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A Latent Class Analysis of Mental Health Severity and Alcohol Consumption: Associations with COVID-19-Related Quarantining, Isolation, Suicidal Ideations, and Physical Activity

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Abstract

The present study examined latent class cluster group patterns based on measures of depression and anxiety symptom severity and alcohol consumption during the COVID-19 pandemic. Hypothesized correlates with latent class cluster groups including quarantining, self-isolation, suicidal ideations, sitting hours per day, and physical activity (vigorous intensity exercise in minutes per week) were examined. The delimited participant sample consisted of 606 university young adults 18 to 25 years of age ($M = 21.24 \pm 1.62$). Latent cluster analysis (LCA) modeled patterns of depression and anxiety symptom severity and alcohol consumption during the COVID-19 pandemic. Between group analysis and multinomial logistic regression analysis were used to examine relationships between latent class clusters and correlates including quarantining, self-isolation, suicidal ideations, sitting hours per day, and physical activity (vigorous intensity exercise in minutes per week). LCA results showed that six latent cluster groups provided optimal model-to-date fit based on mental health symptom severity and alcohol consumption ($L^2 = 56.31$, $BIC = 5012.79$, $AIC = 4849.74$, and the bootstrap L^2 p-value $= .88$; Entropy $R^2 = .89$). Identified latent class clusters were as follows: cluster one = moderate anxiety and depression severity and moderate alcohol consumption ($n = 156$; 25.7%); cluster two = high mental health severity and alcohol consumption ($n = 133$; 21.9%); cluster three = low mental health symptoms and moderate alcohol consumption ($n = 105$; 17.3%); cluster four = lowest mental health severity and alcohol consumption ($n = 95$; 15.7%); cluster five = moderate depression severity, low anxiety severity, and low alcohol consumptions ($n = 74$; 12.2%); and cluster six = moderate anxiety severity, low depression severity, and low alcohol consumption ($n = 43$; 7.1%). Multinomial logistic regression analysis results found that quarantining, self-isolation, suicidal ideations, sedentary behavior, and physical activity were differentially associated with cluster group membership. Findings from this study demonstrate associations between COVID-19 public health restrictions, suicidal ideations, and declines in mental health and increases in alcohol consumption among young adult university students.

Keywords COVID-19 · Mental health · Depression · Anxiety · Alcohol use · Quarantining · Suicidality · Physical activity

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The first case of the novel severe acute respiratory syndrome coronavirus 2 virus (SARS-CoV-2) that causes the coronavirus disease 2019 (COVID-19) was reported in the USA in January 2020 (Stokes et al., 2020). By March 2020, in an effort to limit the spread of the virus and prevent overwhelming the US healthcare system, public health measures such as stay at home orders and social distancing were implemented broadly (Moreland et al., 2020). Beginning in September 2020, approximately 8 months after the implementation of initial public health measures, the USA experienced a second surge of cases (Reese et al., 2020). At this time, the USA was averaging approximately 42,000 cases per week (Reese et al., 2020).

As of October 2021, over 43 million people have tested positive for COVID-19, and there have been over 690,000 deaths in the USA, alone (Centers for Disease Control & Prevention, 2021). Due to both public health measures (e.g., quarantining and social distancing) and accompanying isolation and loneliness, the COVID-19 pandemic has had a worldwide impact on mental health and wellness (Banerjee & Rai, 2020; Hwang et al., 2020; Loades et al., 2020). Recent studies have also made connections between the COVID-19 pandemic, related public health quarantining, stay-at-home orders and social distancing and increased rates of substance misuse including alcohol misuse (Coakley, et al., 2021a; Fernández et al., 2020; Sallie et al., 2020), as well as decreases in physical activity (Jiménez-Pavón et al., 2020; Coakley, 2021a, b, c; Zhang et al., 2009).

Mental Health, Alcohol Use, and COVID-19 Pandemic

In the USA, the Centers for Disease Control and Prevention (CDC) reported in June 2020 that 31% of adults reported symptoms of depression and anxiety, 26% reported a trauma/stress-related disorder, and 11% had thoughts of suicide (Czeisler et al., 2020). Among young adults, 18 to 24 years of age, specifically, 46% experienced COVID-19-related trauma- and stressor-related disorder symptoms, and 74.9% reported one or more adverse mental health or behavioral by June 2020; nearly, 25% started or increased substance use to cope with pandemic-related stress (Czeisler et al., 2020). Furthermore, mental distress among young people in the face of COVID-19 may be exacerbated by lack of coping mechanisms and environmental factors including loss of income, domestic violence, and inability to access the internet or maintain social connectivity (Harnish et al., 2000; Shanahan et al., 2020). University students may be particularly at-risk due to remote learning and rapid adjustment to COVID-19-related restrictions (Copeland et al., 2021).

The relationship between mental health severity and substance use is well-documented (Hunt et al., 2020). Contemporary studies on the COVID-19 have identified a sobering association between public health quarantining, stay-at-home orders and social distancing, mental health symptom development, and increased rates of alcohol consumption and misuse (Czeisler et al., 2020; Fernández et al., 2020; Jiménez-Pavón et al., 2020). For instance, the CDC has reported a 25% increase alcohol and drug use associated with stay-at-home orders and quarantining during COVID-19 (Czeisler et al., 2020). Rodriguez et al. (2020) specifically identified that alcohol sales increased by 55% in March 2020 compared to the year prior. Among young adults specifically, alcohol consumption has increased more among those with prior symptoms of depression and anxiety, and poor stress reaction, when compared to those who identified as social drinkers (Dumas et al., 2020). There is some evidence to indicate that alcohol consumption and misuse among young adults, particularly college students, is likely to increase

as the COVID-19 pandemic continues (Charles et al., 2021). This is largely attributed to stressors such as social isolation, public health quarantines, and financial hardship that will continue as the pandemic maintains its hold in the USA and globally. Limited research is published examining the relationship between mental health severity and alcohol consumption among young adults in response to COVID-19 pandemic, and even less has examined the connection to physical activity.

Health promotion behavioral strategies and interventions are needed to strengthen resiliency and positive mental health outcomes of youth and young adults. Physical activity has been overlooked as a lifestyle habit and ad hoc therapeutic intervention approach to preserve mental health. Recent research has, however, indicated a number of interacting neuro-biological, psychological, and social mechanisms thought to be at play among those engaging in physical exercise, including changes to the structure and function of the brain and changes to feelings of competence and confidence (Biddle et al., 2019, 2021). Individuals who exercise regularly are less likely to be diagnosed with depression or anxiety (Goodwin & Morrissey, 2003) and display reductions in alcohol consumption (Lardier et al., 2021). In addition, increased physical activity has been correlated with lower rates of suicidal ideations among both adolescents and older adults (Vancampfort et al., 2017).

Contemporary research has found that those who met physical activity (PA) guidelines (≥ 150 min/week or ≥ 75 min/week of moderate or vigorous intensity aerobic exercise, respectively) reported a nearly 40% reduction in poor mental health (Fluetsch et al., 2019). Individuals who exercise regularly are more likely to have positive self-esteem, increased sense of well-being, and a reduction of stress and anxiety (Khosravi et al., 2019). Similarly, physical activity is inversely linked with alcohol use and the number of standard drinks consumed per day (Jensen et al., 2019). Unfortunately, evidence has demonstrated a high prevalence of sedentary behavior among university students, and an overall increase in daily sitting time of 28% since the beginning of the COVID-19 pandemic (Kaur et al., 2020). Increases in sedentary behavior may be partially due to restrictions in accessing places of exercise, such as gyms and park due to the COVID-19 pandemic (Hunt et al., 2020). Nonetheless, there is evidence to support that increases in sedentary behavior are associated with anxiety and stress, depression (Kaur et al., 2020; Qi et al., 2020), and alcohol misuse (Boschuetz et al., 2020; Dumas et al., 2020).

Studies exploring mental health symptom severity and alcohol consumption during the COVID-19 pandemic among college-age young adults are critical to develop effective prevention-interventions. The distribution and contributing factors related to increased mental health symptom severity and alcohol consumption during the COVID-19 pandemic have relevance to prevention and intervention programming in adapting and meeting the complex needs of college-age young adults on and off university campus. In addition, protective factors such as exercise are under-explored as approaches to existing prevention and intervention programs, as well as clinical programming (Lardier et al., 2021).

Methodologies such as person-centered or latent class analyses (LCA) can help to statistically uncover subpopulations with distinct combinations of mental health symptoms and alcohol consumption. While studies have used LCA to examine and uncover subpopulations with distinct combinations of mental health symptoms and alcohol consumption (e.g., Edwards et al., 2020; Nelon et al., 2019), expansion of these analyses can help differentiate mental health symptom severity and alcohol consumption between subgroups to further inform prevention-intervention and clinical programming. Therefore, the purpose of this study was to examine the associations between latent class cluster groups, drawn from LCA, of mental health symptom severity and alcohol consumption during the COVID-19 pandemic and hypothesized correlates such as quarantining, self-isolation, suicidal

ideations, sitting hours per day, and physical activity (vigorous intensity exercise in minutes per week) among young adult university students.

Methods

Recruitment

Undergraduate students 18–25 years of age at a large public university in the southwest region of the USA were recruited for the study. Participants were enrolled at the university in spring 2020, at the start of the COVID-19 pandemic, and in fall 2020, during a second wave of cases. Four thousand students were contacted via email during a 2-week period in October–November 2020. Selection was random to create a representative sample of the university population by gender, race/ethnicity, and campus enrollment. At the end of the survey, participants could provide their email address to receive one of twenty $50 gift card incentives. Consent was obtained when survey was started; no consent signature was required. The study was approved by the University's Institutional Review Board.

Data Collection

Data were collected via Opinio, an online survey tool approved for research. The survey included initial screening questions assessing inclusion criteria: age (18–25 years) and student status (current student and student in spring 2020).

Latent Class Cluster Variables

This study focused on multiple variables to create latent class cluster groups. *Anxiety symptom severity* was measured using the seven-item *Generalized Anxiety Disorder Scale-7* (GAD-7) (Spitzer et al., 2006), which is a validated measure of anxiety symptoms in the past 2 weeks (Spitzer et al., 2006). Responses to the seven GAD-7 questions include 0 (not at all), 1 (several days), 2 (more than half the days), and 3 (nearly every day). The GAD-7 was scored according to standard guidelines, with higher scores reflecting greater anxiety symptom severity (Spitzer et al., 2006). Categories of anxiety symptoms are identified as low anxiety (0–4), mild anxiety (5–9), moderate anxiety (10–14), and severe anxiety (≥ 15) (Spitzer et al., 2006). Prior research has displayed adequate internal validity and reliability with Cronbach's alphas ranging from 0.85 to 0.91 (Johnson et al., 2019; Tiirikainen et al., 2019). In primary care settings, the GAD-7 has been found to be reliable and valid for adults, with a sensitivity of 89% and specificity of 82% at a cut-point of 10 points in clinical populations (Kroenke et al., 2007; Spitzer et al., 2006). The GAD-7 is moderately good at screening other common anxiety disorders such as panic disorder (sensitivity 74%, specificity 81%) and social anxiety disorder (sensitivity 72%, specificity 80%) (Sapra et al., 2020). For the present study, raw GAD-7 scores ranged from 0 to 21 ($M = 10.43 \pm 6.11$; Cronbach's $\alpha = 0.92$).

 Depression symptom severity was measured using the *Patient Health Questionnaire-9* (PHQ-9), which is a validated measure of depression severity over the past 2 weeks (Kroenke et al., 2001). Responses to the nine PHQ-9 question include 0 (not at all), 1 (several days), 2 (more than half the days), and 3 (nearly every day). The PHQ-9 was scored according to standard guidelines, with higher scores reflecting

greater depression severity (Kroenke et al., 2001). Categories of depression severity are identified as mild (5–9), moderate (10–14), moderately severe (15–19), or severe (≥ 20) (Kroenke et al., 2001). Prior research has displayed adequate validity and reliability with Cronbach's alphas ranging from 0.84 to 0.95 (El-Den et al., 2018). The PHQ-9 has also been shown to have 88% and a specificity of 88% for detecting major depressive disorders (El-Den et al., 2018). Raw PHQ-9 scores ranged from 0 to 27 ($M = 10.04 \pm 5.29$; Cronbach's $\alpha = 0.90$).

Alcohol consumption (average number of standard drinks consumed in the past 30 days) was measured using two questions from the *COVID-19 Community Response Survey Module*, a widely used survey tool in the USA to assess the impact of the COVID-19 pandemic (Johns Hopkins Bloomberg School of Public Health, 2020). The two questions assessed the number of days out of the past 30 that participants drank one or more alcoholic beverages, and on days participants drank, the number of standard drinks usually consumed. Responses were utilized to calculate the number of standard drinks consumed in the past 30 days (number of days multiplied by number of standard drinks consumed on drinking days). Raw alcohol consumption scores ranged from 0 to 450 ($M = 23.35 \pm 43.74$).

Predictors of Latent Class Groups

Self-isolation since the start of the COVID-19 pandemic and *quarantining* since the start of the COVID-19 pandemic were collected using two dichotomous response (*yes* = 1 and *no* = 0) questions. Participants also indicated if they had practiced social distancing since the start of the COVID-19 pandemic (*yes* = 1 and *no* = 0). Approximately, 46.2% of participants were self-isolated, and 52.0% of participants were quarantined since the start of the COVID-19 pandemic.

Suicidal ideation was examined using a single question from the *National Survey on Drug Use and Health* (Substance Abuse & Mental Health Services Administration, 2020) that asked participants whether, during the past month, they had serious thoughts about ending their life. Data were collected using a dichotomous response option of either yes (1) or no (0), with 10.3% of participants indicating that during the past month, they had thoughts about ending their life.

Current *vigorous intensity exercise* in minutes per week was calculated using the product of two questions from the *International Physical Activity Questionnaire (IPAQ)*, which is validated for young adults (Craig et al., 2003). These questions asked participants the number of days they engaged in vigorous physical activities during the last 7 days (item: During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, digging, aerobics, or fast bicycling?) and to estimate their vigorous physical activities in minutes per day (item: How much time did you usually spend doing vigorous physical activities on one of those days [in minutes per day]?). *Vigorous intensity exercise* is via Moderate-to-Vigorous Physical Activity (MVPA) guidelines as ≥ 75–150 min/week (Bull et al., 2020). Participants engaged in, on average, 145.90 ± 339.80 min per week of *vigorous intensity exercise* (range = 0 min per week to 3000 min per week).

The number of sitting hours per day was calculated using a single question from the *IPAQ* (Craig et al., 2003), which asked participants to estimate the amount of time they currently spend sitting on a typical week day (in hours per day). Participants engaged in 8.54 ± 4.38 h of sitting per day (range = 0 to 24 h).

Covariates

Several *sociodemographic covariates* were included in analyses (Table 1). Covariates were included in LCA and multinomial logistic regression models and retained based on performance in these models. These covariates included *age*, *race/ethnicity*, *gender*, *sexual* or *affectional orientation*, *academic standing at the university*, and *Federal Pell grant status*.[1] *Age* was measured in years. *Race-ethnicity* was collected using seven categorical response options that asked participants their race-ethnicity, including American Indian or Alaska Native (1), Asian (2), Black or African American (3), Hispanic/Latinx/Spanish (4), Native Hawaiian/Pacific Islander (5), and White non-Hispanic (6), or other option not indicated (7). Participants were given the option to choose multiple options. *Gender* was collected using five categorical response options including female (1), male (2), transgender (3), gender fluid (4), or other option not indicated (5). *Sexual or affectional orientation* was collected using nine categorical response options including asexual (1), bisexual (2), gay (3), lesbian (4), pansexual (5), queer (6), questioning (7), and straight/heterosexual (8), or other option not indicated (9). *Academic standing at the university* was collected using four categorical response options that included: freshman (1), sophomore (2), junior (3), and senior (4). Last, responses regarding the use of *Federal Pell grants* were collected dichotomously (yes = 1, no = 0). Participants could also select "Not sure."

Data Analysis

Complete responses to survey questions were not required; however, only participants who answered questions on alcohol consumption were included in data analyses. Since responses were not required, some demographic data were missing (1–4 responses depending on question), presenting as a small limitation in interpretability. Among the delimited sample used in this study ($n = 606$), there were no missing data among main analytic variables, and therefore, no imputation or deletion techniques were used during subsequent analyses.

Statistical power and sample size requirements are understudied in LCA, but generally not a concern (Tein et al., 2013). As a probabilistic or model-based technique, and variant of traditional cluster analysis, simulation studies support that minimal power (0.70 to 0.80) is needed to correctly determine the number of classes (Tein et al., 2013). Therefore, subsequent power analyses were calculated for multinomial logistic regression.

Given that multinomial logistic regression is an extension of binary logistic regression (De Jong et al., 2019; Pampel, 2000), power estimates for this study were obtained using a two-tailed simple logistic regression formula in G*Power (Faul et al., 2007, 2009), resulting in conservative power estimates. To achieve 0.80 power based on an expected odds or relative risk ratio (*RR*) of 2.00, inclusion of a minimum of three covariates with moderate associations (0.50) to latent class cluster groups with a value equal to 0.125, and 0.05 error, a sample of 566 participants was needed, with power estimates ranging from 0.70 ($n = 400$; odds ratio = 1.30) to 0.95 ($n = 900$; odds ratio = 2.35). While multinomial logistic regression does not necessitate a specific sample size (De Jong et al., 2019), power analyses

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[1] Federal Pell Grants in the USA are awarded only to undergraduate students who display exceptional financial need and have not earned a bachelor's, graduate, or professional degree (see for more information, Federal Pell Grants | Federal Student Aid). It was used in this study as a proxy for lower socioeconomic status.

Table 1 Sociodemographic variables for sample between latent cluster groups

Variable	Cluster 1[b]		Cluster 2[b]		Cluster 3[b]		Cluster 4[b]		Cluster 5[b]		Cluster 6[b]		Total (N=606)		χ^2	df	p-value
	n	%	n	%	n	%	n	%	n	%	n	%	n	%			
Age (in years)[a]															3.27	5	.65
18–20	47	30.1	38	28.8	27	25.7	23	24.2	24	32.9	9	20.9	168	27.8			
21–25	109	69.9	94	71.2	78	74.3	72	75.8	49	67.1	34	79.1	436	72.2			
Gender															25.69	10	.004
Male	47	30.1	35	26.3	39	37.9	48	50.5	27	37.0	14	32.6	210	34.8			
Female	98	62.8	90	67.7	63	61.2	47	49.5	43	58.9	28	65.1	369	61.2			
Transgender	11	7.1	8	6.0	1	1.0	0	0.0	3	4.1	1	2.3	24	4.0			
Race/ethnicity															34.26	25	.102
American Indian	6	3.8	7	5.3	5	4.8	4	4.2	1	1.4	3	7.0	26	4.3			
Asian	7	4.5	10	7.5	8	7.7	14	14.7	1	1.4	1	2.3	41	6.8			
Hispanic/Latino/Spanish	44	28.2	40	30.1	39	37.5	26	27.4	31	41.9	14	32.6	194	32.1			
White non-Hispanic	57	36.5	51	38.3	27	26.0	30	31.6	19	25.7	15	34.9	199	32.9			
More than one race/ethnicity	39	25.0	23	17.3	24	23.1	21	22.1	22	29.7	10	23.3	139	23.0			
Sexual or affectional orientation															66.94	20	<.001
Heterosexual	94	60.3	71	53.8	78	75.0	83	87.4	49	67.1	34	79.1	409	67.8			
Gay, lesbian, queer	9	5.8	15	11.4	9	8.7	7	7.4	6	8.2	2	4.7	48	8.0			
Bisexual	32	20.5	23	17.4	9	8.7	1	1.1	6	8.2	4	9.3	75	12.4			
Asexual	5	3.2	2	1.5	5	4.8	3	3.2	6	8.2	0	0.0	21	3.5			
Other/questioning	16	10.3	21	15.9	3	2.9	1	1.1	6	8.2	3	7.0	50	8.3			
Academic standing at the university															30.78	25	.19
Freshman	1	0.6	4	3.0	0	0.0	1	1.1%	2	2.7	0	0.0	8	1.3			
Sophomore	26	16.7	35	26.3	21	20.0	13	13.7	18	24.3	7	16.3	120	19.8			
Junior	53	34.0	31	23.3	29	27.6	31	32.6	15	20.3	10	23.3	169	27.9			

Table 1 (continued)

Variable	Cluster 1[b]		Cluster 2[b]		Cluster 3[b]		Cluster 4[b]		Cluster 5[b]		Cluster 6[b]		Total (N=606)		χ2	df	p-value
	n	%	n	%	n	%	n	%	n	%	n	%	n	%			
Senior	75	48.1	61	45.9	55	52.4	50	52.6	39	52.7	25	58.1	305	50.3			
Federal Pell grant recipients															24.23	15	.08
No	63	40.4	54	40.6	47	44.8	52	54.7	29	39.2	24	55.8	269	44.4			
Yes	93	59.6	79	59.4	57	54.3	43	45.3	44	59.5	19	44.2	335	55.3			

[a]Mean age=21.24±1.62. [b]Cluster group labels are as follows: cluster 1=moderate anxiety and depression severity and moderate alcohol consumption (n=156; 25.7%); cluster 2=high mental health severity and alcohol consumption (n=133; 21.9%); cluster 3=low mental health symptoms and moderate alcohol consumption (n=105; 17.3%); cluster 4=lowest mental health severity and alcohol consumption (n=95; 15.7%); cluster 5=moderate depression severity, low anxiety severity, and low alcohol consumption (n=74; 12.2%); and cluster 6=moderate anxiety severity, low depression severity, and low alcohol consumption (n=43; 7.1%)

Table 2 Comparison of fit statistics for latent class analysis models conducted among depression and anxiety severity and 30-day alcohol consumption ($N=606$)

	LL	BIC(LL)	AIC(LL)	Npar	L^2	df	Bootstrap p-value	Class.Err	Entropy R^2
1-Cluster	− 3241.44	6559.77	6506.89	12	1763.46	227	< .001	0.00	.40
2-Cluster	− 2714.36	5537.64	5462.72	17	709.29	222	< .001	0.00	.53
3-Cluster	− 2546.82	5234.59	5137.64	22	374.21	217	< .001	0.00	.55
4-Cluster	− 2433.20	5039.40	4920.41	27	146.98	212	< .001	0.00	.60
5-Cluster	− 2408.34	5021.70	4880.68	32	97.25	207	.05	0.06	.83
6-Cluster	**− 2387.87**	**5012.79**	**4849.74**	**37**	**56.31**	**202**	**.88**	**0.08**	**.89**
7-Cluter	− 2385.26	5039.61	4854.52	42	51.09	197	.90	0.12	.83
8-Cluster	− 2383.13	5067.39	4860.27	47	46.84	192	.66	0.12	.83
9-Cluster	− 2382.85	5098.85	4869.70	52	46.26	187	.91	0.16	.80
10-Cluster	− 2381.44	5128.07	4876.88	57	43.45	182	.92	0.17	.75

Bold indicates latent class group model chosen for subsequent analysis. *LL* Log-likelihood, *BIC* Bayesian information criterion, *AIC* Akaike information criterion, *Npar* number of parameters, L^2 likelihood ratio chi-squared statistic, *df* degrees of freedom, *Class. Err*. classification error

indicate that this study was adequately powered based on the current delimited sample ($N=606$) to identify appropriate *RR* in multinomial logistic regression models.

Following analyses of descriptive statistics, latent class analysis (LCA) was used to identify distinct subgroups based on measures of anxiety symptom severity (GAD-7), depression symptom severity (PHQ-9), and alcohol consumption. LCA identifies unobserved subgroupings based on specific indicators. LCA modeling with maximum likelihood (ML) estimations was conducted using Latent Gold 5.1 (Vermunt & Magidson, 2013). LCA using ML estimation is appropriate to examine responses on a set of categorically measured (Collins & Lanza, 2009; Vermunt & Magidson, 2013). LCA is a person-entered analysis that is methodologically stronger and allows the researcher to categorize and uncover participation within subgroups and generate outcomes that align theory and how groups of individuals function relative to others within the same population (Vermunt & Magidson, 2013). Ten cluster groups were modeled, and indices were transformed into quintiles so that data were standardized and maintained ordinal response scales for the purpose of latent class modeling (Vermunt & Magidson, 2013).

Model fit was assessed for each of the ten latent class cluster models to determine the most parsimonious and best fitting cluster model to the sample data. Model fit was also used to assess the latent class cluster model that captured the largest amount of total association between observed indicators (see Table 2). The likelihood ratio chi-squared statistic (L^2), degrees of freedom (*df*), number of parameters (*Npar*), Bayesian Information Criterion (BIC), Akaike Information Criterion (AIC), and Entropy R^2 were used as comparative indicators to assess model fit (Vermunt & Magidson, 2013). The bootstrap difference in log-likelihood value (*-2LL*-difference statistic) was also used to assess model fit (Vermunt & Magidson, 2013).

L^2 and the associated *df*, as well as a larger *Npar*, and significant bootstrap *p*-value, indicate poor model-to-data fit, or more highly negative than maximum precision can indicate, rendering values meaningless (Vermunt & Magidson, 2013). Smaller BIC and AIC in relation to a smaller L^2, smaller *Npar*, and a nonsignificant bootstrap *p*-value, indicate good model-to-data fit (Vermunt & Magidson, 2013). Entropy R^2 was also considered

when choosing the most parsimonious and best-fitting latent class cluster model for subsequent analyses. Last, the bootstrap *-2LL*-difference statistic was examined to compare the final identified latent class cluster group with other latent class cluster groups. Bootstrap *-2LL*-difference statistical analyses provide further evidence for the chosen latent class cluster group (Lo et al., 2001; Magidson et al., 2020); bootstrap *p*-values of ≤ 0.05 provide evidence of a significant difference between the chosen latent class cluster group and other latent class cluster groups. Simulation studies indicate that these bootstrap likelihood ratio tests (BLRT) provide an accurate method for deciding the most representative number of latent classes while maintaining adequate power (≥ 0.70) and reasonable effect size (Cohen's $d = 0.80$) in samples ≥ 500 (Tein et al., 2013).

After completing LCA modeling, heterogeneity was examined among cluster groups. Between group tests were conducted on sociodemographic characteristics among cluster groups, followed by mean-level between group analyses on indicators of mental health severity (PHQ-9 and GAD-7 scores), alcohol consumption, and following COVID-19 measures including quarantining and self-isolation, suicidal ideations, and physical activity including sitting hours per day and vigorous intensity exercise.

Last, multinomial logistic regression (*mlogit*) analyses were conducted between quarantining, self-isolation, suicidal ideations, and physical activity on cluster group membership. The reported *risk ratios (RR)* are adjusted for sociodemographic characteristic covariates. *RR* is used in STATA to describe the exponentiated coefficients from a *mlogit* model (Norton et al., 2013; StataCorp, 2020). Covariates with *p*-values of ≤ 0.20 were included in the multinomial logistic regression (Bursac et al., 2008) and retained based on performance in these models (Aneshensel, 2012). Traditional levels such as 0.05 can fail in identifying variables known to be important (Bursac et al., 2008).

Multinomial logistic regression analyses are a useful technique for examining indicators of depression and anxiety symptom severity and alcohol consumption latent class cluster group membership. Multinomial logistic regression is a simple extension of binary logistic regression that allows for more than two categories of the dependent or outcome (De Jong et al., 2019; Pampel, 2000). Multinomial logistical regression procedures are used to predict categorical placement in or the probability of category membership based on multiple independent variables (De Jong et al., 2019; Pampel, 2000). More importantly, multinomial logistic regression analyses help account for shared variance among latent class cluster groups (dependent variables) to produce more accurate *RRs*, residuals, and goodness-of-fit tests based on these subpopulations, relative to conducting standard logistic regression analyses for each latent class cluster group, independently (De Jong et al., 2019; Pampel, 2000). Based on these justifications, multinomial logistic regression was deemed appropriate. Additional assumptions of independence when creating latent class cluster groups, as well as the non-perfect separation of latent class cluster groups when conducting these analyses were met, which will support the estimation of more accurate *RR*. These sets of analyses were conducted in Stata v. 15 software (StataCorp, 2020).

Results

Sociodemographic

Of the 852 individuals that started the survey, 75 were excluded (23 did not meet inclusion criteria, five reported an age outside the age range, and 47 did not complete questions

on alcohol consumption). The final sample in the parent study (Coakley, et al., 2021b) included 777 participants, yielding a response rate of 19.40%. For this secondary data analysis study, 606 participants with complete data were retained and included in final LCA model (see Vermunt & Magidson, 2013).

Table 1 presents sociodemographic characteristics of the study sample. All participants were undergraduate students between 18 and 25 years ($M = 21.24 \pm 1.62$), with 72.20% between 21 and 25 years of age. Participants were predominantly female (61.20%), White non-Hispanic (32.90%) and Hispanic/Latino/Spanish (32.10%), and heterosexual (67.80%). Participants were predominantly junior (27.90%) and senior (50.30%) standing. Over half of the participants were eligible for Federal Pell grants (55.30%), an indicator of low income.

Sample sociodemographic characteristics align with those of the university student population. In Fall 2020, the average age of undergraduate students was 23.1 years; 58% of undergraduate students identified as female; and 50% were Hispanic, 30% were White, 5.7% were American Indian, 4.10% were Asian, 2.60% were African American, and 7.70% reported other, unknown, or two or more races. Approximately, 39.20% of participants were Federal Pell grant recipients.

Latent Class Analysis: Mental Health Severity and 30-Day Alcohol Consumption

Interpreter indicators of model fit (Table 3) were examined. Individual cases were assigned to latent class clusters using standard-modal classification. Only complete cases were assigned to classes ($n = 606$). Results showed that the six-cluster model provided the optimal model-to-data fit to the sample data. Bootstrapping was then conducted to obtain model fit estimates (Langeheine et al., 1996). The bootstrap difference in log-likelihood value (*-2LL*-difference statistic *[-2LL diff]*), which compares models with different numbers of latent class cluster groups (Lo et al., 2001; Vermunt & Magidson, 2013; Vuong et al., 2010), yielded a significant *p*-value between latent class cluster groups five and six (*-2LL* diff. = 40.94, $p < 0.001$) indicating that there was a statistically significant difference between models. Further examination of latent class cluster groups also showed no statistically significant difference between latent class cluster groups six and seven (*-2LL* diff. = 5.21, $p = 0.31$), which points toward the more parsimonious model for inclusion in subsequent analyses.
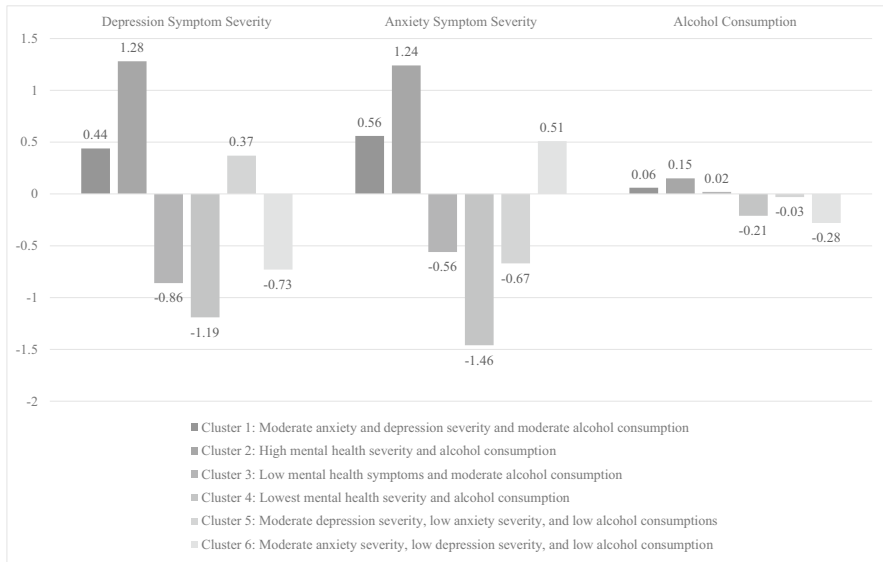
Fit statistics for the best-fitting six-cluster model were as follows: $L^2 = 56.31$, $BIC = 5012.79$, $AIC = 4849.74$, and the bootstrap L^2 *p*-value = 0.88 (see Table 2). The six-cluster group model provided a standard R^2 value of 0.88, indicating that these six cluster groups account for a large proportion of the variance in these three indicators. See Fig. 1 for a standardized visual representation of cluster groups.

Cluster one was identified as *moderate anxiety and depression severity and moderate alcohol consumption* ($n = 156$; 25.70%) and had moderate GAD-7 scores ($M = 13.21 \pm 2.42$) and PHQ-9 scores ($M = 14.00 \pm 3.64$) and moderate 30-day alcohol consumption ($M = 28.41 \pm 54.54$). Cluster two was identified as *high mental health severity and alcohol consumption* ($n = 133$; 21.90%) due to higher GAD-7 ($M = 18.35 \pm 2.13$) and PHQ-9 scores ($M = 20.20 \pm 3.65$) and higher 30-day alcohol consumption ($M = 32.76 \pm 60.02$). Cluster three was identified as *low mental health symptoms and moderate alcohol consumption* ($n = 105$; 17.30%) based on lower GAD-7 ($M = 6.71 \pm 1.34$) and PHQ-9 scores ($M = 5.62 \pm 2.23$) and moderate rates of 30-day alcohol consumption ($M = 18.03 \pm 25.39$), relative to cluster groups one and two. Cluster four was identified as

Table 3 Mean-level differences of cluster groups among indicators of mental health severity and 30-day alcohol consumption

Variable	Cluster 1[a]		Cluster 2[a]		Cluster 3[a]		Cluster 4[a]		Cluster 5[a]		Cluster 6[a]		Total (N=606)		χ^2	df	p-value
	n	%	n	%	n	%	n	%	n	%	n	%	n	%			
Quarantined since the start of the COVID-19 pandemic															16.57	5	.005
No	59	38.8	44	34.1	55	52.9	44	48.9	34	46.6	26	61.9	262	44.4			
Yes	93	61.2	85	65.9	49	47.1	46	51.1	39	53.4	16	38.1	328	55.6			
Self-isolation since the start of the COVID-19 pandemic															23.91	5	<.001
No	69	45.4	54	41.9	62	59.6	56	62.2	38	52.1	32	76.2	311	52.7			
Yes	83	54.6	75	58.1	42	40.4	34	37.8	35	47.9	10	23.8	279	47.3			
Suicidal ideations															58.48	5	<.001
No	135	86.5	96	72.2	104	99.0	93	97.9	66	89.2	42	97.7	536	88.4			
Yes	21	13.5	37	27.8	1	1.0	2	2.1	8	10.8	1	2.3	70	11.6			
COVID-19 testing															12.12	20	.91
No	87	57.2	80	62.0	61	58.7	55	61.1	44	60.3	29	69.0	356	60.3			
Yes, negative	62	40.8	45	34.9	40	38.5	33	36.7	28	38.4	13	31.0	221	37.5			
Yes, positive test	3	2.0	3	2.3	2	1.9	1	1.1	1	1.4	0	0.0	10	1.7			
Yes, tested but never received result	0	0.0	1	0.8	1	1.0	0	0.0	0	0.0	0	0.0	2	0.3			
Yes, tested but I am waiting	0	0.0	0	0.0	0	0.0	1	1.1	0	0.0	0	0.0	1	0.2			

[a]Cluster group labels as follows: cluster 1 = moderate anxiety and depression severity and moderate alcohol consumption (n = 156; 25.7%); cluster 2 = high mental health severity and alcohol consumption (n = 133; 21.9%); cluster 3 = low mental health symptoms and moderate alcohol consumption (n = 105; 17.3%); cluster 4 = lowest mental health severity and alcohol consumption (n = 95; 15.7%); cluster 5 = moderate depression severity, low anxiety severity, and low alcohol consumptions (n = 74; 12.2%); and cluster 6 = moderate anxiety severity, low depression severity, and low alcohol consumption (n = 43; 7.1%)

Fig. 1 Standardized visual representation of cluster groups

lowest mental health severity and alcohol consumption ($n=95$; 15.70%) due to low GAD-7 ($M=2.21\pm1.45$) and PHQ-9 scores ($M=2.81\pm2.56$) and lowest 30-day alcohol consumption ($M=1.83\pm23.92$). Cluster five was identified as *moderate depression severity, low anxiety severity, and low alcohol consumptions* ($n=74$; 12.20%) due to moderate PHQ-9 score ($M=13.07\pm2.81$), low GAD-7 score ($M=6.91\pm1.99$), and low 30-day alcohol consumption ($M=18.52\pm22.45$) relative to cluster groups one and two. Cluster six was identified as *moderate anxiety severity, low depression severity, and low alcohol consumption* ($n=43$; 7.10%) based on moderate GAD-7 score ($M=12.63\pm2.24$), low PHQ-9 score ($M=6.35\pm2.19$), and low alcohol consumption ($M=18.68\pm28.77$) relative to cluster groups one and two.

Between Group Differences on Sociodemographic Characteristics among Cluster Groups

Next, we tested cluster group differences among sample sociodemographic characteristics (see Table 1). Statistically significant differences were noted for gender ($\chi^2=25.69[10]$, $p=0.004$), with those identifying as female more likely to identify in all cluster groups, compared to male participants, and transgender participants except for cluster four. Differences were also identified on sexual orientation ($\chi^2=66.94$ [20], $p<0.001$) with heterosexual participants more likely to identify in all cluster groups. Relative to their entire study sample, however, gay, lesbian, and queer participants were more likely to identify in cluster group two (high mental health severity and alcohol consumption; 11.40%), and bisexual students were more likely to identify in cluster group one (moderate anxiety and depression severity and moderate alcohol consumption; 20.50%) and cluster group two (high mental health severity and alcohol consumption; 17.40%).

Differences in Practicing COVID-19-Related Public Health Measures and Suicidal Ideation by Cluster Group

Differences in practicing COVID-19-related public health measures including quarantining and self-isolating, suicidal ideation, and COVID-19 test results were also examined between cluster groups. Statistically significant differences were identified in *quarantining during COVID-19* ($\chi^2 = 16.57$ [5], $p = 0.005$). Those in cluster one (moderate anxiety and depression severity and moderate alcohol consumption; 61.20%) and cluster two (high mental health severity and alcohol consumption; 65.90%) were more likely to report quarantining during COVID-19. Statistically significant differences were identified in self-isolation during COVID-19 ($\chi^2 = 23.91$ [5], $p < 0.001$) between clusters. Those in cluster one (moderate anxiety and depression severity and moderate alcohol consumption; 54.60%) and cluster two (high mental health severity and alcohol consumption; 58.10%) were more likely to self-isolate during COVID-19. Last, statistically significant differences were identified in suicidal ideations ($\chi^2 = 58.48$ [5], $p < 0.001$) with those in cluster one (moderate anxiety and depression severity and moderate alcohol consumption; 13.50%) and cluster two (high mental health severity and alcohol consumption; 27.80%) more likely to report suicidal ideations relative to the entire sample of participants (11.60%).

Mean Level Group Differences Between Cluster Groups in Sedentary Behavior and Vigorous Days of Physical Activity

Mean-level group differences were identified between cluster groups in sitting hours per day (t [5] $= 3.85$, $p = 0.002$) and number of days participants reported vigorous physical activity in the past week (t [5] $= 2.93$, $p = 0.01$). Those in cluster one (moderate anxiety and depression severity and moderate alcohol consumption; $M = 8.87 \pm 4.37$) and cluster two (high mental health severity and alcohol consumption; $M = 9.66 \pm 4.91$) reported the highest mean sitting hours per day. Those in cluster group three (low mental health symptoms and moderate alcohol consumption; $M = 167.85 \pm 190.39$), cluster group four (lowest mental health severity and lowest alcohol consumption; $M = 179.54 \pm 228.22$), and cluster group five (moderate depression severity, low anxiety severity, and low alcohol consumptions; $M = 158.02 \pm 467.24$) reported the highest number of days of reporting vigorous physical activity (Table 4).

Multinomial Logistic Regression Model Assessing Associations Between Quarantining, Self-Isolation, Suicidal Ideations, and Physical Activity on Latent Cluster Group Membership

Last, we examined associations between quarantining, self-isolation, suicidal ideations, sitting hours per day, and vigorous intensity exercise on latent cluster group membership. Sociodemographic factors including gender and sexual orientation were included as covariates in the analysis. Adjusted *risk ratios (RR)* are presented in Table 5. Cluster four (lowest mental health severity and alcohol consumption) served as the reference group category.

Results indicated that compared to cluster four (lowest mental health severity and alcohol consumption), participants in cluster one (moderate anxiety and depression severity and moderate alcohol consumption) showed increased relative risk of quarantining ($RR = 2.41$, 95% CI $= 1.18$, 4.90), suicidal ideations ($RR = 6.09$, 95% CI $= 1.78$, 47.50), and sitting hours per day ($RR = 1.49$, 95% CI $= 1.31$, 1.98). Similarly, those in cluster two (high

Table 4 Mean level group differences between cluster groups and the number of siting hours per day and vigorous intensity exercise

	Cluster 1[a]		Cluster 2[a]		Cluster 3[a]		Cluster 4[a]		Cluster 5[a]		Cluster 6[a]		Total (N=606)		F (5)	p-value
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD		
The number of siting hours per day	8.87	4.37	9.66	4.91	8.03	4.05	7.27	4.12	8.14	3.74	8.67	4.29	8.54	4.38	3.85	.002
Vigorous intensity exercise	153.15	525.42	96.25	157.54	167.85	190.39	179.54	228.22	158.02	467.24	154.62	196.15	145.92	339.79	2.93	.01

[a]Cluster group labels as follows: cluster 1 = moderate anxiety and depression severity and moderate alcohol consumption (n = 156; 25.7%); cluster 2 = high mental health severity and alcohol consumption (n = 133; 21.9%); cluster 3 = low mental health symptoms and moderate alcohol consumption (n = 105; 17.3%); cluster 4 = lowest mental health severity and alcohol consumption (n = 95; 15.7%); cluster 5 = moderate depression severity, low anxiety severity, and low alcohol consumptions (n = 74; 12.2%); and cluster 6 = moderate anxiety severity, low depression severity, and low alcohol consumption (n = 43; 7.1%)

Table 5 Multinomial logistic regression model assessing association between quarantining, self-isolation, suicidal ideations, the number of siting hours per day, and vigorous intensity exercise on latent class group membership ($N = 606$) (analyses adjusted for covariates: gender and sexual orientation)

	Cluster 1: Moderate anxiety and depression severity and moderate alcohol consumption			Cluster 2: High mental health severity and alcohol consumption			Cluster 3: Low mental health symptoms and moderate alcohol consumption			Cluster 5: Moderate depression severity, low anxiety severity, and low alcohol consumptions			Cluster 6: Moderate anxiety severity, low depression severity, and low alcohol consumption		
	RR	95% CI		RR	95% CI		RR	95% CI		RR	95% CI		RR	95% CI	
Quarantined	2.41**	1.18	4.90	2.86***>	1.36	6.03	1.76	.80	1.76	.80	1.76	.80	.67	.30	1.48
Self-isolated	1.79*	1.01	3.17	2.04**	1.09	3.75	2.68*	1.09	2.18	1.09*	1.01	2.99	.57	.23	1.36
Suicidal ideations	6.09**	1.78	47.05	16.71***	3.86	72.33	3.86	.45	3.86	.45	3.86	.45	1.12	.09	1.36
Vigorous intensity exercise	1.00	.99	1.00	1.00	.99	1.00	.79*	.59	.90	.59*	.49	.79	1.05	.87	1.13
Sitting hours per day	1.49**	1.31	1.98	1.13***	1.04	1.22	.95	.86	.95	1.11	1.02	1.21	1.11**	1.01	1.21

Reference group: cluster 4 = lowest mental health severity and alcohol consumption

RR relative risk ratio, *CI* confidence interval

*$p < .05$, **$p < .01$, ***$p < .001$

mental health severity and alcohol consumption) displayed increased relative risk of quarantining ($RR = 2.86$, 95% CI = 1.36, 6.03), self-isolation ($RR = 2.04$, 95% CI = 1.09, 3.75), suicidal ideations ($RR = 16.71$, 95% CI = 3.86, 72.33), and sitting hours per day ($RR = 1.13$, 95% CI = 1.04, 1.22), when compared to cluster four.

Furthermore, in comparison to reference group cluster four, those in cluster three (low mental health symptoms and moderate alcohol consumption) and cluster five (moderate depression severity, low anxiety severity, and low alcohol consumptions) showed greater relative risk of self-isolation ($RR_{cluster\ 3} = 2.68$, 95% CI = 1.09, 2.18; $RR_{cluster\ 5} = 1.09$, 95% CI = 1.01, 2.99). Participants in both cluster three ($RR = 0.79$, 95% CI = 0.59, 0.90) and cluster five ($RR = 0.59$, 95% CI = 0.49, 0.79) also engaged in less intense vigorous exercise than reference group cluster four. In addition, participants in cluster five showed greater relative risk of engaging in more sitting hours per day ($RR = 1.11$, 95% CI = 1.02, 1.21) than reference group cluster four. Similarly, those in cluster group six (moderate anxiety severity, low depression severity, and low alcohol consumption) showed greater relative risk of also participating in more sitting hours per day ($RR = 1.11$, 95% CI = 1.01, 1.21) than reference group cluster four.

Discussion

The COVID-19 pandemic has affected mental health and alcohol consumption in the USA (Stokes et al., 2020). Young adults face disparities related to mental health and alcohol misuse, particularly college and university students (Coakley et al., 2021a; Copeland et al., 2021; Shanahan et al., 2020; Zhang et al., 2020). While studies are emerging that begin to examine the association between mental health and alcohol use in young adults (Coakley, 2021a; Copeland et al., 2021; Zhang et al., 2020), rates of mental health concerns and alcohol use under-reported. Further, there is limited research that examines heterogeneity in subgroups of participants with varying degrees of depression and anxiety severity and alcohol consumption as well as the association with COVID-19 specific predictors (e.g., quarantining and self-isolation), suicidal ideations, and physical activity predictors (e.g., engagement in vigorous exercise and sitting hours per day). This study therefore fills an important gap and provides useful insight into connections between mental health symptom severity during COVID-19 pandemic and factors hypothesized to predict group identification.

Using LCA, this study assessed and identified cluster groups of participants with symptoms of anxiety and depression, as well as alcohol consumption. Our study positions the potential risk and protective factors related to depression and anxiety symptom severity and alcohol consumption among young adults during COVID-19 pandemic. Prior to the COVID-19 pandemic, research suggested quarantining to prevent the spread of disease, particularly longer quarantines, significantly impacted mental health including symptoms associated with Post-Traumatic Stress Disorder (PTSD) and depression (Chatterjee & Chauhan, 2020). Yet, as our study findings highlight, there are acute mental health impacts due to the COVID-19 pandemic and instituted public health measures. For instance, in the current study, latent class groups one (25.70% of participants characterized by moderate anxiety and depression severity and moderate alcohol consumption) and two (21.90% of participants characterized by high mental health severity and alcohol consumption) reported elevated anxiety and depression severity and greater

alcohol use consumption. More specifically, quarantining, self-isolation, as well as suicidal ideations had a statistically significant relationship with these cluster groups.

Similar to prior investigations early in the pandemic, depression, stress, and confinement negatively affect adult health behaviors including increased alcohol consumption (Nnamdi et al., 2021; Rossinot et al., 2020). More importantly, in college students in particular, mood disorder symptoms, perceived stress, and alcohol use increased significantly in spring 2020 compared to fall 2019 (Charles et al., 2021). Students with more symptoms of depression and anxiety reported greater increases in alcohol consumption following the closure of a university in the USA (Lechner et al., 2020). While the acute impacts of the COVID-19 pandemic on mental health and wellness, including alcohol consumption, are clear, long-term impacts are likely to continue emerging.

In addition to these findings, there was also a unique relationship between physical activity-related behavior and latent class cluster group identification. In the present study, sitting hours per day (defined as sedentary behavior) was associated with identification in latent class cluster groups one (25.70% of participants characterized by moderate anxiety and depression severity and moderate alcohol consumption) and two (21.90% of participants characterized by high mental health severity and alcohol consumption). When compared to cluster group four (lowest mental health severity and alcohol consumption), sitting hours per day was associated with a 49% greater relative risk of identifying in cluster group one (moderate anxiety and depression severity and moderate alcohol consumption), 13% greater relative risk of identifying in cluster group two (high mental health severity and alcohol consumption), and 11% greater relative risk of identifying in both cluster groups five (moderate depression severity, low anxiety severity, and low alcohol consumptions) and six (moderate anxiety severity, low depression severity, and low alcohol consumption).

Similar findings for university students have been reported where an increase in sitting time per day was linked to a decline in mental health (Lee & Kim, 2019). Meta-analytical data have suggested that mentally passive sedentary behavior (or sitting hours per day) such as television watching is associated with depressive symptoms and should be avoided (Yuchai et al., 2020). It appears, however, that minimal amounts of physical activity, such as achieving just 10 min of daily activity, can reduce symptoms of depression (Dunn et al., 2001). Therefore, replacing passive sedentary behavior (or sitting hours per day) with low levels of physical activity may be important for mental health among university students during COVID-19 restrictions.

Yet, vigorous intensity exercise appeared to be important to those with lower mental health symptoms and alcohol consumption indicating potential health promotion benefits. Prior studies have shown that vigorous exercise is often linked to high intensity interval exercise, which has been shown to alleviate symptoms of anxiety and depression (Legrand et al., 2020; Viana et al., 2019) and engagement in alcohol misuse (Lardier et al., 2021). Further, moderate physical exercise has also been associated with lower rates of non-suicidal self-harm and suicide attempts among university students (Grasdalsmoen et al., 2020). One possible mechanism is that higher intensity exercise results in the release of neurotrophic factors in the brain that promote neurogenesis in regions controlling psychological constructs (Gujral et al., 2017). Another explanation is that high intensity exercise strengthens endogenous stress coping skills by reducing anxiety sensitivity (Binder et al., 2004; Mason et al., 2018). In line with findings that replacing sedentary behavior with minimal PA has benefits on mental health, these data suggest that implementing vigorous (or high intensity interval exercise) exercise programs may have an added benefit beyond low levels of PA.

Limitations and Future Directions

The results of the study should be interpreted with caution and several limitations in mind. First, the response rate was lower (17%) than desired for an online survey; however, the sample size is comparable to similar survey studies that analyzed PA and mental health during COVID-19 lockdowns (Barkley et al., 2020; Carriedo et al., 2020). Second, the survey was conducted at one university in the southwest region of the USA and may not be generalizable to all undergraduate students. Third, the cluster groups identified in this study were uncovered using a data-driven approach. While methodologically rigorous and objective, this approach to identifying latent class cluster groups may be influenced by the demographic composition of this university sample, and therefore, as noted, may not be generalizable to all undergraduate students or groups beyond university students. Third, students could have completed the survey more than once or could have forwarded the recruitment email to another student not selected into the survey sample. These are difficult variables to control in online survey-based studies; however, these must be considered in interpreting results. However, prior research does suggest that duplicates generally account for $< 3\%$ of responses (Teitcher et al., 2015). Last, the physical activity and sedentary behavior was assessed by self-report using the IPAQ, which is potentially subject to misreporting. However, this study used a short-term recall of physical activity (last 2 weeks) which may reduce the magnitude of reporting errors (Lee et al., 2011; Matthews et al., 2012).

Despite limitations, findings from this study demonstrate sobering associations between COVID-19 public health restrictions, suicidal ideations, and declines in mental health and increases in alcohol consumption among young adult university students (Czeisler et al., 2020). Social isolation coupled with academic-related stress and long-term perceptions of an unknown future may be linked to elevations in symptoms of depression and anxiety. Findings from this study further illustrate that during COVID-19 public health orders, sitting hours per day was associated more with severe mental health concerns and alcohol consumption, while vigorous exercise decreased mental health symptoms and alcohol consumption. Given the cross-sectional nature of the study, it is impossible to determine cause and effect relationship; however, results further highlight physical activity as an important stress relieving behavior. Public health messages in the community and on university campuses should encourage not only physical exercise but provide proactive opportunities for social connection through online-based platforms like Zoom. It may also be reasonable to support safe, socially distanced activities that allow young adults in college to develop critical interpersonal relationships. More specifically, it may be reasonable to organize exercise-based activities such as yoga, bicycling, or jogging that can be completed with social distance measures in mind. Colleges and universities or local community organizations may even consider creating online exercise platforms that allow for maximum social distancing and simultaneously group connection.

Declarations

Conflict of Interest The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Informed Consent All procedures followed were in accordance with the ethical standards of the responsible committee on humansubject's research (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000 (5).Informed consent was obtained from all participants for being included in the study.

Ethical Approval This research was approved by the research ethics committee of the University of New Mexico.

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