Trends in US Alcohol Consumption Frequency During the First Wave of the SARS-CoV-2 Pandemic

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Background: The SARS-CoV-2 pandemic created disruptions and stressors which may have influenced alcohol consumption frequency trends. Varying COVID-19 health burden and alcohol policies may have contributed to different consumption trends between states. The aim of this study is to assess trends in alcohol consumption and moderation by state of residence.

Methods: We examined trends in adult drinking days, during the first wave of the pandemic (March 10 to June 8) using longitudinal data from the Understanding America Study (N = 6,172 unique participants; N = 28,059 observations). Because state mandates were responsive to disease burden, we modeled the interaction of time by COVID-19 burden, defined as whether the state had the median (or higher) daily incidence of COVID-19 cases on the survey date, and state random effects. We controlled for individual sociodemographics, perceived personal/familial COVID-19 burden, mental health symptomology, and risk avoidance.

Results: Drinking days increased throughout the duration (incidence risk ratio [IRR] for drinking per increase in one calendar day = 1.003, 95% CI 1.001, 1.004); trends were heterogeneous by disease burden, with individuals living in states with lower COVID-19 burden increasing (IRR = 1.005, 95% CI 1.003, 1.007) faster than those living in states with higher COVID-19 burden (IRR = 1.000, 95% CI 0.998, 1.002). Trends were heterogeneous between states, but there was no evidence of systematic geographic clustering of state trends.

Conclusions: Drinking days increased during the first months of the COVID-19 pandemic, particularly among residents of states with lower disease burden.

Key Words: Alcohol, SARS-CoV-2, Trends.

COMMUNITY SPREAD OF SARS-CoV-2, the virus causing coronavirus disease 2019 (COVID-19), in the United States led to unprecedented disturbances in the day-to-day lives of US residents. Millions of lives were impacted directly by health concerns related to the virus, and the majority of US residents also experienced school and daycare closures, job loss, economic insecurity, and stay-at-home orders restricting typical movement, consumption, and social routines (Alon et al., 2020; Bartik et al., 2020; Bayham and Fenichel, 2020; Shanthakumar et al., 2020; Tull et al., 2020). People experiencing financial, social, and family stress, as well as major disasters, may increase alcohol consumption as a form of coping (Brown et al., 2014; Diggs and Neppl, 2018; Fergusson et al., 2014; Keyes et al., 2011; Rospenda et al., 2010; Sillaber and Henniger, 2004); thus, the pandemic may have led to increases in alcohol consumption and problematic alcohol use. Indeed, in the early months of the pandemic, academic editorials warned that the virus and subsequent state and municipal responses may lead to increases in heavy drinking, relapses for those struggling with alcohol use disorder, and subsequently a spike in alcohol-related diseases and disorders, such as liver disease (Clay and Parker, 2020; Da et al., 2020). Alternatively, many contexts and locations that promote alcohol consumption (e.g., social events, college campuses, bars) were disrupted due to the pandemic, and alcohol consumption may have in fact declined either at the population level or in select demographics as a result as opportunities for consumption dwindled.

Alcohol consumption is a leading cause of death and disability both globally and in the United States (GBD, 2016 Alcohol Collaborators, 2018; Stahre et al., 2014). Even at relatively low levels, alcohol consumption has been associated with adverse health outcomes, in particular for heart health (Braillon and Wilson, 2018; Gallagher et al., 2017). At the population scale, as average population alcohol consumption increases, so do higher-risk alcohol consumption patterns like binge drinking, heavy drinking, and alcohol use disorders. Alcohol consumption as a form of coping is considered maladaptive and is associated with increased risks for depression and subsequent substance use disorders (Hussong et al., 2011; Thompson et al., 2010; Wardell et al., 2020). Acute increases in alcohol consumption are concerning for their increased risks of injuries and poisoning (Rehm and

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Imtiaz, 2016; Skog, 2001). If alcohol consumption increases as a response to COVID-19, both short- and long-term health effects may increase as well. The epidemic has persisted in the United States into late 2020, and widely available vaccines are not expected in the United States until late in 2021 (Goldhill, 2020; Kane et al., 2020). Social and economic disruptions may therefore continue for some time, in which case epidemic-related increases in alcohol consumption could be anticipated to lead to a variety of morbidity and mortality outcomes including heart disease, metabolic diseases, liver disease, and cancers (Bagnardi et al., 2015; Kuypers et al., 2012; Mellinger, 2019; Rehm and Imtiaz, 2016; Skog, 2001; Tramacere et al., ,2010, 2011). While the quantity of alcohol individuals consume is directly related to disease risk, so is consumption frequency (e.g., number of drinking days per week or month). Higher frequencies of drinking days are related to both all-cause mortality (Hartz et al., 2018) and chronic disease risk (Elgendy et al., 2019), even among those who only drink one or two drinks daily (Hartz et al., 2017).

Evidence from other countries suggests that the pandemic and its impact on social systems have influenced alcohol consumption. However, the direction of change has not been consistent with the hypothesized increases. In Poland, for example, 30% of adults reported changing their drinking patterns during the COVID-19 pandemic; but among those respondents, 14% increased and 16% reduced alcohol consumption (Chodkiewicz et al., 2020). In the United States, many economic indicators suggest alcohol consumption may be increasing: for example, a Nielson report early in the pandemic found sales of alcohol increased by 55% in the third week of March 2020 (Brenmer, 2020), and online liquor sales increasing to 243% compared with the same time period a year prior (House, 2020). It is unclear, however, to what extent these national sales trends correspond to consumption —early in the pandemic, many consumers were purchasing goods in excess for fear of shortages, and online sales may simply have supplanted on-site or in-person purchases at liquor stores or bars (Loxton et al., 2020). Limited research on self-reported alcohol consumption in the United States during this time period does suggest, however, that alcohol consumption increased as a result of the pandemic: compared with the spring of 2019, adults in May and June of 2020 on average reported greater frequencies of past-month alcohol consumption (Pollard et al., 2020). US residents who reported feelings of anxiety and fear related to COVID-19 consumed more drinks in a typical drinking occasion, and on more days in a typical month (Rodriguez et al., 2020). A sample of US college students—a population normally at elevated risks of alcohol consumption—endorsed higher levels of alcohol consumption after university closure due to COVID-19 than in the weeks before, with students reporting anxiety and depression symptomology reporting the highest increases (Lechner et al., 2020). Further, solitary drinking (i.e., drinking alone rather than with other people) increased among people who reported social distancing—that is, decreasing the frequency of contact and increasing the physical space between individuals—compared with retrospective recall of their drinking behaviors prior to social distancing (McPhee et al., 2020). Regarding coping, findings from a Canadian sample showed that alcohol consumption frequency and solitary drinking increased during the pandemic relative to the month prior to the pandemic and that drinking as a way to cope with stress was a major contributor to these changes (Wardell et al., 2020). Stressors during the COVID-19 pandemic—for example, depressive symptoms, lower social connectedness, childcare stress—increased alcohol use and were mediated through individual coping drinking motivation. Alcohol consumption may have continued to increase as the pandemic progressed, based on evidence comparing consumption rates in March 2020 to April 2020, as mental health has worsened (French et al., 2020).

Alcohol policy is largely determined at the state- or local- (i.e., county-, municipal-) level, and throughout the pandemic in the United States, individual states and jurisdictions within states reacted with heterogeneous changes to alcohol policies responses, which may have contributed to changes in alcohol consumption. For example, the timing, enforcement, and details of state stay-at-home orders varied from state to state, all of which led to varying social and economic environments for residents. In addition, some states responded to the pandemic by expanding alcohol access; for example, New York State expanded alcohol sales to include off-premises consumption and sales of "to go" drinks. However, a handful of states—including Pennsylvania and New Mexico —restricted alcohol access by not deeming liquor stores essential businesses (Rieper, 2020). Both state-level and individual-level responses have been sensitive to COVID-19 burden—for example, local disease prevalence, rates of hospitalization, etc.—suggesting that variability in alcohol consumption may also be related to state-level COVID-19 burden (Bergquist et al., 2020; Capano et al., 2020).

While data are emerging to indicate that both alcohol consumption frequency and volume have increased during the COVID-19 pandemic, it is unknown how these alcohol consumption patterns relate to state-level trends during this time period. Based on the existing evidence linking alcohol consumption during the pandemic to stress and coping pathways, we anticipate that residents of states with higher COVID-19 burdens have increased the frequency of alcohol consumption relative to those in states with lower COVID-19 burdens. On the other hand, those in states with lower COVID-19 burden may have fewer limitations to accessing alcohol, especially if venues for purchasing and consuming alcohol remained open during the first wave of the pandemic (i.e., in the spring and summer when cases initially peaked and then declined nationwide before increasing again). To better understand alcohol consumption behaviors during the COVID-19 pandemic, we compared temporal associations between alcohol consumption frequency and state-level COVID-19 burden during the first wave of the pandemic in the United States.

MATERIALS AND METHODS

Sample

We used self-reported data from the Understanding America Study (UAS), a national, longitudinal survey of roughly 7,400 US households administered online by University of Southern California (Alattar et al., 2018). This is an ongoing survey series with continuous recruitment beginning in 2014 and currently has 22 sample batches being monitored longitudinally. Batch recruitment refers to the process by which respondents are requested to join the survey; briefly, the unweighted demographics of the current sample are analyzed, and new respondents are recruited to re-balance the sample to maintain national representativeness. This is done through targeting ZIP codes based on demographic composition, and contacting households within those targeted ZIP codes via US mail with survey login information. Response rate varies by sample batch (i.e., changes across each new recruitment period), with approximately 15% of surveyed households ultimately participating in the online panels, that is, joining the UAS survey respondent pool.

Beginning in March 2020, adults over the age of 18 received questions specific to COVID-19 and behavioral health. These surveys were administered in five overlapping periods between March 10 and June 8, 2020. At the first survey, UAS invited 8,815 respondents who were active in their respondent pool to respond to surveys querying behaviors during the COVID-19 pandemic; of these, 7,145 (81%) completed the initial survey. Subsequent surveys continued to query samples from the entire active respondent pool, such that those who did not respond in the first survey remained eligible to respond to subsequent follow-ups; Table S1 contains information regarding participation rates for all five surveys, and links to resources made available by UAS. To be eligible for the current study, participants must have participated in at least one survey and provided a current state of residence (including Washington, D.C.). To measure trends over time, we also required that only those for whom the date of survey response was available could be included in this study. The final eligible sample was $N = 7{,}397$ eligible unique participants with $N = 31{,}244$ eligible observations over 5 surveys. Dates were coded according to when respondents completed the survey: the first survey corresponds to March 10–March 31, and the fifth survey corresponds to May 13–June 8. Figure S1 shows the start and end dates, by survey, for the analytic sample.

Measures

Alcohol Consumption Frequency. Alcohol consumption frequency was assessed via the question, "Out of the past 7 days, what is your best estimate of the number of days that you did each of the following activities? Consumed alcohol." This response was measured as a discrete count variable, with range 0 to 7.

State COVID-19 Burden. The state-level burden of COVID-19 was operationalized as whether or not, on the interview date, a state had at or above the national median daily incidence of COVID-19 cases. We chose to use this state-level measure for two reasons. The first was pragmatic—states are the highest resolution for geographic references in the UAS. The second was theoretical—while smaller geographies (i.e., counties or municipalities) may have been more salient to individual disease risk, for policies regarding quarantines, mask-wearing, mobility and accessibility of goods and services, states policies frequently preempted municipal policies (McDonald III et al., 2020; Treskon and Docter, 2020).

We chose to use disease burden as a state-level indicator of risk, rather than COVID-19 policies such as the date of state stay-at-home orders, because stay-at-home orders did not actually correspond closely to quarantine orders or alcohol policy changes; rather, various disease burden statistics were utilized as benchmarks for states in decision making around opening of businesses and schools long after stay-at-home orders had expired (Harris, 2020). For example, New York State's state closing order expired on May 15, but phased re-openings were conditional on meeting certain disease-related metrics including testing and incidence rates (New York State Governor's Office, 2020).

Time-varying state-level COVID-19 data were made available by USA Facts which collected state- and county-level COVID-19 data directly from state and county public health websites. This publicly available database tracked cumulative incidence of COVID-19 at the state level. Based on the changes in cumulative incidence, we derived daily incidence (i.e., N new cases each day) for use as a proxy for state-level disease burden during the first wave of the pandemic. During the March 10 to June 8 study period, the daily national incidence ranged from 0 cases (e.g., for the majority of states at study onset) to 13,262 (New York State, April 3). The distribution was positively (right) skewed (Fig. S2), and we chose to use the median incidence over the study period ($N = 147$ cases) as a cutoff for dichotomizing states into those with relatively higher (i.e., median or above) or lower disease (i.e., below median) burden at each observation day. There is no established "best" cutoff for high vs. low state COVID-19 burden, so to confirm that our findings were robust to the choice of cutoff (median), we show sensitivity analyses of our main models using two different criteria—cutoffs at the first quartile ($N = 28$) and third quartile ($N = 458$). While absolute case count drove state responses during the early days of the pandemic, we also considered relative (i.e., per capita) measures of disease burden in sensitivity analyses, dichotomizing states as high or low disease burden based on the median daily incidence per capita ($N = 36$ cases/1 million residents).

Covariates. We present main models without adjustment for individual-level covariates. However, because individual covariates may be related both to differential social/economic experiences during the COVID-19 pandemic and to frequency of alcohol consumption, we additionally show main models with control for these covariates to confirm that the variation in state-level and marginal trends persisted above and beyond the effects on these individual-level characteristics. Time-invariant covariates were gender (Grucza et al., 2018), having children under the age of 18 at home (Wardell et al., 2020), race (categorized as White, Black, Asian, or other), and Hispanic ethnicity (Meyers et al., 2017). Time-varying covariates were respondents' age (Grucza et al., 2018), employment status (Collins, 2016; Frone, 2008), and a dichotomous measure of whether or not they reported avoiding public spaces to avoid disease risk at the time of each survey, as social distancing may be related to frequency of consumption (McPhee et al., 2020). We additionally include two mental health covariates, depression and anxiety, both of which are associated with alcohol consumption (Marmorstein, 2009; McHugh and Weiss, 2019; Smith and Randall, 2012). Both were measured using the Patient Health Questionnaire-4 (PHQ-4) (Kroenke et al., 2009), which consists of ascertaining the frequency of two anxiety items (feeling nervous, anxious, or on edge; being unable to stop or control worrying) and two depression items (little interest or pleasure in doing things; feeling down, depressed, hopeless). Responses are asked how frequently they have been bothered by any of the items over the past two weeks, with scores for each item ranging from 0 ("not at all") to 3 ("nearly every day"). Respondents were coded as having anxiety or depression if they received sum scores at or above 3 for either set of items.

Finally, because individuals' perceived presence of COVID-19 among the network of people they know may influence both stress, coping, and frequency of alcohol consumption, we also included a measure of individuals' perceived personal/familial COVID-19 burden. At each survey, respondents were asked whether they had received a COVID-19 diagnosis, if they thought they had COVID-19, and how many people they knew who they thought might be infected. If they endorsed a positive diagnosis, or a positive belief that they have COVID-19, or a nonzero value for the number of people in their life whom they believe to be infected, they were classified as having a high perceived personal/familial COVID-19 burden; if otherwise, they were classified as low.

Statistical Analysis

We examined marginal trends in number of drinking days during the study period as well as state-level variation in trends. We used survey-weighted multilevel growth models with both a state-level random intercept and random slope for time (to allow for state-level variation in time trends) and a participant-level random intercept to account for nonindependence across multiple observations. Because respondents occasionally moved states during the study duration, individuals were not fully nested in states and random effects for both individuals and states were modeled to allow cross-classification. For all models, we used negative binomial regression to model number of drinking days as discrete count data. Time was measured as count of t days beginning on March 10, 2020, so the model estimates reflect the incident risk ratio (IRR) for count of drinking days given a 1-day increase in calendar time. Effect modification by COVID-19 presence was assessed using interaction between linear time and an indicator variable for whether or not the state had reported the median cumulative incidence of disease cases on that date. Time trends were modeled using model-based marginal predicted count of drinking days from interaction models. Models included a uniform offset of 1. Global Moran's I assessed spatial autocorrelation for the incidence risk ratio of US states and DC. Analyses were performed using SAS 9.4, and figures were produced using R version 4.0.

Among the 7,397 eligible participants with 31,244 observations, outcome information was missing for 43 (0.1%) of observations and covariate information was missing for 3,142 (9.9%) observations. Main models were analyzed using complete case analysis (N = 6,172 (83.4%) unique participants; N = 28,059 (89.8%) observations) due to computational barriers to imputing hierarchical, multilevel data. To explore the possibility of bias due to missingness, we examined distributions predictors of outcome and covariate missingness, and how those varied compared with the complete case sample.

Sensitivity Analyses. As described above, we performed sensitivity analyses with different cut-points to dichotomize states with relatively high or low COVID-19 burdens, including using relative (i.e., per capita) rather than absolute measures.

We performed two other sensitivity analyses. Eligible participants responded to at least one survey of the possible five. To confirm that observed trends were not a spurious function of those who responded only at earlier surveys having meaningfully different drinking patterns than those who responded at only later surveys, we performed a sensitivity analysis restricting the sample to only those who responded to all five surveys (N = 4,874 participants and N = 23,518 observations).

We also examined trends in alcohol consumption frequency in the spring of 2019. In 2019, a sample of the UAS active respondent pool received a single survey administration asking a comparable alcohol measure ("In the last three months, on average, how many days per week have you had any alcohol to drink? [For example, beer, wine, or any drink containing liquor.]") to the one used in the current study. Among those queried, 914 respondents are also represented in our current eligible sample. The survey was administered over the period April 29 through July 1, 2019, with each participant responding once. Trends over time in this subsample in the spring of 2019 (from April 29 to June 8, corresponding to the time period in the current study) were examined to determine the trend in alcohol consumption frequency during a comparable time period one year before.

RESULTS

Table 1 shows demographic characteristics and number of drinking days for respondents according to whether or not a state had a high COVID-19 burden at the time of the survey. For observations during periods of higher state COVID-19 burden, we observed higher average frequencies of alcohol consumption (drinking days = 1.57 vs. 1.43, $p < 0.001$), younger respondents, a higher proportion of respondents with children in the house, a lower proportion of White respondents, and higher proportions of respondents reporting avoiding public spaces, experiencing unemployment, and reporting high perceived personal/familial COVID-19 burdens.

Figure 1 shows the predicted count of drinking days from marginal (top) and interaction (bottom) models without adjustment for individual covariates. Overall, the number of drinking days increased during the study period; at the beginning of the study period, respondents on average reported 1.30 (95% CI: 1.26, 1.34) drinking days. By the end of the study period, respondents on average reported 1.65 (95% CI: 1.41, 1.92) drinking days.

We observed heterogeneity by state-level COVID-19 case burden. At the beginning of the observation period, respondents living in states with higher cumulative incidence of COVID-19 cases had a predicted 1.51 (95% CI: 1.42, 1.59) drinking days per week, whereas those in states with lower COVID-19 presence had a predicted 1.21 (95% CI: 1.17, 1.26) drinking days per week. By the end of the study period, respondents living in states with higher COVID-19 presence had a predicted 1.46 (95% CI: 1.24, 1.71) drinking days per week, whereas those in states with lower COVID-19 presence had a predicted 1.83 (95% CI: 1.54, 2.17) drinking days per

Table 1. Demographic and Outcome Characteristics of Respondents, Stratified by Whether or not State had Median Cumulative Incidence of COVID-19 Cases at the Time of the Survey, March 10, 2020–June 8, 2020

	State had < median COVID-19 cases (N = 8,021 observations)	State had ≥ median COVID-19 cases (N = 20,038 observations)	
Number of drinking days (mean, SD)	1.43 (2.15)	1.57 (2.20)	$p < 0.001$
Male gender	3,373 (42.1%)	8,490 (42.4%)	$p = 0.63$
Age (mean, SD)	52.2 (15.7)	50.8 (16.1)	$p < 0.001$
Children live in the house	2,948 (36.8%)	7,913 (39.5%)	$p < 0.001$
White race	6,595 (82.2%)	15,739 (78.6%)	$p < 0.001$
Hispanic	738 (9.2%)	3,263 (16.3%)	$p < 0.001$
Respondent avoids public spaces	5,215 (65.0%)	17,535 (87.5%)	$p < 0.001$
Respondent has a job	4,572 (57.0%)	10,102 (50.4%)	$p < 0.001$
Respondent has high personal/familial perceived COVID-19 burden	749 (9.3%)	3,862 (19.3%)	$p < 0.001$
Depression PHQ4 ≥ 3	791 (9.9%)	2,427 (12.1%)	$p < 0.001$
Anxiety PHQ4 ≥ 3	1,159 (14.5%)	3,270 (16.3%)	$p < 0.001$

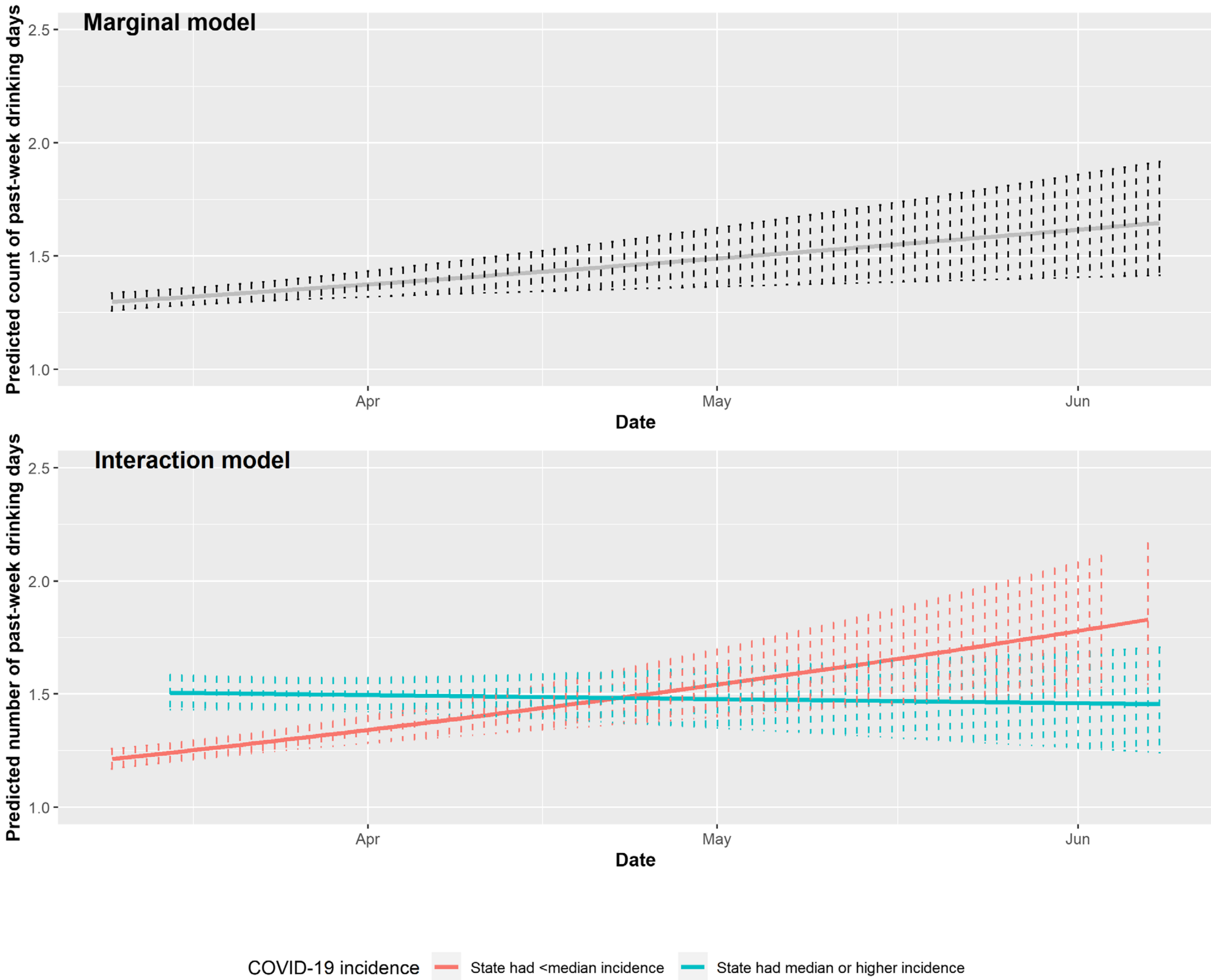

Fig. 1. Predicted count of drinking days over time and state-level COVID-19 presence, March 10, 2020–June 8, 2020; marginal estimates and with interaction by disease burden.

week. Statistical tests for interaction confirmed that slopes over time evidenced differences according to COVID-19 presence ($F = 27.86$, $p < 0.01$). Figure S3 shows the number of states with less than median COVID-19 presence over the study duration, which varied over time. At the beginning of the study, all states reported less than the median cumulative incidence of COVID-19 cases; by the end of the study, 19 states reported below the median.

Table 2 shows the model estimates for both the unadjusted (corresponding to Fig. 1) and adjusted models, including both parameter estimates (i.e., beta estimates and standard errors) and incident risk ratios (IRRs) for count of drinking days over time. Model 1 is the average, marginal change without interaction for COVID-19 presence; on average, the number of drinking days increased between March 10 and June 8, with every day of calendar time associated with a.3% increase in number of drinking days (IRR: 1.003, 95% CI: 1.001, 1.004). Model 2 in Table 2 is the average, marginal change over time with interaction by COVID-19 presence. We observed heterogeneity in trends in alcohol consumption frequency according to state-level COVID-19 presence. States with higher COVID-19 burden had an increased risk of drinking days (IRR: 1.244, 95% CI: 1.163, 1.3330) at baseline (intercept) compared to those with fewer than the median cases. However, though states with a lower caseload evidenced fewer drinking days at baseline, the trends over time increased relative to states with a higher caseload. The average number of drinking days in states with lower caseloads increased by 0.5% (IRR: 1.005, 95% CI: 1.003, 1.007) each day, whereas drinking days in states with higher caseloads remained stable during this time period (IRR: 1.000, 95% CI: 0.998, 1.002). Models 3 and 4 are adjusted for individual-level covariates, and the estimates and interpretation are not meaningfully different than those without covariate adjustment.

In sensitivity analyses, we examined whether this heterogeneity varied according to the threshold at which we dichotomized states into high or low COVID-19 presence. Trends using the first quartile (daily incidence = 28 cases) and third quartile (daily incidence = 458 cases) did not meaningfully

Table 2. Model Parameters and Incident Risk Ratios of Alcohol Consumption Over Time Among Adults in the UAS, March 10, 2020–June 8, 2020; N = 6,712 Unique Participants and N = 28,059 Observations

Predictor	Estimate	Model 1 Time trend only, unadjusted	Model 2 Time trend with interaction, unadjusted	Model 3 Time trend only, adjusted[a]	Model 4 Time trend with interaction, adjusted[a]
Time	B (SE)	0.0027 (0.0009)	0.0046 (0.0010)	0.0021 (0.0009)	0.0039 (0.0010)
	p-value	$p < 0.01$	$p = 0.01$	$p = 0.02$	$p = 0.03$
	IRR (95% CI)	1.003 (1.001, 1.004)	1.005 (1.003, 1.007)	1.002 (1.000, 1.004)	1.004 (1.002, 1.006)
High state-level COVID-19 presence	B (SE)		0.2180 (0.0340)		0.2171 (0.0354)
	p-value		$p < 0.01$		$p < 0.01$
	IRR (95% CI)		1.244 (1.163, 1.330)		1.242 (1.159, 1.332)
Time × high COVID-19 presence	B (SE)		−0.0050 (0.0009)		−0.0047 (0.0010)
	p-value		$p < 0.01$		$p < 0.01$
	IRR (95% CI)		0.995 (0.993, 0.997)		0.995 (0.993, 0.997)
IRR (95% CI), states with low COVID-19 burden			1.005 (1.003, 1.007)		1.004 (1.002, 1.006)
IRR (95% CI) states with high COVID-19 burden			1.000 (0.998, 1.002)		0.999 (0.997, 1.001)

[a]Adjusted for gender, age, race, Hispanic ethnicity, presence of children in the house, current employment status, whether or not respondent currently avoids public spaces to reduce disease risk, anxiety, depression, and perceived personal/familial COVID-19 burden.

impact the estimates (Table S2). We additionally examined whether this heterogeneity was sensitive to relative rates, by using median daily incidence per capita as the threshold for dichotomizing states. Trends using incidence per capita did not evidence different results or interpretation than those using absolute measures (Table S3). Among those who responded to all five surveys (N = 4,874 participants and N = 23,518 observations), trends over time were indistinguishable from the full eligible complete case sample (Table S4).

We examined trends in alcohol consumption frequency among the subsample of respondents who were also queried in 2019 during a similar time period (i.e., from April 29, 2019, to June 8, 2019). We show the unadjusted marginal trends for 2019 in Fig. S4. Trends in alcohol consumption in 2019 during this time period evidenced average increases by day (IRR: 1.025, 95% CI 1.010, 1.040). This incidence rate ratio was higher than the daily incident rate ratio for those same respondents in 2020, suggesting alcohol consumption frequency during the same time period 2020 increased at a slower rate than in the previous year.

Figure 2 shows, for each state, the slope of the increase in drinking days during the study period (from March 10, 2020, through June 8, 2020), with adjustment for individual-level covariates. The color of the line indicates whether the state had greater than or equal to the median number of COVID-19 cases at any point during the study period. These estimates correspond to state random effects from model 4. Table S5 shows the adjusted state-level estimates that correspond to Fig. 2, as well as the range of respondents per survey and total number of observations per state. Figure S5 shows a map with the geographic distribution of IRRs by state, corresponding to both Fig. 2 and Table S5. The majority of states (N = 35, including D.C.) did not evidence changes in number of drinking days throughout the study period. Eight states (Kentucky [IRR = 0.991], Arkansas [IRR = 0.992], Iowa [IRR = 0.992], West Virginia [IRR = 0.992], New Hampshire [IRR = 0.994, Indiana [IRR = 0.995], Virginia [IRR = 0.996], and Tennessee [IRR = 0.997] evidenced significant decreases in trends during this time period; all of these states experienced at or above the median cumulative incidence of COVID-19 during the study. Eight states (Alaska [IRR = 1.014], Maine [IRR = 1.011], Nevada [IRR = 1.009], Missouri [IRR = 1.006], Colorado [IRR = 1.007], Oregon [IRR = 1.006], Washington [IRR = 1.004], and Georgia [IRR = 1.003]) evidenced increases in trends during this time period. Among these, four (West Virginia, Alaska, Maine, and Oregon) experienced less than the median cumulative incidence of COVID-19 cases, while the remaining twelve experienced at or above the median. Incidence risk ratio was not spatially autocorrelated (I = 0.03). To confirm that there was no further underlying geographic patterning, we tested a final model with interaction between time and US region based on US census criteria (US Department of Commerce, n.d.); tests of interaction between time and US region showed no meaningful heterogeneity (F = 0.81, p = 0.59).

Finally, regarding missing data, we examined distributions of covariates comparing complete cases to those with missing outcome or missing control variables. Outcome missingness was unrelated state COVID-19 burden, though it was associated with age and race (Table S6). The covariate distribution of the complete case sample was different than that of the eligible sample (i.e., those excluded were on average younger, less likely to be White, more likely to have children in the house, more likely to be depressed or anxious), though inclusion of covariates in the main models did not change results,

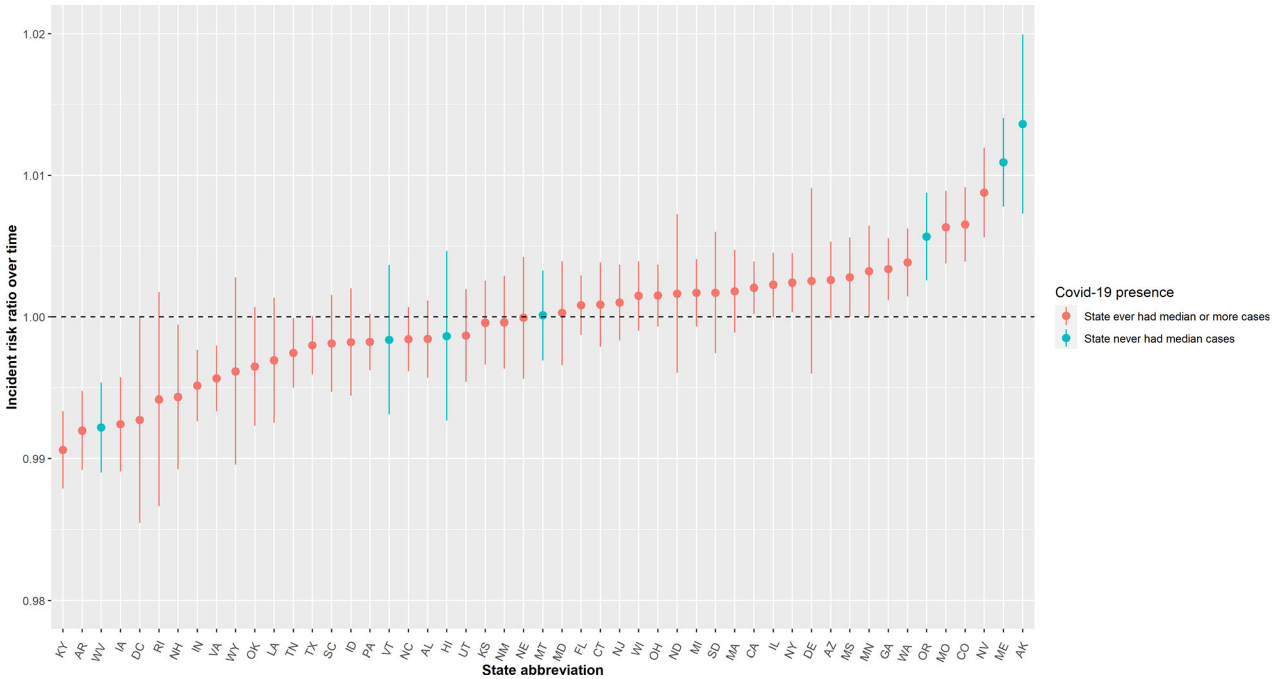

Fig. 2. Incident rate ratio for the count of drinking days as a function of time, from March 10, 2020 to June 8, 2020, by US state, ranked by magnitude of slope.

suggesting that bias from missingness was not a contributor to the overall observed effects.

DISCUSSION

In this study, we analyzed trends in alcohol consumption frequency during the first wave of the COVID-19 pandemic in the United States. The number of drinking days increased between March 15 and June 8, 2020, with a model-based 0.3% increased risk of increase in drinking days each day. We observed heterogeneity in this trend by both COVID-19 burden. Namely, while individuals living in states with higher COVID-19 burdens reported a higher average number of drinking days at the beginning of the epidemic, there was no evidence of further increases as the epidemic progressed; however, respondents living in states with lower COVID-19 burdens increased the number of drinking days throughout the first wave of the pandemic. These findings were robust to multiple specifications of COVID-19 burden, whether it was measured in terms of absolute or per capita incidence.

Regarding state-level heterogeneity, we observed that these trends differed by state, with residents in eight states evidencing decreases in the number of drinking days and residents in eight states evidencing increases. Among the states with increases, three (Alaska, Maine, Oregon) experienced consistently lower COVID-19 presence than the national median cumulative incidence. The majority of US states disallowed on-premise alcohol consumption at some point during the pandemic, though they varied in when they re-opened drinking establishments (Alcohol Policy Information System, 2020). Alaska re-opened bars and restaurants with restrictions in April 2020, Oregon re-opened bars and restaurants in May 2020, and Maine re-opened bars and restaurants in June; all three allowed curb-side and take-out alcohol purchases during the pandemic. However, overall, the majority of states did not evidence meaningful changes in trends in drinking days. The limited heterogeneity in trends suggests that the observed trends were largely invariant to other state-level features, and we additionally observed no apparent variation in trends according to geographic region.

Though literature regarding alcohol consumption during this time period suggests that it is overall increasing, our findings suggest that the general increases mask meaningful heterogeneity according to state disease burden. The increases in alcohol consumption were exclusively among those living in states with a relatively low disease burden, whereas those living in states with a relatively high burden did not increase alcohol consumption frequency. In fact, compared with trends in alcohol consumption frequency in 2019, trends in 2020 were much less pronounced, suggesting that residents of states with higher COVID-19 burden consumed alcohol less frequently than in the same season in the previous year. Limitations of the 2019 data are that respondents were queried only once throughout the spring; therefore, these analyses are not strictly comparable. They do, however, suggest that trends in alcohol consumption frequency during the first wave of the pandemic are aberrant from what might be expected in an otherwise normal year during this season.

The mechanisms determining these trends remain unknown. Respondents living in states with higher disease burden could be less willing to leave their homes to purchase alcohol because of fear of disease risk, or during this time period these respondents may have experienced more supply-chain disruptions during COVID-19 (Hobbs, 2020). Enforcement of policies, including stay-at-home orders, has not been uniform; states with a higher COVID-19 burden may have both implemented more stringent policies and enforced them more strictly, which may have contributed to variation in alcohol consumption (Bergquist et al., 2020; Cain, 2020; Capano et al., 2020; Jennings and Perez, 2020). Alternatively, respondents living in states experiencing a high COVID-19 burden early in the pandemic may have increased drinking days before the survey onset, and then remained at the increased levels as respondents in states with relatively lower burdens eventually "caught up" to these higher rates. As the pandemic progresses, further inquiry into the patterning of alcohol behaviors across axes of state-level differences may shed light on the contextual drivers of these health behaviors.

While we had hypothesized that respondents in states with higher COVID-19 burden would evidence higher rates of increase in alcohol consumption, due primarily to pathways related to stress and coping, we did not find support for this hypothesis in our findings. The role of stress and coping in relation to state-level features like policies and state-level pandemic response is unknown, and these mechanisms may still play a large role in the increases among states with relatively lower COVID-19 burdens. However, these findings point to the importance of state-level, rather than individual-level, mechanisms that facilitate increases in alcohol consumption.

State-level variation in alcohol policy impacts when, where, and under what circumstances individuals can purchase and consume alcohol (Naimi et al., 2014). These include permissive policies like drink special laws as well as alcohol taxes and state-mandated opening or closing times. These contextual features are central drivers of alcohol consumption and alcohol-related harms, including heavy drinking, impaired driving, and injury (Naimi et al., 2014, 2018; Nelson and McNall, 2016; Xuan et al., 2015). Aside from being a mediator of alcohol policy's impact on consumption, alcohol availability—including alcohol outlet density—is positively associated with increases in alcohol consumption (Campbell et al., 2009). Limiting outlet density is regarded as among the most effective policies for reducing adult and youth binge drinking (Campbell et al., 2009; Nelson et al., 2013). New COVID-19 policy changes that increase alcohol availability—including legalizing take-out alcoholic beverages and alcohol delivery—are likely contributors to the increased alcohol consumption frequency evidenced in this study. While there was limited evidence of geographic patterning of drinking days during the COVID-19 pandemic to link state-level variation to clear geographic or policy differences, we expect that as the pandemic progresses we may see long-term impacts in the states with the most permissive policy changes.

In addition to variation in state-level alcohol climate, major economic downturns—for example, the Great Recession of 2008—and mass traumatic events, like natural disasters, are sources of stress and despair that can increase alcohol consumption and exacerbate problematic consumption patterns (Bor et al., 2013; Cerdá et al., 2011). However, certain consumption patterns may be more sensitive to these events than others; for example, in the case of the Great Recession, average alcohol consumption declined (presumably due to decreased flexible resources to spend on alcohol use) but the frequency of binge episodes—that is, drinking multiple alcoholic beverages in a short period of time—increased (Bor et al., 2013). Problematic alcohol consumption after mass traumas can also develop in the years after the trauma, rather during the event or in the immediate aftermath (North et al., 2011); therefore, it is vital to continue to closely monitor these trends as the COVID-19 pandemic continues and ultimately resolves.

Among the limitations in our study were limited alcohol measures. Our primary outcome—the number of drinking days in the past week—is an incomplete measure of overall consumption, as the volume consumed on drinking days is critical information. While more quantity-based measures later became available in the UAS, these were not introduced until later surveys that corresponded to the peak of the pandemic in many states. However, the number of drinking days has been shown to be highly correlated with quantity-based measures of alcohol consumption like volume of alcohol consumed and average quantity consumed in a typical drinking day (Leigh, 2000); further, frequency of alcohol consumption itself is an important determinant of health which has been implicated in mortality risk, even among those who consume only one or two beverages per drinking occasion (Hartz et al., 2017, 2018).

We use complete case analysis to examine these trends, and approximately 10% of our sample were missing covariate information. The patterning of missing suggests that those missing data had different distributions of individual covariates, which may have impacted nonresponse. However, given that outcome missingness was unrelated to COVID-19 burden and that main analyses were invariant to covariate control, we feel reassured that selective missing was unlikely to produce biases in our estimated trends and selection was not a major contributor to our findings and interpretation.

Finally, we did not have information about preexisting alcohol consumption disorders among this sample. Drinking after disasters predominantly occurs among those who already have preexisting alcohol conditions, and these disasters exacerbate their symptoms (North et al., 2011). However, state-level differences in underlying alcohol consumption disorders are unlikely to contribute to the observed trends in the study, as they are unlikely to be related to state-level COVID-19 burden.

CONCLUSION

The COVID-19 pandemic in the United States resulted in mass disruption, including via public health measures to curb the spread of the virus. We find that during the first wave of the pandemic in the United States, the average number of drinking days increased, and these increases were primarily among individuals living in states with relatively lower COVID-19 burden. Health behaviors, including alcohol consumption, are sensitive to contextual and psychosocial influences, and this study underscores the necessity of screening not just for COVID-19 symptoms, but for risky health behaviors as well. Alcohol consumption is a normalized health behavior, but nevertheless is a major contributor to morbidity and mortality, and care providers and policy-makers ought to continue to remain mindful that focusing resources on the current epidemic must not come at the expense of screening and management of other health risks.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Fig. S1 UAS surveys and dates submitted among study sample, March 10 to June 8, 2020.

Fig. S2 Histogram of cumulative incidence of state COVID-19 cases between March 10 and June 8, 2020.

Fig. S3 Number of states with less than the median cumulative incidence of COVID-19 cases, over time, from March 10 to June 8, 2020.

Fig. S4 Predicted count of drinking days over time among 2019 UAS respondents, April 29, 2019–June 8, 2019; marginal estimates.

Fig. S5 Geographic distribution of incidence risk ratio by US states and DC (n = 51).

Table S1 UAS COVID-19 surveys and responses rates.

Table S2 Incident risk ratios for alcohol consumption over time among adults in the UAS, March 10 2020–June 8, 2020 using alternative cut-points for dichotomizing high and low COVID-19 burden, N = 28,059 observations.

Table S3 Incident risk ratios for alcohol consumption over time among adults in the UAS, March 10 2020–June 8, 2020 using per capita incidence measures for high and low COVID-19 burden, N = 28,059 observations.

Table S4 Incident risk ratios for alcohol consumption over time among adults in the UAS, March 10 2020–June 8, 2020, only among respondents who participated in all 5 waves, N = 4,874 participants and N = 23,518 observations.

Table S5 Incident risk ratios of alcohol consumption over time among adults in the UAS, March 10, 2020–June 8, 2020, by state, adjusted for individual covariates.

Table S6 Predictors of missing outcome data and predictors of any item missingness in eligible sample.