may underestimate the level of health risk in the population due to excluding individuals who do not have access to telephones. Fifth, declining response rates among telephone surveys should be noted, as non-response bias may affect estimates. Finally, the study did not assess when ACEs or ABI occurred; therefore, some respondents may have experienced an ABI before experiencing early adversity or may have experienced the ABI as a result of early adversity (ie, physical abuse). Due to the retrospective and cross-sectional nature of the data, temporality and causality cannot be established. However, previous studies have established the general validity of self-reported childhood adversity.[37] Furthermore, ACEs measured on the BRFSS do not encompass the entire spectrum of early adversities that a child may experience nor do the items measure critical dimensions of exposure (ie, age of onset or severity), which can significantly moderate the impact of ACEs on health and well-being.[38]

This paper highlights the link between ACEs and ABI, including TBI. Prevention of early adversity may help in reducing the incidence of ABIs and TBIs, preventing future unintentional injuries. Assuring the conditions that prevent early adversities, like ACEs, from occurring in the first place, comprehensive approaches that promote protective factors and minimise risk factors are critical. Strategies that change social norms, provide quality childcare and education, improve economic conditions for families and intervene to lessen harm and prevent future risk can help children to achieve their optimal health.[39] To improve outcomes for those who have experienced adversity, healthcare providers who are informed about ACEs and equipped with treatment options and resources could reduce the number of children and adults that need treatment and care further downstream. By assuring that all children have access to safe, stable, nurturing relationships and environments,[40] healthcare providers and communities can prevent ACEs and alleviate the impact of ACEs on health and well-being, including injury and health outcomes.

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What does this study add?

- This study identifies the relationship between adverse childhood experiences (ACEs) and acquired brain injury (ABI) and the potential impact of early adversity on later brain injury.
- The findings from this study highlight the potential impact of preventing ACEs to reduce ABI, including traumatic brain injury.

What is already known on this subject?

- ACEs can have a lasting impact on lifelong health and opportunity, increasing the risk for experiencing a host of negative outcomes in adulthood.
- ABI is a challenging health condition that contributes to death and disability worldwide, causing a wide range of short-term or long-term functional changes affecting the quality of life for the individual and their families.

Table 1

2014 North Carolina Behavioral Risk Factor Surveillance System acquired brain injury and traumatic brain injury prevalence by cause

Cause	Total (N=201)	Weighted %	95% CI
Health problem (tumour, stroke, aneurism)	60	22.53	0.14 to 29.93
Other cause or multiple causes	28	14.02	7.33 to 20.71
Lack of oxygen to the brain (near drowning, drug overdose, heart attack/ failure, electrical shock)	3	1.10	0.00 to 2.51
Don't know/not sure	3	2.83	0.00 to 6.45
Motor vehicle crash *	53	25.37	17.09 to 33.65
Fall *	21	10.38	5.13 to 15.63
Sports-related event *	18	15.27	7.64 to 22.91
Assault (violence inflicted by others, including a gunshot) *	8	5.68	0.93 to 10.43
Equestrian accident *	4	1.47	0.00 to 3.63
Bicycle crash *	3	1.34	0.00 to 3.00

* Classified as a TBI.

Table 2

Demographic characteristics of the 2014 North Carolina Behavioral Risk Factor Surveillance System

	ABI			NO-ABI			Total		
Characteristics	**N**	**Weighted %**	**95% CI**	**N**	**Weighted %**	**95% CI**	**N**	**Weighted %**	**95% CI**
Sex									
Female	98	42.78	33.46 to 52.09	1764	53.26	50.64 to 55.88	1862	52.66	50.14 to 55.19
Male	103	57.22	47.91 to 66.54	1222	46.74	44.12 to 49.36	1325	47.34	44.81 to 49.86
Age group									
18–24 years	9	13.79	5.39 to 22.18	150	12.49	10.18 to 14.80	159	12.56	10.33 to 14.79
25–34 years	17	14.57	6.93 to 22.22	313	17.05	14.84 to 19.26	330	16.91	14.78 to 19.04
35–44 years	14	9.24	3.76 to 14.72	395	17.25	15.27 to 19.23	409	16.79	14.90 to 18.69
45–54 years	42	22.13	14.15 to 30.12	455	17.13	15.20 to 19.06	497	17.41	15.54 to 19.29
55–64 years	54	18.54	12.48 to 24.61	660	16.59	15.00 to 18.19	714	16.7	15.16 to 18.24
65+years	65	21.72	14.70 to 28.74	1013	19.49	18.01 to 20.98	1078	19.62	18.17 to 21.07
Race/ethnicity									
White	152	77.00	69.11 to 84.90	2060	67.79	65.41 to 70.18	2212	68.32	66.02 to 70.61
Black	18	8.11	3.90 to 12.32	584	20.66	18.55 to 22.77	602	19.94	17.93 to 21.96
American Indian/Alaskian Native	4	1.33	0.02 to 2.65	39	1.10	0.67 to 1.53	43	1.11	0.71 to 1.52
Asian	1	0.55	0.00 to 1.63	33	1.20	0.72 to 1.67	34	1.16	0.71 to 1.61
Other	7	3.05	0.35 to 5.75	19	0.74	0.28 to 1.20	26	0.87	0.41 to 1.34
Multiracial	3	1.48	0.00 to 3.36	35	1.30	0.68 to 1.92	38	1.31	0.72 to 1.90
Hispanic	13	8.47	2.10 to 14.85	191	7.21	5.90 to 8.52	204	7.28	6.00 to 8.57
Household income									
<US$15 000	42	21.81	13.69 to 29.92	333	12.70	10.97 to 14.42	375	13.22	11.53 to 14.91
US$15 000–US$24 999	38	34.12	23.25 to 44.99	481	20.35	17.92 to 22.78	519	21.14	18.74 to 23.54
US$25 000–US$34 999	14	8.91	4.01 to 13.82	297	10.90	9.25 to 12.54	311	10.78	9.20 to 12.37
US$35 000–US$49 999	19	11.04	3.56 to 18.52	366	15.87	13.65 to 18.09	385	15.59	13.45 to 17.72
≥US$50 000	47	24.12	15.74 to 32.49	911	40.19	37.34 to 43.04	958	39.27	36.53 to 42.01
Educational attainment									
Less than high school	30	24.09	14.74 to 33.45	411	15.04	13.14 to 16.93	441	15.55	13.67 to 17.44
High school diploma/General Educational Development	53	24.91	17.08 to 32.73	819	27.24	24.86 to 29.62	872	27.11	24.82 to 29.40

	ABI			NO-ABI			Total		
Characteristics	**N**	**Weighted %**	**95% CI**	**N**	**Weighted %**	**95% CI**	**N**	**Weighted %**	**95% CI**
Some college	61	31.47	22.70 to 40.25	779	32.65	30.09 to 35.22	840	32.59	30.12 to 35.06
College degree	57	19.53	13.25 to 25.81	967	25.07	23.11 to 27.03	1024	24.75	22.87 to 26.63
Employment status									
Employed	54	38.28	29.11 to 47.46	1385	55.62	53.08 to 58.16	1439	54.63	52.17 to 57.09
Unemployed	11	6.24	1.76 to 10.72	147	6.90	5.23 to 8.56	158	6.86	5.27 to 8.45
Unable to work	63	21.95	15.63 to 28.26	275	8.45	7.11 to 9.79	338	9.22	7.91 to 10.53
Other	73	33.53	24.11 to 42.95	1168	29.03	26.94 to 31.13	1241	29.29	27.24 to 31.34

No ABI includes respondents who did not report an ABI. Frequencies are unweighted; percentages are weighted; $p<0.05$.

ABI, acquired brain injury; GED, general educational development.

Table 3

2014 North Carolina Behavioral Risk Factor Surveillance System adjusted bivariate relationships among adverse childhood experiences (ACEs) and acquired brain injury (ABI)

	ABI				
ACE	**N**	**Weighted %**	**b**	**Adjusted OR**	**95% CI**
Sexual abuse					
No (N=2705)	148	76.68	Ref.	1	–
Yes (N=343)	45	23.32	0.55	3	1.81 to 4.97 *
Emotional abuse					
No (N=2263)	121	63.02	Ref.	1	–
Yes (N=765)	71	36.98	0.25	1.64	1.06 to 2.53 *
Physical abuse					
No (N=2649)	149	41.16	Ref.	1	–
Yes (N=398)	43	58.84	0.29	1.78	1.05 to 3.00 *
Household mental illness					
No (N=2661)	146	76.04	Ref.	1	–
Yes (N=390)	46	23.96	0.44	2.41	1.47 to 3.95 *
Incarcerated household member					
No (N=2886)	177	91.24	Ref.	1	–
Yes (N=180)	17	8.76	0.39	2.16	0.95 to 4.93
Witnessing intimate partner violence					
No (N=2565)	152	79.58	Ref.	1	–
Yes (N=449)	39	20.42	0.25	1.65	0.96 to 2.83
Household substance abuse					
No (N=2303)	120	61.22	Ref.	1	–
Yes (N=772)	76	38.78	0.31	1.86	1.19 to 2.90 *
Parental separation/divorce					
No (N=2265)	132	69.84	Ref.	1	–
Yes (N=743)	57	30.16	0.18	1.42	0.87 to 2.33
ACE score					
0 (1239)	52	29.21	Ref.	1	–

	ABI				
ACE	**N**	**Weighted %**	**b**	**Adjusted OR**	**95% CI**
1 (644)	45	25.28	0.2	1.6	0.91 to 2.82
2 (308)	20	11.24	0.31	1.48	0.66 to 3.32
3 (191)	18	10.11	0.31	2.55	1.12 to 5.77 *
4+ (301)	43	24.16	0.21	3.51	1.95 to 6.32 *

* P<0.001.

Table 4

2014 North Carolina Behavioral Risk Factor Surveillance System adjusted bivariate relationships among adverse childhood experiences (ACEs) and traumatic brain injury (TBI)

	TBI				
ACE	**N**	**Weighted %**	**b**	**Adjusted OR**	**95% CI**
Sexual abuse					
No (N=2633)	79	76.7	Ref.	1	–
Yes (N=321)	24	23.3	0.55	3.16	1.54 to 6.51 *
Emotional abuse					
No (N=2210)	60	59.41	Ref.	1	–
Yes (N=726)	41	40.59	0.25	1.8	0.94 to 3.45
Physical abuse					
No (N=2581)	75	73.53	Ref.	1	–
Yes (N=373)	27	26.47	0.29	2.4	1.20 to 4.80 *
Household mental illness					
No (N=2591)	77	76.23	Ref.	1	–
Yes (N=368)	24	23.76	0.44	2.53	1.26 to 5.05 *
Incarcerated household member					
No (N=2800)	93	90.29	Ref.	1	–
Yes (N=171)	10	9.71	0.39	3.41	1.36 to 8.52 *
Witnessing intimate partner violence					
No (N=2491)	81	79.41	Ref.	1	–
Yes (N=430)	21	20.59	0.25	1.15	0.53 to 2.49
Household substance abuse					
No (N=2244)	65	62.5	Ref.	1	–
Yes (N=736)	39	37.5	0.31	1.74	0.95 to 3.21
Parental separation/divorce					
No (N=2205)	65	65	Ref.	1	–
Yes (N=712)	35	35	0.18	1.6	0.82 to 3.12
ACE score					
0 (1272)	22	23.16	Ref.	1	–

	TBI				
ACE	**N**	**Weighted %**	**b**	**Adjusted OR**	**95% CI**
1 (660)	31	25.28	0.2	1.85	0.81 to 4.24
2 (320)	9	11.24	0.31	2.22	0.63 to 7.80
3 (199)	10	10.11	0.31	4.16	1.47 to 11.76*
4+ (323)	23	24.16	0.21	3.39	1.45 to 7.90*

* P<0.001.