

## Partitioning the Composition of Adverse Childhood Experiences From Accumulated Adversity: Cross-Sectional Evidence From 2 U.S. Samples



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**Introduction:** Adverse childhood experiences are linked to adult morbidity and mortality. However, it is unknown whether the patterning of adverse childhood experiences, individually and in combination, confer health risk distinct from that of a cumulative adversity score. This study evaluates whether individual and comorbid adverse childhood experience exposures within a cumulative risk score are equally associated with current smoking and lifetime history of depression.

**Methods:** Cross-sectional analysis of adverse childhood experience assessments in the Behavioral Risk Factor Surveillance System from 21 states in 2019 ( $n=115,183$ ) and 23 states in 2020 ( $n=120,416$ ) was performed. We modeled cumulative adverse childhood experience scores and the 5 most common distinct adverse childhood experience components that compose a given adverse childhood experience score, up to a cumulative score of 4. We compared adverse childhood experience components, adjusting for covariates.

**Results:** Across both samples, 23% and 57%–58% of persons reported 1 adverse childhood experience and 2 or more adverse childhood experiences, respectively. In 2019 smoking prevalence was 10.4% for persons reporting zero adverse childhood experiences and 14.2% for persons reporting 1 adverse childhood experience. When the single adverse childhood experience was experiencing parental divorce, smoking was higher (16.6%) than when the single adverse childhood experience was verbal abuse (11.8%) or living with a mentally ill household member (9.5%). Lifetime depression prevalence was 9.6% and 14.1% across zero and 1 adverse childhood experience, respectively, whereas it was 26.6% if the single adverse childhood experience was living with a mentally ill household member and 11.0% when the adverse childhood experience was experiencing parental divorce. This heterogeneity was replicated in 2020 data. Additional heterogeneity was observed for higher cumulative adverse childhood experience scores.

**Conclusions:** Cumulative adverse childhood experience scores mask substantial health risk heterogeneity, which can be delineated by examining distinct components of cumulative adverse childhood experience scores.

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### INTRODUCTION

Adverse childhood experiences (ACEs), defined as potentially traumatic events that occur in childhood,<sup>1</sup> are reported by almost two thirds of U.S. adults.<sup>2</sup> Greater adversity in childhood, as indexed by a cumulative ACE risk score, that is, a count of the number of experienced

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adversities, is strongly linked to a number of poor health and life outcomes, including chronic disease, unhealthy behavior, poor mental health, and premature death.<sup>3–5</sup> Despite the prognostic value of the cumulative ACE score, a critical but untested assumption of this cumulative approach is that each specific exposure or exposure combination is equally associated with health outcomes within each adversity, that is, is exchangeable.<sup>6–8</sup> It has been well documented that a cumulative score cannot capture exposure heterogeneity,<sup>7,9</sup> nor can it delineate which adversities co-occur, precluding a clear understanding of potential mechanisms for intervention.<sup>7,9</sup>

Although the statistical associations of individual ACE exposures vary,<sup>8,10–13</sup> we are unaware of any studies that directly evaluate whether distinct ACE exposures are exchangeable with one another. This gap is due in part to an inability to partition discrete ACE clustering patterns. Person-centered approaches, such as latent class analysis, purport to identify distinct, mutually exclusive, and homogeneous subgroups,<sup>14</sup> and such classes can predict health risk beyond cumulative risk scores.<sup>5</sup> However, class membership is probabilistic, and individuals' exposures are not often clearly separated by latent class membership.<sup>5,9,15</sup> In this study, we present a novel method of partitioning cumulative ACE exposures into their observed components within cumulative risk scores. This approach generates mutually exclusive and homogeneous exposure groups, permitting the identification of the most frequently occurring adversities and adversity clusters within categories of cumulative ACE exposure. We then evaluate whether these distinct adversity exposures are equivalently associated with health outcomes within a given cumulative risk score.

The health outcomes include current smoking and lifetime history of depression, which compose the largest population-attributable risks for ACE exposure in the U.S.<sup>16</sup> and have evidenced divergent associations with individual ACEs.<sup>8,11,12</sup> We first partition ACE exposures and then evaluate their exchangeability for smoking and lifetime depression in a representative sample of 114,000 U.S. adults. We then repeat these analyses using an independent probability sample of 119,000 adults, confirming the main findings of the first analysis. This method to partition individual and comorbid ACEs identifies both harmful and neutral childhood exposures depending on the outcome, which may improve targeted efforts to reduce the burden of childhood adversity.

## METHODS

### Study Sample

The Behavioral Risk Factor Surveillance System (BRFSS) is an annual telephone survey that collects health

information from civilian, non-institutionalized U.S. adults in the 50 U.S. states, the District of Columbia, and U.S. territories (referred to as states in the remaining parts of this paper). A core question set is administered to all respondents, and individual states can add optional survey modules, including the ACE module. In 2019<sup>17</sup> and 2020,<sup>18</sup> 21 and 27 states, respectively, fielded the optional ACE module. Only states with publicly available ACE modules were included, leaving 23 states available in the 2020 data. Data were weighted to represent the population totals for the included states for each year, including weight adjustments for 5 states that fielded the survey to a subset of their statewide sample. This study used nonidentifiable publicly available data and thus did not require ethical approval and was pre-registered at [https://osf.io/5twjs/?view\\_only=296e2477081a4a64a06a82886db6488b](https://osf.io/5twjs/?view_only=296e2477081a4a64a06a82886db6488b).

### Measures

The ACE module includes 11 items,<sup>19</sup> which are dichotomized for scoring.<sup>20</sup> An ACE cumulative risk score was created by summing affirmative responses for persons with valid values for all ACE items (score range=0–11).<sup>20,21</sup> Because a key study goal was to describe and evaluate individual exposures, we examined items individually rather than collapsing them into categories.<sup>2,20</sup> Verbatim item descriptions are provided in the survey documentation.<sup>19</sup>

To reveal the co-occurrence of ACEs within cumulative risk categories, we created an ACE component score. We first multiplied each of the 11 binary ACE items by increasing orders of magnitude beginning with 1. We summed these transformed items to create a new variable, the component score, which encodes the form of all observed response combinations for the 11 ACE items,<sup>22</sup> shown in [Appendix Table 1](#) (available online). We report the top 5 most frequently occurring ACE combinations within each of the cumulative risk categories, that is, within cumulative risk scores of 1, 2, 3, and 4. These 5 component scores were retained for description and heterogeneity evaluation. Unlike statistical approaches to clustering ACE exposures, component scores generate mutually exclusive and distinct exposure clusters that are isomorphic with regard to reported adversities. We examined 5 composites to keep the number of composites manageable and to provide sufficient sample sizes for estimation.

We examined 2 outcomes: current cigarette smoking and a lifetime history of depression. Current cigarette smoking was defined as having smoked at least 100 cigarettes in a lifetime and reporting smoking now every day or on some days (Centers for Disease Control and Prevention<sup>23</sup>). Lifetime depression was determined by

whether the respondent was diagnosed with a depressive disorder (including depression, major depression, dysthymia, or minor depression) by a healthcare professional. In addition to these primary outcomes, we present heterogeneity analyses for an ancillary outcome, overweight/obesity. Overweight/obesity is weakly linked to cumulative ACE exposure<sup>4,11,16</sup> and was included for discriminant validity.

Several variables associated with both ACEs and the outcome variables were selected a priori as covariates in multivariable analysis. These included age in years, sex, race/ethnicity (non-Hispanic White, non-Hispanic Black, non-Hispanic Asian, American Indian, other non-Hispanic race), education (less than high school, high school graduate, some college, college graduate or higher), and workforce status (unemployed or not). Race and ethnicity were self-reported by participants using categories prespecified in the BRFSS survey instrument.

### Statistical Analysis

Data were analyzed between April 20, 2022 and December 15, 2022. We evaluated the association of ACEs with health risk using a generalized linear model with a Poisson distribution, a log link, and robust SEs, exponentiated to produce incidence rate ratios. The incidence rate ratio is the ratio of the outcome prevalence in the exposed group divided by the prevalence in the unexposed group. This ratio is less biased and simpler to interpret than ORs from logistic regression.<sup>24,25</sup> We also did not use ORs because they incorporate an arbitrary scaling factor that precludes comparisons of ORs across models and studies.<sup>26–28</sup> The log-binomial model is appropriate for binary outcomes but is less robust to model misspecification.<sup>29</sup>

All regression analyses incorporated the complex survey design. We evaluated the heterogeneity of the 5 regression coefficients within each cumulative risk category using a Wald test. This tests the null hypothesis that the difference in rate ratios across a pair of adversity categories is zero.<sup>30</sup> We used Stata 18.0 (Stata Corp., College Station, TX) for all analyses, and comparisons were considered statistically significant with a 2-tailed  $p < 0.05$ . We validated the regression coefficient heterogeneity observed in the 2019 data by repeating the analyses using the 2020 data. Therefore, no adjustments were made for multiple comparisons. Frequencies for each outcome were screened within each composite ACE category, and per BRFSS guidelines, we suppressed comparisons on the basis of raw cell sizes  $< 50$  for any outcome variable.<sup>31</sup>

Table 1 presents the sociodemographic characteristics of the samples (52% female, 62%–72% non-Hispanic White, and 27%–28% college graduates or higher). The study followed the STROBE guidelines,<sup>32</sup> details of

which are reported in Appendix Figure 1 (available online) and Appendix Methods 1 (available online). There were 1,443 and 1,483 unique combinations of ACE exposure observed in 2019 and 2020, respectively.

### Identifying the Components of Cumulative Adverse Childhood Experience Scores

Population-weighted percentages for cumulative ACE exposure categories and the 5 most frequently occurring components within each cumulative exposure category (up to 4) are presented in Table 2. Parental divorce, verbal abuse, physical abuse, having a problem drinker in the household, and household mental illness were the most common singleton ACEs. These 5 ACEs also comprised the most common pairwise combinations. At higher cumulative risk, household violence co-occurred with these 5 adversities. The form and ordering of component risks at the single and double cumulative risk score were identical across 2019 and 2020. At higher cumulative risk, the components were also identical across survey years but were ordered slightly differently from 2019 to 2020 (Table 2). The order of exposures within cumulative risk groups was similar when using an 8-category ACE classification,<sup>20</sup> that is, when combining the 3 sexual abuse questions and the alcohol and substance abuse questions (data not shown). These commonly combined exposures did not cluster strongly and were rare relative to the exposures examined in this study. Individual ACE item endorsement percentages overall and for the analytic samples are presented in Appendix Table 2 (available online).

### Partitioning the Association of Cumulative and Composite Adverse Childhood Experience Exposures With Health Risk

Greater cumulative risk was associated with a higher prevalence of smoking and lifetime depression in both samples (Table 3). However, these risk categories masked variability in the associations among the individual components of each cumulative risk score. For example, household mental illness was unrelated to smoking when it occurred alone, as a pair (in combination with verbal abuse), or as a trio (with both verbal and physical abuse) (Table 3). Similarly, for lifetime depression, experiencing parental divorce by itself was unrelated, whereas household mental illness was strongly associated, by itself or in combination with other ACEs (Table 3). Unadjusted incidence rate ratios are in Appendix Table 3 (available online).

Although statistical conclusions varied across the component exposures, heterogeneity of individual ACE prevalence ratios is evaluated by directly comparing regression coefficients with each other rather than

**Table 1.** Demographic Characteristics, BRFSS 2019 and 2020

Variables	2019 (n=116,032)		2020 (n=120,416)	
	n	% or mean <sup>a</sup>	n	% or mean <sup>a</sup>
Age, years (mean, SD)	49.1	18.9	48.8	21.3
Women, n (%)	64,296	51.9	66,056	52.4
Men, n (%)	50,887	48.1	54,360	47.6
Race and ethnicity, n (%)				
Asian (non-Hispanic)	1,024	2.6	3,279	3.3
American Indian	1,518	1.2	2,307	0.9
Black (non-Hispanic)	10,493	12.1	10,788	14.1
Hispanic	6,068	9.7	9,119	17.3
Other non-Hispanic race	2,756	1.8	4,449	2.0
White (non-Hispanic)	93,324	72.5	90,474	62.3
Education level, n (%)				
Less than high school	8,038	11.1	7,891	12.4
High school diploma	32,787	30.0	32,041	28.2
Some college	32,413	30.8	35,059	32.4
College graduate or higher	41,945	28.1	45,425	27.0
Marital status, n (%)				
Married	58,857	51.1	63,683	50.8
Divorced	16,106	11.0	15,354	11.0
Widowed	15,964	7.5	14,411	7.5
Separated	2,310	2.3	2,326	2.5
Never married	18,104	23.2	20,067	23.1
Partnered	3,383	4.4	4,034	4.7
Missing	459	0.5	541	0.5
Employed <sup>b</sup> , n (%)				
No	101,760	87.8	106,515	86.8
Yes	13,423	12.2	13,901	13.2
Smoking status, n (%)				
Never/former smoker	97,117	82.8	103,703	84.7
Current smoker	17,551	16.7	16,209	14.9
Missing	515	0.5	504	0.4
Lifetime depression, n (%)				
No	92,380	80.1	97,805	81.2
Yes	22,344	19.5	22,158	18.4
Missing	459	0.4	453	0.4
BMI>25, n (%)				
No	32,610	29.5	35,729	29.6
Yes	76,350	64.5	77,721	64.0
Missing	6,223	6.0	6,966	6.5

Note: BMI was calculated by weight in kilograms/height in meters squared.

For all states (not just those who fielded the optional ACE module) in the 2019 and 2020 samples, respectively, smoking prevalence was 15.3% (95% CI=15.0%, 15.5%) and 14.2% (95% CI=14.0%, 14.5%), lifetime depression prevalence was 18.8% (95% CI=18.6%, 19.0%) and 18.3% (95% CI=18.1%, 18.6%), and BMI >25 was 66.6% (95% CI=66.3%, 66.9%) and 66.8% (95% CI=66.4%, 67.1%).

<sup>a</sup>Percentages are weighted to represent the states surveyed.

<sup>b</sup>Employed included homemakers, students, and retired persons.

ACE, adverse childhood experience; BRFSS, Behavioral Risk Factor Surveillance System.

comparing differences in statistical significance for the coefficients.<sup>30,33</sup> Heterogeneity tests for each rate ratio are presented in [Appendix Tables 4 and 5](#) (available online). As illustrated by the adjusted smoking and lifetime depression percentages, there was consistent heterogeneity for composite ACEs for these outcomes

([Figure 1](#)). Among the 23% of the sample who experienced a single ACE, divorce was associated with higher smoking than the following ACEs: verbal abuse, problem drinking, and household mental illness. The 7% difference in smoking prevalence for household mental illness versus divorce within the single ACE category is

**Table 2.** Cumulative and Component ACEs, BRFSS 2019 and 2020

Cumulative ACE score and ACE components	2019			2020		
	<i>n</i>	Weighted %	95% CI	<i>n</i>	Weighted %	95% CI
0	46,229	35.5	35.0, 36.0	48,465	36.7	36.0, 37.3
1	26,134	22.7	22.2, 23.2	27,571	23.0	22.5, 23.6
Divorce	6,859	7.3	7.0, 7.6	7,650	8.0	7.6, 8.3
Verbal abuse	6,423	5.6	5.3, 5.8	7,109	5.1	4.9, 5.4
Physical abuse	3,961	3.2	3.0, 3.4	3,883	3.3	3.1, 3.6
Problem drinker	3,678	2.4	2.3, 2.5	3,539	2.5	2.3, 2.6
Household mental illness	2,097	1.8	1.6, 1.9	2,122	1.6	1.5, 1.8
All other single ACEs	3,116	2.5	2.3, 2.6	3,268	2.5	2.3, 2.7
2	14,610	13.0	12.6, 13.4	15,132	12.5	12.1, 12.9
Verbal/physical abuse	2,217	1.9	1.8, 2.1	2,286	1.7	1.5, 1.9
Divorce/verbal abuse	1,406	1.5	1.3, 1.6	1,572	1.6	1.4, 1.8
Verbal abuse/drinker	1,254	0.9	0.8, 1.0	1,208	0.8	0.7, 0.9
Divorce/drinker	1,108	1.0	0.9, 1.1	1,177	1.0	0.8, 1.1
Verbal abuse/mental illness	1,035	1.0	0.9, 1.1	1,095	0.8	0.8, 0.9
All other double ACEs	7,590	6.7	6.4, 7.0	7,794	6.6	6.3, 6.9
3	9,281	8.7	8.4, 9.0	9,818	8.6	8.2, 9.0
Verbal abuse/physical abuse/HHV	710	0.6	0.5, 0.7	758	0.6	0.5, 0.7
Divorce/verbal abuse/physical abuse	638	0.8	0.6, 0.9	698	0.6	0.5, 0.7
Verbal abuse/physical abuse/drinker	550	0.4	0.4, 0.5	558	0.4	0.3, 0.5
Verbal abuse/physical abuse/mental illness	533	0.5	0.4, 0.5	579	0.4	0.3, 0.4
Divorce/verbal abuse/drinker	469	0.5	0.4, 0.6	569	0.4	0.4, 0.5
All other triple ACEs	6,381	5.9	5.6, 6.2	6,656	6.1	5.8, 6.4
4	6,692	6.5	6.2, 6.7	6,825	6.1	5.8, 6.4
Verbal abuse/physical abuse/drinker/HHV	677	0.5	0.5, 0.6	596	0.4	0.4, 0.5
Divorce/verbal abuse/physical abuse/HHV	447	0.5	0.4, 0.5	468	0.4	0.3, 0.5
Verbal abuse/physical abuse/mental illness/HHV	296	0.2	0.2, 0.3	296	0.2	0.2, 0.2
Divorce/verbal abuse/physical abuse/drinker	285	0.3	0.2, 0.3	253	0.2	0.1, 0.3
Divorce/verbal abuse/drinker/HHV	268	0.2	0.2, 0.2	288	0.2	0.2, 0.3
All other quadruple ACEs	4,719	4.8	4.5, 5.0	4,924	4.6	4.3, 4.9
≥5	13,086	13.6	13.3, 14.0	13,619	13.1	12.7, 13.5

Note: Cumulative ACE score is the sum of the number of any reported ACEs. ACE components reflect the most common individual ACEs within each cumulative exposure category.

Percentages are weighted to reflect the adult civilian non-institutionalized population of 21 and 23 participating U.S. states for 2019 and 2020, respectively. Percentages for the individual ACE components under each of the cumulative ACE counts sum to the percentage for the count. ACE components are reported in descending order on the basis of unweighted 2019 data. The top 5 single and combination ACEs were the same across 2019 and 2020, and the rank order of those ACE exposures was identical for single and double ACEs. Rank order was slightly different for triple and quadruple ACE components in 2020 relative to that in 2019. Only persons with 11 valid ACE items were included.

Divorce, reporting parental separation or divorce; verbal abuse, reporting being sworn at, insulted, or put down by a parent or adult in the home; physical abuse, being hit, beaten, kicked, or physically hurt by a parent or adult in the home; problem drinker/drinker, living with a problem drinker or alcoholic; depression, living with someone who was depressed, mentally ill, or suicidal; and HHV, parents or adults in the household slap, kick, hit, punch, or beat each other up.

These estimates are from sample sizes of 116,032 and 121,430 for 2019 and 2020, respectively.

ACE, adverse childhood experience; BRFSS, Behavioral Risk Factor Surveillance System; HHV, household violence.

clinically important and equal to or greater than the smoking prevalence difference seen when comparing zero ACEs with cumulative ACE scores of 1, 2, or 3. Household mental illness was consistently associated with lower smoking prevalence across both samples, both alone and in the presence of other adversities.

For lifetime depression, 18 (of 21) statistically significant heterogeneity comparisons in 2019 were replicated

in 2020. Absolute differences in lifetime depression prevalence across ACE components ranged from 4% to 5% in the single cumulative ACE category, except for the large absolute differences (~15%) in lifetime depression for divorce compared with that for household mental illness (Figure 1). In contrast to the smoking findings, lifetime depression prevalence was consistently lower for persons experiencing parental divorce, whereas it was

**Table 3.** Association of Cumulative and Component ACEs with Current Smoking and Lifetime Depression, BRFSS 2019 and 2020

Cumulative ACE score and ACE components	2019			2020		
	IRR	95% CI	p-value	IRR	95% CI	p-value
Smoking prevalence						
0 ACEs	1.0	ref		1.0	ref	
1 ACE	1.37	1.27, 1.47	<0.001	1.38	1.24, 1.53	<0.001
Divorce	1.59	1.44, 1.77	<0.001	1.62	1.40, 1.87	<0.001
Verbal abuse	1.17	1.01, 1.35	0.03	1.14	0.96, 1.35	0.014
Physical abuse	1.37	1.17, 1.60	<0.001	1.17	0.94, 1.46	0.15
Problem drinker	1.31	1.13, 1.53	<0.001	1.18	0.94, 1.49	0.15
Household mental illness	0.94	0.76, 1.17	0.59	0.92	0.70, 1.19	0.51
0 ACEs	1.0	ref		1.0	ref	
2 ACEs	1.60	1.47, 1.73	<0.001	1.60	1.41, 1.81	<0.001
Verbal/physical abuse	1.52	1.25, 1.84	<0.001	1.39	1.07, 1.81	0.01
Divorce/verbal abuse	1.74	1.47, 2.06	<0.001	1.71	1.11, 2.65	0.02
Verbal abuse/drinker	1.57	1.20, 2.05	0.001	1.44	0.96, 2.15	0.08
Divorce/drinker	1.86	1.53, 2.25	<0.001	1.60	1.24, 2.05	<0.001
Verbal abuse/mental illness	1.29	1.00, 1.67	0.052	1.17	0.72, 1.90	0.53
0 ACEs	1.0	ref		1.0	ref	
3 ACEs	1.77	1.61, 1.95	<0.001	1.71	1.52, 1.92	<0.001
Verbal abuse/physical abuse/HHV	1.89	1.35, 2.63	<0.001	2.06	1.42, 2.98	<0.001
Divorce/verbal abuse/physical abuse	1.65	1.28, 2.12	<0.001	1.29	0.97, 1.71	0.08
Verbal abuse/physical abuse/drinker	1.82	1.34, 2.48	<0.001	2.23	1.54, 3.22	<0.001
Verbal abuse/physical abuse/mental illness	1.09	0.76, 1.56	0.65	1.14	0.76, 1.73	0.52
Divorce/verbal abuse/drinker	1.75	1.30, 2.34	<0.001	1.79	1.35, 2.36	<0.001
0 ACEs	1.0	ref		1.0	ref	
4 ACEs	2.02	1.83, 2.23	<0.001	1.95	1.73, 2.20	<0.001
Verbal abuse/physical abuse/ drinker/HHV	1.94	1.41, 2.65	<0.001	2.13	1.55, 2.95	<0.001
Divorce/verbal abuse/physical abuse/HHV	1.80	1.36, 2.37	<0.001	1.89	1.24, 2.89	0.003
Verbal abuse/physical abuse/mental illness/HHV	a	a	a	a	a	a
Divorce/verbal abuse/physical abuse/drinker	2.04	1.45, 2.87	<0.001	1.97	1.19, 3.25	0.008
Divorce/verbal abuse/drinker/HHV	2.05	1.43, 2.94	<0.001	a	a	a
Lifetime history of depression						
0 ACEs	1.0	ref		1.0	ref	
1 ACE	1.46	1.36, 1.58	<0.001	1.47	1.35, 1.61	<0.001
Divorce	1.14	1.00, 1.30	0.06	1.04	0.89, 1.22	0.61
Verbal abuse	1.59	1.40, 1.80	<0.001	1.64	1.45, 1.86	<0.001
Physical abuse	1.19	1.02, 1.39	0.03	1.22	1.00, 1.48	0.05

(continued on next page)

**Table 3.** Association of Cumulative and Component ACEs with Current Smoking and Lifetime Depression, BRFSS 2019 and 2020 (continued)

Cumulative ACE score and ACE components	2019			2020		
	IRR	95% CI	p-value	IRR	95% CI	p-value
Problem drinker	1.46	1.29, 1.65	<0.001	1.51	1.23, 1.86	<0.001
Household mental illness	2.75	2.40, 3.15	<0.001	2.78	2.39, 3.23	<0.001
0 ACEs	1.0	ref		1.0	ref	
2 ACEs	2.04	1.89, 2.21	<0.001	2.15	1.94, 2.38	<0.001
Verbal/physical abuse	1.95	1.66, 2.31	<0.001	2.52	2.07, 3.07	<0.001
Divorce/verbal abuse	1.46	1.19, 1.79	<0.001	2.16	1.48, 3.14	<0.001
Verbal abuse/drinker	1.73	1.41, 2.14	<0.001	1.59	1.25, 2.02	<0.001
Divorce/drinker	1.45	1.19, 1.77	<0.001	1.43	1.05, 1.95	0.02
Verbal abuse/mental illness	4.00	3.40, 4.70	<0.001	3.89	3.34, 4.53	<0.001
0 ACEs	1.0	ref		1.0	ref	
3 ACEs	2.49	2.28, 2.72	<0.001	2.29	2.09, 2.51	<0.001
Verbal abuse/physical abuse/HHV	2.02	1.55, 2.63	<0.001	1.53	1.18, 2.00	0.002
Divorce/verbal abuse/physical abuse	1.82	1.39, 2.40	<0.001	1.66	1.25, 2.20	<0.001
Verbal abuse/physical abuse/drinker	2.40	1.70, 3.39	<0.001	2.74	2.01, 3.72	<0.001
Verbal abuse/physical abuse/mental illness	4.12	3.42, 4.98	<0.001	4.09	3.47, 4.83	<0.001
Divorce/verbal abuse/drinker	1.91	1.46, 2.48	<0.001	1.90	1.31, 2.75	0.001
0 ACEs	1.0	ref		1.0	ref	
4 ACEs	2.69	2.46, 2.95	<0.001	2.54	2.29, 2.81	<0.001
Verbal abuse/physical abuse/ drinker/HHV	2.24	1.80, 2.78	<0.001	1.57	1.14, 2.16	0.006
Divorce/verbal abuse/physical abuse/HHV	1.82	1.38, 2.41	<0.001	2.64	1.79, 3.89	<0.001
Verbal abuse/physical abuse/mental illness/HHV	3.64	2.91, 4.55	<0.001	3.28	2.55, 4.20	<0.001
Divorce/verbal abuse/physical abuse/drinker	2.66	2.03, 3.47	<0.001	1.33	0.81, 2.16	0.26
Divorce/verbal abuse/drinker/HHV	1.87	1.32, 2.66	<0.001	1.60	1.00, 2.54	0.048

Note: Estimates are adjusted for age, sex, race/ethnicity, education, and employment status. Cumulative ACE score is the sum of the number of any reported ACEs. ACE components reflect the most common individual ACEs within each cumulative exposure category.

Divorce, reporting parental separation or divorce; verbal abuse, reporting being sworn at, insulted, or put down by a parent or adult in the home; physical abuse, being hit, beaten, kicked, or physically hurt by a parent or adult in the home; problem drinker/drinker, living with a problem drinker or alcoholic; depression, living with someone who was depressed, mentally ill, or suicidal; and HHV, parents or adults in the household slap, kick, hit, punch, or beat each other up.

<sup>a</sup>Cells with smoking frequencies below 50 were suppressed.

ACE, adverse childhood experience; BRFSS, Behavioral Risk Factor Surveillance System; HHV, household violence; IRR, incidence rate ratio.

(A)

	2019		2020	
<b>Smoking prevalence</b>				
<b>Cumulative ACE score and ACE components</b>	<b>Adjusted %</b>	<b>95% CI</b>	<b>Adjusted %</b>	<b>95% CI</b>
0 ACEs	10.4	9.9–10.9	9.6	8.9–10.3
1 ACE	14.2	13.4–15.0	13.2	12.2–14.3
Divorce	16.6	15.1–18.1	15.5	13.6–17.5
Verbal abuse	11.8	10.2–13.4	10.6	8.9–12.2
Physical abuse	13.9	11.8–16.0	11.0	8.7–13.3
Problem drinker	13.3	11.4–15.3	11.0	8.6–13.4
Household mental illness	9.5	7.5–11.6	8.5	6.3–10.7
0 ACEs	10.4	9.8–10.9	9.5	8.8–10.2
2 ACEs	16.6	15.5–17.6	15.2	13.7–16.7
Verbal/physical abuse	15.5	12.6–18.3	13.0	9.7–16.3
Divorce/verbal abuse	17.8	14.9–20.7	16.0	9.1–22.8
Verbal abuse/drinker	15.9	11.8–20.1	13.4	8.0–18.7
Divorce/drinker	19.0	15.4–22.5	14.9	11.3–18.5
Verbal abuse/mental illness	13.1	9.8–16.4	10.9	5.6–16.1
0 ACEs	10.4	9.8–10.9	9.5	8.8–10.2
3 ACEs	18.4	16.9–19.9	16.3	14.8–17.8
Verbal abuse/physical abuse/HHV	19.2	12.9–25.5	19.2	12.2–26.2
Divorce/verbal abuse/physical abuse	16.8	12.7–21.0	12.1	8.8–15.3
Verbal abuse/physical abuse/drinker	18.5	12.8–24.2	20.7	13.1–28.3
Verbal abuse/physical abuse/mental illness	11.0	7.1–15.0	10.6	6.3–15.0
Divorce/verbal abuse/drinker	17.8	12.6–22.9	16.7	12.1–21.2
0 ACEs	10.4	9.8–10.9	9.5	8.8–10.2
4 ACEs	21.0	19.3–22.7	18.6	16.7–20.4
Verbal abuse/physical abuse/drinker/HHV	19.7	13.6–25.8	19.9	13.6–26.2
Divorce/verbal abuse/physical abuse/HHV	18.3	13.3–23.3	17.7	10.3–25.0
Verbal abuse/physical abuse/mental illness/HHV	a	a	a	a
Divorce/verbal abuse/physical abuse/drinker	20.7	13.7–27.8	18.3	9.2–27.4
Divorce/verbal abuse/drinker/HHV	20.9	13.4–28.3	a	a

**Figure 1.** Adjusted current smoking (A) and lifetime depression (B) prevalence by cumulative and component ACEs, BRFSS 2019 and 2020.

Prevalence is adjusted for age, sex, race/ethnicity, education, and employment status. Braces denote statistically significant heterogeneity between regression coefficients for individual ACE elements. Bold braces denote heterogeneity observed in 2019 that were replicated in 2020.

Cumulative ACE score is the sum of the number of any reported ACEs. ACE components reflect the most common individual ACEs within each cumulative exposure category.

Divorce, reporting parental separation or divorce; verbal abuse, reporting being sworn at, insulted, or put down by a parent or adult in the home; physical abuse, being hit, beaten, kicked, or physically hurt by a parent or adult in the home; problem drinker/drinker, living with a problem drinker or alcoholic; depression, living with someone who was depressed, mentally ill, or suicidal; and HHV, parents or adults in the household slap, kick, hit, punch, or beat each other up.

<sup>a</sup>Cells with smoking frequencies below 50 were suppressed.

ACE, adverse childhood experience; BRFSS, Behavioral Risk Factor Surveillance System; HHV, household violence.



(B)

<b>Lifetime history of depression</b>				
<b>Cumulative ACE score and ACE components</b>	<b>Adjusted %</b>	<b>95% CI</b>	<b>Adjusted %</b>	<b>95% CI</b>
0 ACEs	9.6	9.1–10.2	9.2	8.7–9.8
1 ACE	14.1	13.4–14.8	13.6	12.7–14.4
Divorce	11.0	9.7–12.3	9.6	8.3–11.0
Verbal abuse	15.2	13.5–16.9	15.1	13.5–16.8
Physical abuse	11.3	9.6–13.0	11.1	9.0–13.1
Problem drinker	14.1	12.5–15.7	14.0	11.2–16.8
Household mental illness	26.6	23.4–29.8	25.8	22.3–29.3
0 ACEs	9.7	9.2–10.3	9.3	8.7–9.9
2 ACEs	19.9	18.8–21.0	20.0	18.4–21.6
Verbal/physical abuse	18.7	15.8–21.7	23.2	18.8–27.6
Divorce/verbal abuse	14.0	11.3–16.7	19.9	12.6–27.2
Verbal abuse/drinker	16.7	13.3–20.1	14.7	11.3–18.1
Divorce/drinker	14.0	11.3–16.6	13.2	9.2–17.3
Verbal abuse/mental illness	38.5	32.8–44.3	36.0	30.9–41.1
0 ACEs	9.8	9.3–10.4	9.4	8.8–10.0
3 ACEs	24.5	22.9–26.0	21.6	20.1–23.1
Verbal abuse/physical abuse/HHV	19.4	14.4–24.4	14.1	10.5–17.7
Divorce/verbal abuse/physical abuse/HHV	17.5	12.9–22.2	15.3	11.1–19.5
Verbal abuse/physical abuse/drinker	23.1	15.2–31.0	25.2	17.6–32.9
Verbal abuse/physical abuse/mental illness	39.7	32.6–46.8	37.8	31.8–43.8
Divorce/verbal abuse/drinker	18.3	13.6–23.0	17.5	11.1–24.0
0 ACEs	9.8	9.3–10.4	9.4	8.8–10.0
4 ACEs	26.5	24.8–28.2	23.9	22.0–25.7
Verbal abuse/physical abuse/drinker/HHV	21.5	16.9–26.1	14.4	9.8–19.0
Divorce/verbal abuse/physical abuse/HHV	17.5	12.8–22.2	24.3	15.0–33.6
Verbal abuse/physical abuse/mental illness/HHV	35.0	27.5–42.5	30.2	22.8–37.6
Divorce/verbal abuse/physical abuse/drinker	25.5	18.9–32.2	12.2	6.3–18.1
Divorce/verbal abuse/drinker/HHV	18.0	11.8–24.2	14.7	7.9–21.5

Figure 1 Continued.

substantially higher for a household member with mental illness, the latter robustly demarcating higher prevalence across all cumulative risk scores. If the only reported ACE was household mental illness, lifetime depression prevalence for that group exceeded that for cumulative risk scores of 1, 2, 3, or 4 (Figure 1). Heterogeneity for lifetime depression was substantial and consistent across independent samples. In contrast, infrequent and inconsistent heterogeneity was observed for overweight/obesity prevalence shown in Appendix Tables 6 and 7 (available online). Similar heterogeneity patterns for divorce and household mental illness were seen when we retrospectively compared the ORs of individual ACE exposures with those of smoking and lifetime depression reported for

the 2011 BRFSS data, shown in Appendix Table 8 (available online).<sup>11</sup>

## DISCUSSION

This study is the first, to our knowledge, to address a key limitation of ACE literature by establishing a novel method to identify distinct ACE exposure patterns beyond pairwise co-occurrence.<sup>7,8</sup> The cumulative ACE scoring method, the dominant model of childhood adversity exposure classification, assumes that all ACEs are equivalently associated with health risk. Our ACE component scores identify unique patterns of adversity and enable detection of the most harmful exposures, which in turn can be used to better understand the

burden of individual risk. Although cumulative ACE exposures are unequally distributed in the population,<sup>2</sup> this study shows that the composition of adversities within a given cumulative exposure denotes health risks comparable with the differences between cumulative exposures, particularly for smoking and lifetime depression history.

We found that 20% of respondents, representing 115 million U.S. adults, reported a single adversity. Although a single adversity considered in isolation is purported to have limited explanatory value,<sup>34</sup> these single adversities had substantially different associations with health outcomes. Parental divorce, reported by 7%–8% of the sample, was linked to considerably higher smoking, particularly when compared with persons who had only experienced household mental illness. Household mental illness did not confer the same risk as other ACEs for smoking, whereas smoking prevalence was similar among 3 other common ACEs: verbal abuse, physical abuse, and having a problem drinker in the household.

These singleton ACE associations reversed when examining lifetime history of depression. Having experienced household depression was associated with a 15% higher absolute lifetime depression prevalence than parental divorce. Moreover, depression prevalence for those who reported parental divorce was similar to that for persons with zero ACEs. Recent work examining singleton ACEs shows the same pattern seen in this study—parental separation but not household mental illness is positively associated with smoking—and this reverses when the outcome is low mental well-being.<sup>35</sup>

For lifetime depression prevalence, the majority of singleton ACEs (7 of 10 comparisons) were not exchangeable, underscoring the limitations of aggregating ACE exposures. Any ACE cluster of 2 or 3 that included household mental illness showed higher lifetime depression prevalence than all other clusters, indicating the importance of partitioning this exposure from cumulative risk scores for this outcome. Variation in lifetime depression prevalence among ACE elements within each cumulative risk score (15%–24%) was equal to or greater than the difference between zero ACEs and the corresponding cumulative risk score. Less heterogeneity was observed at the highest cumulative risk category for both outcomes, in part because no dominant set of clusters occurred there.

In summary, parental divorce is a potent correlate of adult smoking, whereas household mental illness is not, and the associations reverse for lifetime depression prevalence, a pattern seen in earlier BRFSS data<sup>11</sup> and in population-based data from the United Kingdom.<sup>35</sup> The association of divorce with smoking is robust across a

number of studies.<sup>11,21,35,36</sup> These associations were replicated across 2 independent probability samples of over 230,000 adults and were most pronounced at low cumulative risk, that is, 1 or 2 ACEs. Despite the lower cumulative exposure, the specific ACE components within those 2 cumulative risk scores represent approximately 25% of the population. Therefore, these findings have clear ecologic relevance for a large population at risk. For overweight/obesity as an outcome, weak and inconsistent associations were seen for ACE components and cumulative risk, but heterogeneity may exist for this and other outcomes when considering less common adversities.<sup>8,11</sup>

Heterogeneous health risk across unique ACE exposures suggests limitations of common statistical approaches, such as latent variable analysis and factor analysis, to identify homogeneous risk exposures.<sup>5,9,20</sup> Latent variable approaches are based on correlations among adversities. This approach ignores singleton exposures<sup>7</sup> or combines them with zero ACEs<sup>13</sup> and often aggregates household depression and parental divorce in the same category,<sup>9,20,37</sup> which is undesirable given their distinct associations with health risk seen in this study and elsewhere.<sup>8,10,11</sup> Although some latent class models predict health outcomes beyond cumulative risk scores,<sup>5</sup> latent variable approaches have been discouraged because ACE co-occurrence does not align with the hypothesized character of specific exposures, that is, threat versus deprivation.<sup>38</sup> Finally, group membership in statistically derived categories is probabilistic, whereas component scores reflect explicitly defined exposures expressed in their actual population prevalence and, as shown in this study, are consistent across large samples.

The multiple individual risk model, which simultaneously enters individual ACEs into a single model, provides information about specific adversities.<sup>8</sup> However, the marginal change in the probability of an outcome (e.g., smoking) for a given ACE exposure is dependent on the level of all other variables in that model.<sup>39</sup> Therefore, to estimate health risk for ecologically valid ACE combinations, one would have to know the most common co-occurring ACEs and specify those combinations within the multiple individual risk model. The present approach complements the multiple individual risk model by describing ecologically valid co-occurrence of ACEs and extends that approach to evaluate exchangeability of individual ACEs.

Heterogeneity in ACE-related health risk is inconsistent with a general negative influence of accumulated adversity<sup>4,6,40,41</sup> and points to a more nuanced conceptualization of adversity.<sup>7,9,13,34,42</sup> For example, parental divorce may result in the removal of an abusive adult

from the home and, therefore, not confer any negative long-term mental health consequences.<sup>10</sup> In contrast, smoking is higher among divorced/separated persons<sup>43</sup> and could underlie higher smoking prevalence. Why smoking prevalence is lower among persons experiencing household mental illness is unclear and is worthy of future investigation. The association of household mental illness with adult depression is also seen with concurrent depression assessments,<sup>44</sup> so it is unlikely to reflect healthcare access. More broadly, the sizable association of household mental illness with lifetime depression clearly warrants examining adversity composition rather than accumulation.

Although this study was designed to reveal the composition of cumulative ACE scores and to test their exchangeability, the data presented in this study have clinical and public health implications. First, the apparent vulnerability for a count exposure is highly dependent on the composition of that exposure. In particular, for 2 of the leading causes of morbidity and mortality, individual exposures are either neutral or associated with elevated risk, depending on the outcome. This nuance is not captured by cumulative risk scores, and understanding these disparate patterns permits improved specificity of both clinical and public health interventions.

The description of the prevalence of these common clusters also facilitates clinical classification. It is straightforward to categorize individuals using the distinct and mutually exclusive categories provided by the present approach. The magnitude of excess health risk associated with these ACE composites is clearly described in absolute terms of the outcome, not just by statistical measures of association. Together, these data provide a strong foundation for clinical translation as well as public health planning.

### Limitations

This study is cross-sectional and should not be interpreted as causal nor as evidence for longitudinal change beginning prior to adversity.<sup>45</sup> Retrospective adversity reports are subject to recall limitations,<sup>46</sup> but recall inaccuracy would be unlikely to produce differential associations with health risk. Our study lacked adversity duration and intensity measurements,<sup>7,34,42</sup> and heterogeneity analyses excluded less common ACE exposures, such as sexual abuse, which are linked to adult health risk<sup>11,47</sup> and may have ecologically and clinically important associations with health risk. We did not have measures of belonging and social relationships, which are protective in the presence of ACEs,<sup>48,49</sup> nor adversities such as peer victimization and community violence exposure, which could reclassify exposure.<sup>50,51</sup> Broader

ACE assessments could also change the prevalence rankings of the ACEs seen in this study but would be unlikely to affect the observed heterogeneity. Geographic and social variations in ACE prevalence and composition could alter the associations reported in this paper.

### CONCLUSIONS

This study described a novel method to disaggregate ACE exposure combinations, the ACE component score, and characterized the prevalence of these unique exposures. The form and prevalence of ACE components were consistent across 2 population-based samples, as were the distinct associations of these components with smoking and depression. This novel method advances our understanding of the types and patterns of experiences that drive the cumulative ACE association, a core ambition of ACE scholarship. Reliably identifying adversity patterns is a precondition for understanding their mechanisms, and the components identified in this study directly inform community and public health approaches to mitigate and prevent ACEs.

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### CREDIT AUTHOR STATEMENT

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### SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at [doi:10.1016/j.focus.2024.100192](https://doi.org/10.1016/j.focus.2024.100192).

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