Published in final edited form as:

Addict Behav. 2019 April ; 91: 12–20. doi:10.1016/j.addbeh.2018.10.040.

E-cigarettes, Alcohol Use, and Mental Health: Use and perceptions of e-cigarettes among college students, by alcohol use and mental health status

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Abstract

Introduction: Electronic cigarettes (e-cigarettes) are popular among college students, who display risky alcohol use patterns. However, little is known about patterns of co-use of e-cigarettes and alcohol. Further, relationships between e-cigarette use and mental illness among college students are unclear.

Methods: College student participants (N=631) at a northeastern U.S. university were invited via email to participate in a survey about e-cigarettes and alcohol use. Mental health was self-reported diagnosis of psychiatric (depression, bipolar disorder, schizophrenia, PTSD, anxiety disorder, personality disorder), and substance (alcohol and other drug) use disorders. Current use of e-cigarette, combustible cigarette, and other tobacco products were assessed via self-reported past 30-day use frequency. Alcohol consumption was assessed via number of self-reported standard

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Contributors

M.S. and K.H. designed the initial survey with the MIRECC and Yale TCORS. A.S., S.M., and K.C. modified the survey. All authors contributed to the design of the study. A.S. and S.M. distributed the survey under the supervision of K.C. K.H. conducted data analysis and interpretation, created tables, and wrote the manuscript with critical assistance from M.S. All authors contributed to and have approved the final manuscript.

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Conflict of Interest

All authors declare that they have no conflicts of interest.

alcoholic beverages consumed during a typical drinking episode. Participants also reported regarding co-use of alcohol, e-cigarettes and/or combustible cigarettes. Participants were categorized as non-drinkers, moderate drinkers or binge drinkers, and associations between e-cigarette use, drinking patterns and mental health diagnoses were examined

Results: E-cigarette use was associated with drinking alcohol $\chi^2=18.62$, $p<.001$, and binge drinking (vs. moderate drinking) $\chi^2=12.20$, $p<.001$. Students who had tried e-cigarettes reported drinking more alcohol per episode ($\chi^2=15.94$, $p<.001$). E-cigarette use was more prevalent among those with psychiatric and substance use disorders $\chi^2=11.65$, $p<.001$.

Conclusions: Drinking college students (especially binge drinkers) and those with mental illness may have heightened risks for e-cigarette use. More research is needed to elucidate relationships between risky alcohol and/or nicotine use and mental illness, and to guide appropriate prevention and intervention efforts for vulnerable college students.

INTRODUCTION

Although combustible cigarette use is declining among college students nationally (Johnston, O'Malley, Bachman, Schulenberg, & Miech, 2016), e-cigarette use has been rapidly increasing within this population in recent years (Lee, Lin, Seo, & Lohrmann, 2017; Littlefield, Gottlieb, Cohen, & Trotter, 2015; Reinhold, Fischbein, Bhamidipalli, Bryant, & Kenne, 2017; Sutfin, McCoy, Morrell, Hoepfner, & Wolfson, 2013). E-cigarette popularity among college students has been attributed to a variety of factors: young adults have been targeted with successful marketing (Reinhold et al., 2017), college students tend to lead cultural changes in substance use patterns (Johnston, O'Malley, Bachman, & Schulenberg, 2008), and may be especially attracted to the novelty and flavor availability of e-cigarettes (Lee et al., 2017; Sutfin et al., 2013). Although some researchers propose potential benefits of e-cigarettes for adult combustible tobacco smokers (e.g., to reduce or quit smoking) (Bullen et al., 2013; Etter & Eissenberg, 2015; Hajek, 2014), such advantages are less relevant to college students who do not smoke combustible cigarettes but may be more vulnerable to e-cigarette use. Moreover, recent longitudinal research suggesting that never-smoking college students who have used e-cigarettes are more likely to later initiate combustible cigarette use, highlights the importance of identifying predictors and correlates of e-cigarette use within this population (Loukas, Marti, Cooper, Pasch, & Perry, 2018; Spindle et al., 2017).

Synergistic effects and augmented risks associated with concurrent use of nicotine and alcohol have been well established within the general population (e.g., McKee, Falba, O'Malley, Sindelar, & O'Connor, 2007; Verplaetse & McKee, 2016). College students might be especially vulnerable to such multiplicative effects, particularly those displaying alcohol use patterns such as binge drinking that leave them at increased risk. Despite predominantly being aged below the legal drinking limit, 81% of all college students report having tried alcohol, while 32% report recent binge drinking (five or more standard alcoholic beverages on one occasion) (Johnston et al., 2016). Alcohol and tobacco use disorders have been found to be linked prospectively among college students (Jackson, Sher, & Wood, 2000), yet despite the prevalence of both e-cigarette use and binge drinking, few studies have assessed e-cigarette use in the context of drinking behavior amongst college students.

Among adolescents, e-cigarette users are more likely to use combustible cigarettes as well as alcohol (Pentz et al., 2015), while dual users of e-cigarettes and combustible cigarettes are even more likely to use alcohol than those using e-cigarettes alone (Wills, Knight, Williams, Pagano, & Sargent, 2015). Thus, it has been suggested that e-cigarette use may function additively to increase risk for alcohol consumption among adolescents who are already consuming combustible cigarettes (Kristjansson & Sigfusdottir, 2015). Moreover, e-cigarette use is more common among college students who have used alcohol and other nicotine products (Littlefield et al., 2015; Saddleson et al., 2015); however, to date, little attention has been paid to e-cigarette usage in relation to specific alcohol consumption patterns like binge drinking. Moreover, e-cigarette use during drinking episodes remains largely unexamined, and it is unknown how this compares to combustible tobacco and alcohol co-use. Two studies to date suggest an association between binge or “heavy drinking” and e-cigarette use among college students (Littlefield et al., 2015; Saddleson et al., 2015); however, perceptions and motivations for using e-cigarettes were not examined in these studies, reflecting a gap in this literature (Ramo, Young-Wolff, & Prochaska, 2015). Further, a third study suggested that while alcohol use predicted trying and future intention for e-cigarettes use, it was not associated with transitions to adopting regular e-cigarette use (Lee et al. 2017). Thus, little is known about motivations and expectancies associated with e-cigarette use among college students, particularly how these relate to alcohol use patterns (Littlefield et al., 2015).

While mental illness is a known risk factor for combustible cigarette use (Lasser et al., 2000), and e-cigarette use is prevalent among adults with psychiatric and substance use disorders (Hefner et al., 2016; Hefner, Valentine, & Sofuoglu, 2017; Bianco, 2019), the relationship between e-cigarette use and mental illness within college students remains unclear. A recent study suggests a unique association between e-cigarette use and depressive symptoms among college students (Bandiera, Loukas, Li, Wilkinson, & Perry, 2017), while another longitudinal study found no relationship between e-cigarette use and depression or anxiety (Spindle et al., 2017). To the extent that mental health conditions may be associated with increased propensity to use e-cigarettes, which may contribute to nicotine dependence and/or combustible cigarette use in this population (Loukas et al., 2018; Spindle et al., 2017), improved clarity is needed.

The present study examined e-cigarette, combustible cigarette, and alcohol use among college students, as well as motivations and perceptions associated with using e-cigarettes. Specifically, associations between alcohol consumption patterns and e-cigarette use were considered, comparing a) any alcohol use vs. no alcohol use, and b) binge drinking (5 or more drinks per episode) vs. moderate alcohol use. In addition, we examined perceptions and motivations for using e-cigarettes by alcohol consumption patterns, as well as reported e- and combustible cigarette use during drinking episodes. Finally, to clarify inconsistent findings regarding the relationship between e-cigarettes and mental illness, we examined rates of e-cigarette use among college students with psychiatric and substance use disorders as compared to those without these conditions.

METHOD

Participants

Undergraduate students (approximately 4,800) enrolled at a northeastern U.S. university were invited via email to participate in an online survey assessing electronic cigarette, other nicotine, and alcohol use between March and October 2016. Prospective participants were assured that their participation was completely voluntary, anonymous, and confidential, with their responses to be seen only by the research staff, with no penalties for declining to participate, for discontinuing the survey or omitting answers to certain questions. They were given contact information for university psychological services, study supervisors, and IRB staff regarding any potential distress or questions about the research. After reading instructions, participants were informed that by clicking “Next” to continue, they indicated their consent to participate and understood that their participation was voluntary and confidential, the tasks and procedure involved, and the potential risks associated with the study. The study was approved by the university’s Institutional Review Board. For their participation, respondents were entered into a raffle to win one \$100 [Amazon.com](https://www.amazon.com) gift card.

The 46-item, approximately 15-minute survey included questions related to demographics combustible and smokeless tobacco use history, psychiatric and substance use disorder diagnosis, general health, alcohol use, combustible tobacco use, and alcohol and nicotine co-use.

Demographics and Mental Health Conditions

Participants were asked to report their age, race/ethnicity, gender, and whether they had ever been diagnosed with a mental health condition. Those who indicated they had been diagnosed with at least one condition were asked (via survey skip-logic) to select which diagnoses they had received from a list of conditions (major depression, bipolar disorder, posttraumatic stress disorder, anxiety disorder, schizophrenia/schizoaffective disorder, personality disorder, drug use disorder, alcohol use disorder, schizophrenia/schizoaffective disorder).

Alcohol Use

We asked participants to report whether they drink alcohol. Among those reporting alcohol use, participants were asked to report how many standard alcoholic drinks they consume in one typical night of consumption (1–2, 3–4, 5–6, 7–8, 9–10, 11+). Alcohol use was collapsed into the following categories: non-drinkers, moderate drinkers, and binge drinkers, with moderate use of alcohol operationalized as one to four (participants reporting 1–2 or 3–4) drinks per occasion, while binge drinkers were those who reported five or more alcoholic beverages per drinking episode (Johnston et al., 2016).

E-cigarette Use, Knowledge and Perceptions

Usage and knowledge of electronic cigarettes, sources of information about electronic cigarettes, and perceptions about and motivations why one uses or might use e-cigarettes was assessed using items adapted from a previously developed survey used to assess e-cigarette use and psychiatric comorbidity in a clinical sample (Hefner et al., 2016).

Participants reported their past month frequency of e-cigarette use (none, 1–10 days, 11–20 days, 21–30 days). Those who had not used an e-cigarette were asked whether they thought they might try one in the next three months. All participants indicated why they used or might use an e-cigarette, (e.g., “E-cigarettes save money”; “E-Cigarettes reduce the amount I smoke”; see Table 1 for additional items), whether they thought they were as addictive as regular tobacco products, and whether they should be regulated by the government like tobacco products.

Combustible and Smokeless Tobacco and E-cigarette Use Categories

Current tobacco use was assessed in terms of frequency (every day, some days, none) and quantity (less than half a pack per day, half to a pack per day, one to two packs per day, two packs per day, more than two packs per day) in the past 30 days. Due to low overall prevalence of combustible cigarette use, these categories were collapsed into less than one half a pack per day (approximately 58% of smokers) and half a pack or more per day (approximately 40% of smokers, with one non-response on this item). Smokeless tobacco product use (Snus, chew, dip, snuff, pouch) was also assessed; categories were collapsed into any smokeless and no smokeless tobacco use due to low overall prevalence.

Based on reported use of combustible and e-cigarettes, participants were categorized as a never smoker, former smoker, current smoker, whether they had ever tried e-cigarettes, if they were a current e-cigarette user (past 30 day use, any frequency), former e-cigarette user (had tried them but no past-30 day use), current e-cigarette-only user (no combustible tobacco use), current dual use (e-cigarette and combustible cigarette use).

Combustible/E-cigarette and Alcohol Co-use

We also examined e-cigarette and combustible tobacco use during drinking episodes among those who reported consuming alcohol (binge vs. moderate drinkers only). In addition, we also considered quantity of alcohol consumed by those who have and have not used e-cigarettes.

Data Analytic Plan

We present descriptive statistics summarizing the characteristics of the sample. For alcohol use comparisons, an omnibus Pearson χ^2 of independence test assessed whether there were differences for each variable by Alcohol Group. If significant differences were detected by Alcohol Group, follow-up Pearson's χ^2 of independence test were conducted to make comparisons based on alcohol use status (non-drinkers vs. alcohol consumers) and by binge drinking status (moderate vs. binge drinkers). This set of comparisons was selected to enable examination of both associations between e-cigarette use and a) any alcohol consumption, as well as with b) binge drinking among those who do consume alcohol.

For mental health condition analyses, we examined e-cigarette use among those with psychiatric and substance use disorders as compared to those without these conditions. Finally, due to the observed link between alcohol use and e-cigarette use in the present study, we examined alcohol use (none vs. any; moderate vs. binge) as a potential moderator

of the link observed between ever and current e-cigarette use and mental health (any psychiatric or substance use condition) in generalized linear models (GLM).

RESULTS

The sample is comprised of N=631 students who completed the survey and reported on their alcohol use (13.1% of all students invited via email to participate). Demographic information is reported in Table 1 by Alcohol Group (no alcohol, moderate drinkers, and binge drinkers). Where relevant, we report significant group differences.

Alcohol Use

Approximately one-third of participants who reported consuming alcohol reported typically drinking 1–2 alcoholic drinks (33.6%), while another third reported consuming 3–4 drinks (34.1%) per episode. Binge drinkers reported consuming 5–6 (20.1%), or 7 or more (12.1%) alcohol drinks per episode. Students aged 21–30 were more likely to consume alcohol than to be non-drinkers ($\chi^2=8.01$, $p=.018$). There were no other significant group differences in alcohol use (Table 1).

Combustible and Smokeless Tobacco and E-cigarette Use

A greater percentage of binge drinkers (12.1%) than moderate drinkers (5.1%) reporting smoking combustible cigarettes ($\chi^2=5.88$, $p=.015$). Nearly a quarter of the sample reported ever having tried e-cigarettes (21.7%), with greater numbers of drinkers (26.5%) than non-drinkers (10.8%) having tried them ($\chi^2=18.62$, $p<.001$); in addition, more binge drinkers (37.6%) than moderate drinkers (21.3%) had tried e-cigarettes ($\chi^2=12.20$, $p<.001$). Overall, 8.4% of the sample reported current e-cigarette use (within the last 30 days, all frequencies of use collapsed into one group); a greater proportion of drinkers (10.1%) than non-drinkers (4.6%) reported current e-cigarette use ($\chi^2=4.47$, $p=.035$). In terms of future plans to try e-cigarettes, a greater proportion of drinkers (3.7%) than non-drinkers (0.5%) reported that they would likely try an e-cigarette in the next three months ($\chi^2=4.33$, $p=.037$).

Most (83.0%) of those currently using e-cigarettes reported using them less than 10 days during the month. Approximately 5.5% of the entire sample reported using only e-cigarettes currently (no combustible tobacco). Although most of the sample (85.9%) was identified as never smokers of combustible tobacco, only about half of e-cigarette only users (47.2%) indicated they had never smoked combustible cigarettes.

Among current smokers of combustible tobacco (N=45), 64.4% had ever tried e-cigarettes and 40.0% were using e-cigarettes currently. An additional 8.9% of smokers said they would likely try e-cigarettes in the next three months. There were no significant differences in e-cigarette use (having tried, current use, future plans to try) by Alcohol Group within smokers.

Overall, 5.5% of the sample reported using smokeless tobacco products. Although the omnibus χ^2 test indicated group differences by alcohol consumption ($\chi^2=10.17$, $p=.006$), the follow-up tests were non-significant, likely due to reduced power associated with low overall prevalence of smokeless tobacco use.

Perceptions and Motivations Regarding E-cigarette Use

The most popular reason participants endorsed for using e-cigarettes was the belief that vapor is less harmful to others than tobacco smoke (29.5% of full sample). Other popular reasons were to save money (18.9%), that e-cigarettes are better for one's health (17.0%), ability to use e-cigarettes in non-smoking areas (15.1%), and that e-cigarettes taste better than tobacco / flavor variety (14.9%).

Compared to non-drinkers, motivations more commonly endorsed by those consuming alcohol included the ability to use e-cigarettes in non-smoking areas (17.8% of drinkers vs. 8.8% of non-drinkers; $\chi^2=7.98$, $p=.004$), that vapor is less harmful to others (32.3% vs. 23.2%; $\chi^2=4.89$, $p=.027$), and e-cigarettes reduce the amount one smokes (8.5% vs. 3.6%; $\chi^2=4.17$, $p=.041$). Furthermore, compared to moderate drinkers, binge drinkers more frequently endorsed: saving money (28.4% of binge drinkers vs. 16.6% of moderate drinkers; $\chi^2=7.51$, $p=.006$), ability to use in non-smoking areas (24.1% vs. 14.9%; $\chi^2=4.96$, $p=.026$), vapor is less harmful to others (42.6% vs. 27.4%; $\chi^2=9.40$, $p=.002$), and that family and friends prefer e-cigarettes to combustible tobacco (13.5% vs. 5.1%; $\chi^2=8.27$, $p=.004$), as reasons to use e-cigarettes. There were no significant differences by Alcohol Group in perceived harm of e-cigarettes – whether they are as addictive as combustible tobacco or whether they should be regulated like tobacco.

Smoking and E-cigarette Use Behavior Amongst Drinkers

Among drinkers, a greater proportion of binge (18.4%) than moderate drinkers (8.4%) reported smoking combustible cigarettes during drinking episodes ($\chi^2=8.31$, $p=.004$). Quantity of cigarettes smoked while drinking did not differ between moderate and binge drinkers (Table 2).

A greater proportion of smokers than non-smokers reported e-cigarette use while drinking ($\chi^2=11.57$, $p<.001$) (13.3% of smokers vs. 2.6% of non-smokers). In addition, drinkers who reported smoking combustible cigarettes when drinking displayed a greater prevalence of using e-cigarettes while drinking as compared to those who do not smoke when drinking, ($\chi^2=31.44$, $p<.001$) (21.6% of those who smoke while drinking vs. 2.6% of those who do not).

There was a relationship between quantity of alcohol typically consumed per episode and having ever tried e-cigarettes ($\chi^2=15.94$; $p=.001$), such that fewer drinks per episode was associated with never having tried e-cigarettes, and greater drinks per episode was associated with increased rates of having tried e-cigarettes (Table 3). In addition, those who reported typically smoking combustible cigarettes when drinking evidenced a greater prevalence of having tried e-cigarettes than those who do not smoke while drinking ($\chi^2=54.91$, $p<.001$).

E-cigarettes and Mental Health

Demonstrating internal consistency of alcohol use categories, those classified as binge drinkers reported a greater prevalence of alcohol use disorders (2.8%) as compared to moderate drinkers (0.0%), $\chi^2=5.64$, $p=.018$. A greater proportion of participants (33.6%) reporting (non-substance use) mental health condition(s) had tried e-cigarettes as compared

to those without these conditions (19.2%), $\chi^2 = 11.65$, $p < .001$. In addition, a greater proportion of those reporting a (non-alcohol) substance use disorder (55.6%) reported having tried e-cigarettes as compared to those without (21.7%), $\chi^2 = 4.1$, $p = .043$. In contrast, there was no significant difference in rates of current e-cigarette or combustible cigarette use observed between those who did and did not have psychiatric or substance use disorders, though there was a trend towards greater current e-cigarette use among those with substance use disorders than those without ($p = .067$).

In a GLM examining alcohol use (contrasts for none vs. any and moderate vs. binge) as a potential moderator of the link observed between current e-cigarette use and mental health (any psychiatric or substance use condition), the effect of mental health condition on current e-cigarette use was no longer significant ($p = .367$); alcohol consumption alone predicted current e-cigarette use (any vs. none), $B = 1.00$ (95% CI: 0.19, 2.02), $z = 2.21$, $p = .027$. (The contrast for binge vs. moderate drinking on current e-cigarette use was trend level in this model ($p = .113$)). In contrast, in a GLM examining alcohol use (none vs. any and moderate vs. binge) as a potential moderator of the link observed between ever using e-cigarettes and mental health (any psychiatric or substance use condition), the effect of mental health condition on ever e-cigarette use was significant, $B = 0.86$ (95% CI: 0.35, 1.34), $z = 3.42$, $p < .001$, as was the effect of alcohol use (none vs. any; $B = 1.35$ (95% CI: 0.80, 1.96), $z = 4.61$, $p < .001$ and moderate vs. binge drinking, $B = 0.87$ (95% CI: 0.34, 1.41), $z = 3.20$, $p = .001$). The interactions between alcohol use and mental health condition were not significant in predicting ever use of e-cigarettes.

DISCUSSION

We observed a monotonic pattern between quantity of alcohol consumption and prevalence of e-cigarette experience; a greater percentage of drinkers than non-drinkers had tried e-cigarettes, and a greater percentage of binge drinkers than moderate drinkers had tried e-cigarettes. Prevalence of current e-cigarette use was also greater in drinkers than non-drinkers. In addition, a greater proportion of drinkers than non-drinkers also indicated they would likely try e-cigarettes in the next three months. We observed a “dose”-related relationship between quantity of alcohol consumed per episode and prevalence of having tried e-cigarettes, such that reported consumption of a greater number of drinks per episode was associated with higher prevalence of having tried e-cigarettes. A greater proportion of binge drinkers than moderate drinkers reported smoking combustible cigarettes while drinking. However, neither quantity of combustible cigarettes smoked nor rates e-cigarette use while drinking differed between moderate and binge drinkers. A greater percentage of smokers than non-smokers also reported e-cigarette use while drinking. Perhaps not surprisingly, among those who had tried e-cigarettes, a greater proportion reported smoking combustible cigarettes when drinking. College students in this sample endorsed motivations for using e-cigarettes that were similar to adult populations of smokers, such as for use in non-smoking areas, the perception that vapor is less harmful and more acceptable to others (e.g., than combustible tobacco use), and that e-cigarettes help one reduce or quit smoking (e.g., Hefner et al., 2016). Finally, trying e-cigarettes was more prevalent among those with psychiatric and substance use disorders than those without these conditions; in contrast, there were no differences in rates of combustible cigarette use between these groups.

Overall, these findings provide support for the notion that risky alcohol use is associated with greater propensity to try and continue using e-cigarettes. This corroborates recent research suggesting e-cigarette users may mimic traditional tobacco users with respect to their alcohol use (Littlefield et al., 2015). Moreover, our findings may substantiate concerns that co-use of e-cigarettes and alcohol may contribute to increased risks among those already vulnerable to hazardous behaviors (e.g., adolescents and young adults) (Kristjansson & Sigfusdottir, 2015).

Findings that college students endorsed similar motivations for using e-cigarettes as adult smokers, such as using e-cigarettes in non-smoking areas, would appear to conflict with previous studies suggesting that unlike older smokers, college student e-cigarette use is not motivated by desires to reduce or quit combustible cigarette smoking (Littlefield et al., 2015; Sutfin et al., 2013). However, these motivations and perceptions might be better understood within the context of our findings regarding increased e-cigarette use while drinking; that is, e-cigarettes may represent an alternative to accessing tobacco products during drinking episodes in areas where smoking is prohibited. If true, this provides support for the notion that college students who may not otherwise use combustible tobacco products – at least drinkers, and binge drinkers especially – use e-cigarettes as a means to access nicotinic or non-nicotinic reinforcement via vaping (Sutfin et al., 2013), potentially increasing exposure to nicotine and/or future risk for combustible tobacco use. Importantly, however, the cross-sectional nature of the present data cannot address whether e-cigarette use might lead to combustible tobacco use, or vice versa. Notwithstanding, these findings support that college students' perceive e-cigarettes as more socially acceptable for use in public areas than are tobacco products (Reinhold et al., 2017; Trumbo & Harper, 2013). Moreover, at least for a subset of heavier drinking college students, e-cigarettes may be used to replace or supplement combustible tobacco use.

Our findings suggest that alcohol use may explain part of the link between mental health conditions and e-cigarette use, but not its entirety. Specifically, when controlling for alcohol use, the impact of one or more mental health condition in predicting current e-cigarette use disappears. In contrast, both mental health conditions and alcohol use predict ever having tried e-cigarettes, with binge drinkers specifically and all drinkers broadly being more likely to use e-cigarettes, outside of the independent effect of mental health condition. It remains possible that mental health condition does independently predict current e-cigarette use, but the present study was likely underpowered to detect a significant effect due to low prevalence of current e-cigarette use. Notwithstanding, the observation that e-cigarette (but not combustible cigarette) use was more prevalent among college students with mental health conditions is novel and noteworthy, as rates of combustible cigarette smoking are consistently observed to be greater among those with psychiatric and substance use disorders (Lasser et al., 2000; Vanable, Carey, Carey, & Maisto, 2003). Thus, while combustible tobacco use declines among college students (Johnston et al., 2016), present findings may reflect vulnerable college students with mental illness increasingly turning instead to e-cigarettes, potentially mitigating the increased risks for harm associated with combustible tobacco use among this population. However, there is still cause for concern in light of observed relationships between alcohol consumption and e-cigarette use, particularly given that mental health has independent contributions to propensity for trying e-cigarettes,

as these psychiatric and substance use disorders may be exacerbated by alcohol use. Future research is needed to elucidate and carefully weigh the risks and benefits of e-cigarette use among those with mental illness (Hefner, Valentine, & Sofuoglu, 2017).

E-Cigarette, Combustible Tobacco and Alcohol Use – Comparisons to other regions

Rates of binge drinking were somewhat lower than those observed among college students nationally (32% nationally vs. 22% in our sample); in contrast to national data, we did not observe sex differences in alcohol consumption (Johnston et al., 2016). Combustible tobacco use was slightly lower in our sample (7.1% vs. 11% nationally) while e-cigarette usage was on par (8.4% vs. 9% nationally) with the most current data in U.S. college students (Johnston et al., 2016). Our observed prevalence of having tried e-cigarettes in the present study (21.7%) was slightly lower as compared to other recent data (29–30%) collected in western New York state (Saddleson et al., 2015) and the southern US (Littlefield et al., 2015); in contrast, as would be expected given the increasing popularity of e-cigarettes, our observed rate of e-cigarette exposure was notably higher than that of a 2009 study (4.9%) albeit conducted in the southern US (Sutfin et al., 2013). However, the rate of current e-cigarette use (8.5%) in our sample was somewhat lower than observed in other recent samples (14–15%) (Littlefield et al., 2015; Sutfin et al., 2013). Our slightly lower observed prevalence of e-cigarette use may reflect regional differences in tobacco and nicotine use. In addition, it is possible that the age distribution of our sample (63.1% 18–21; 14.6% 21–30; 4.1% 30 and older) may have impacted the observed pattern of results, relative to other samples of college students.

Approximately 5.5% of our sample used only e-cigarettes and not combustible tobacco; this is consistent with prevalence of e-cigarette-only use (6%) documented by Littlefield and colleagues (2015). Nearly half of current e-cigarette users in our sample were never smokers of combustible tobacco (47.2%), standing in stark contrast with earlier research indicating a mere 12% of e-cigarette users had never smoked combustible cigarettes (Sutfin et al., 2013). This finding may indicate that e-cigarette use is growing in popularity among never-smoking college students, which would appear to support the notion that e-cigarette marketing targeting adolescents and college students has been effective (Reinhold et al., 2017; Trumbo & Kim, 2015). Alternatively, such differences may reflect regional differences in smoking prevalence. Our sample evidenced an overall low prevalence of dual use (2.9%) and did not observe significant relationships to alcohol use, while Littlefield and colleagues (2015) suggest dual users displayed comparable heavy drinking to that of other nicotine users. While only 33.9% of our sample's e-cigarette users reported dual use, 55% of e-cigarette users in their sample were dual users (Littlefield et al., 2015); again this may relate to regional differences in smoking prevalence. To our knowledge, no other studies have assessed e-cigarette, tobacco, and alcohol co-use in this region, nor perceptions and motivations for using e-cigarettes. Although there is ample research examining use and perceptions of e-cigarettes in the Midwestern (Hinderaker, Power, Allen, Parker, & Okuyemi, 2018; Lee et al., 2017) and Southern (Cooper, Loukas, Case, Marti, & Perry, 2018; Littlefield et al., 2015; Noland et al., 2016; Sutfin et al., 2013) U.S., future studies should address whether reported rates of combustible and e-cigarette use may be attributable to regional differences in popularity, and/or other factors.

Limitations and Future Directions

The present data are limited in scope in that they are cross-sectional in nature, and drawn from a relatively small sample, with a response rate of 13%, which may have affected our results. For example, results may be biased if only those with e-cigarette interest or curiosity were particularly motivated to respond to such a survey. However, given the relatively low overall prevalence rate of e-cigarette use in our sample, we consider this possibility unlikely. Furthermore, while the response rate was lower than initially anticipated, the sample size is comparable (Copeland, Peltier, & Waldo, 2017)) or larger (Dunn, 2015) than that of other electronic surveys assessing e-cigarette use among college students, and involves a comparable response rate (Noland et al., 2016) to other published reports. However, due to the overall low prevalence of e-cigarette use in this sample, some of the Ns are small and therefore findings should be interpreted with some caution. More research is needed investigating links between e-cigarette use, alcohol use, and mental health conditions, and how this compares to combustible and smokeless tobacco use patterns in college populations. For example, it is possible that smokeless tobacco use likely differs by alcohol consumption patterns, although this study was underpowered to detect group differences due to low overall prevalence of smokeless tobacco use.

The present study's findings regarding the link between e-cigarette use and mental health conditions is limited by the use of self-reported mental health and substance use disorder diagnoses; however, binge drinkers reported higher likelihood of AUD diagnosis, suggesting internal validity at least among these self-report measures. Since this was a preliminary exploration of alcohol use and mental health conditions among college students, we balanced the need for accurate diagnosis with a desire to keep the survey brief. However, this could have impacted the rate of detection or reporting of mental health conditions, or the accuracy of diagnoses reported. Future research should use standardized measures assessing common mental health conditions (e.g., depression, anxiety, alcohol use disorder, etc.).

A strength of the current study is our assessment of binge drinking and quantity of alcohol consumed per episode; however, our data are also limited in lacking assessment of alcohol use frequency. Given that those drinking alcohol more commonly smoked combustible cigarettes and displayed a trend in increased e-cigarette use during drinking episodes, patterns of e-cigarette use may also vary by frequency of drinking episodes. For example, those who drink daily may be more or less likely to use e-cigarettes than those who only binge drink on weekends. In addition, e-cigarette use topography (frequency, quantity of nicotine/e-liquid consumed, puff duration, etc.) will be important to assess in future studies, broadly, as well as in the context of drinking episodes, where topography may differ. Future research assessing alcohol use patterns in greater detail could reveal illuminating information about the implications of drinking on habits of e-cigarette users, moderate and binge drinkers.

Furthermore, as noted earlier, the present findings cannot speak directly to risk sequence for e-cigarette and alcohol use; that is, whether alcohol use increases risk for e-cigarette use, e-cigarettes increase risk for heavier alcohol use, or both, as suggested by a "gateway" hypothesis that has been proposed regarding observed associations between e-cigarette use and other use of other substances (e.g., Temple et al., 2017). Although present data cannot

definitively address this possibility and are limited by lacking assessment of other drug use, findings are consistent with the notion of common addiction liability, an alternative model that provides parsimony in addressing substance use disorder comorbidity and polysubstance use (Etter, 2017; Vanyukov et al., 2012). Future research should systematically assess e-cigarettes use in the context of other illicit drug use such as marijuana, as previous research suggests that e-cigarette use is associated with marijuana use (Littlefield et al., 2015; Saddleson et al., 2015; Sutfin et al., 2013). Moreover, given well-documented synergistic relationship between alcohol and nicotine, co-use of e-cigarettes and alcohol should be experimentally assessed in the laboratory, with precise titration of doses (Verplaetse & McKee, 2016). Finally, knowledge regarding real-world e-cigarette use topography would be advanced by research incorporating ecological momentary assessment of e-cigarette and other drug use.

It has been suggested that smoking policies can impact rates of alcohol use disorders (McKee & Weinberger, 2013). With an increasing focus on regulatory approaches to e-cigarettes (Food and Drug Administration, HHS, 2016), an eye must be kept towards possible consequences of e-cigarette use among those with other risky behaviors such as heavy alcohol use, as co-use may increase propensity towards nicotine and/or alcohol dependence due to multiplicative effects of these substances when used concurrently. Finally, given current and prior findings of increased e-cigarette use prevalence among those with mental illness, future research should carefully assess and weigh risks and benefits of e-cigarette use within this vulnerable population known to be highly susceptible to nicotine dependence (Hefner et al., 2016; Hefner, Valentine, & Sofuoglu, 2017; Lasser et al., 2000).

Conclusions and Implications

E-cigarette use and alcohol use (binge drinking in particular) appear to go hand in hand for a subset of college students. Those with psychiatric and substance use disorders report a greater prevalence of e-cigarette, but not combustible tobacco use. The relationship between mental health conditions and e-cigarette use may be partially attributable to differences in alcohol use patterns between these groups, but alcohol use patterns and mental health conditions each appear to have independent contributions to risk for trying e-cigarettes. That college students with mental health conditions and/or who consume alcohol are particularly susceptible to e-cigarette use, potentially even in the absence of past combustible tobacco use, indicates an opportunity for education and prevention. For example, freshman year programming for incoming students similar to that which is already in place in many universities regarding alcohol use could be developed and implemented to provide students with education regarding the known and unknown risks associated with e-cigarette use, as well as how alcohol and e-cigarette use patterns may interact. Furthermore, although it has previously been suggested that college students have different motivations for using e-cigarettes as compared to older adult smokers, college students (and drinkers in particular) in the present study reported similar motivations for using e-cigarettes which indicate they are using them to supplement or replace combustible tobacco. Although e-cigarettes might thereby reduce some of the harm associated with combustible tobacco use, there remains potential to increase overall exposure to nicotine and even tobacco among young adults who might have otherwise avoided tobacco products. If true, this would be particularly

concerning in light of recent findings showing e-cigarette use to be associated with later combustible cigarette use among never smoker college students (Loukas et al., 2018; Spindle et al., 2017).

Acknowledgments

Role of Funding Sources

Research reported in this publication was supported by the VA New England Mental Illness Research, Education, and Clinical Center (MIRECC) and by the P50DA036151 (Yale TCORS) from the National Institute on Drug Abuse of the National Institutes of Health and the U.S. Food and Drug Administration Center for Tobacco Products under Award Number P50DA036151. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health or of the U.S. Food and Drug Administration, which have no role in the study design, collection, analysis or interpretation of the data, writing the manuscript, or the decision to submit the paper for publication. The content is solely the responsibility of the authors and does not necessarily represent the official view of the National Institutes of Health or the Food and Drug Administration. Since Drs. Hefner and Sofuoglu are/were employees of the U.S. Government at the time the research was conducted, and contributed to the manuscript as part of their official duties, the work is not subject to U.S. copyright.

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Highlights

- Many college students report having used electronic cigarettes (EC)
- Those who drink alcohol and binge drink are more likely to use EC
- EC use is more prevalent among college students with mental illness
- Perceptions and motivations to use EC in drinkers are similar to clinical samples
- EC use appears to co-occur with risky substance use in vulnerable students

Table 1

E-cigarette (EC) and combustible tobacco use by alcohol group (no alcohol vs. alcohol; moderate vs. binge drinkers).

	<u>Total sample N = 631</u>		<u>No alcohol</u>		<u>Moderate drinkers</u>		<u>Binge drinkers</u>		<u>Omnibus test</u>	<u>Group differences; direction and follow-up test</u>
	N	%	<u>N = 194 (30.7%)</u>		<u>N = 296 (46.9%)</u>		<u>N = 141 (22.3%)</u>		χ^2 (p)	χ^2 (p)
Sex (Female)	392	62.1%	123	63.4%	190	64.2%	79	56.0%	2.90 (0.235)	
Age									11.57 (0.021) *	
18–21	398	63.1%	163	84.0%	224	75.7%	11	7.8%	5.19 (0.075)	
21–30	92	14.6%	20	10.3%	59	19.9%	13	9.2%	8.01 (0.018) *	NA < Alcohol 6.48 (0.011) *
30+	26	4.1%	11	5.7%	13	4.4%	2	1.4%	3.84 (0.147)	
Race/ethnic identity									13.43 (0.098)	
Caucasian	447	70.8%	125	64.4%	219	74.0%	103	73.0%		
African-American / Black	51	8.1%	15	7.7%	25	8.4%	11	7.8%		
Asian-American	26	4.1%	13	6.7%	11	3.7%	2	1.4%		
Hispanic/Latino	66	10.5%	23	11.9%	28	9.5%	15	10.6%		
Multi-racial / Other	43	6.8%	18	9.3%	13	4.4%	12	8.5%		
Smoking & EC use characteristics										
Smoke Tobacco Cigarettes (yes/no)	45	7.1%	13	6.7%	15	5.1%	17	12.1%	7.12 (0.028) *	Moderate < Binge 5.88 (0.015) *
Quantity of Smoking									4.49 (0.106)	
Less than half a pack per day	26	4.1%	5	2.6%	11	3.7%	10	7.1%		
Half pack or more per day	18	2.9%	8	4.1%	3	1.0%	7	5.0%		
Smokeless Tobacco	20	5.5%	2	1.0%	8	2.7%	10	7.1%	10.17 (0.006) **	<i>ns</i>
Smoking status										
Never smoker	542	85.9%	178	91.8%	258	87.2%	106	75.2%	19.26 (< 0.001) ***	NA > Alcohol 7.25 (0.007) ** Moderate > Binge 9.01 (0.003) **
Former Smoker	45	7.1%	3	1.5%	24	8.1%	18	12.8%	16.32 (< 0.001) ***	NA < Alcohol 12.00 (< 0.001) ***

	<u>Total sample N = 631</u>		<u>No alcohol</u>		<u>Moderate drinkers</u>		<u>Binge drinkers</u>		<u>Omnibus test</u>	<u>Group differences; direction and follow-up test</u>
			<u>N = 194 (30.7%)</u>		<u>N = 296 (46.9%)</u>		<u>N = 141 (22.3%)</u>		χ^2 (p)	χ^2 (p)
	N	%	N	%	N	%	N	%		
Current Smoker	45	7.1%	13	6.7%	15	5.1%	17	12.1%	7.12 (0.028) *	Moderate < Binge 5.88 (0.015) *
E-cigarette use										
Ever Tried E-cigarettes	137	21.7%	21	10.8%	63	21.3%	53	37.6%	34.47 (< 0.001) ***	NA < Alcohol 18.62 (< 0.001) *** Moderate < Binge 12.20 (< 0.001) ***
Current E-cigarette Use (30 days)	53	8.4%	9	4.6%	25	8.4%	19	13.5%	8.29 (0.016) *	NA < Alcohol 4.47 (0.035) *
Former EC Use (Tried, not current)	87	13.8%	13	6.7	39	13.2%	35	24.8%	22.73 (< 0.001) ***	NA < Alcohol 10.99 (< 0.001) *** Moderate < Binge 8.40 (0.004) **
Current Non-nicotine user (no EC or tobacco cigarettes)	551	87.3%	175	90.2%	264	89.2%	112	79.4%	10.32 (0.006) **	Moderate > Binge 6.78 (0.009) **
Current EC only user (no combustible tobacco)	35	5.5%	6	3.1%	17	5.7%	12	8.5%	4.62 (0.099)	
Current dual use (EC and cigarettes)	18	2.9%	3	1.5%	8	2.7%	7	5.0%	3.79 (0.175)	
Try EC in the next 3 months? (Yes)	17	2.7%	1	0.5%	8	2.7%	8	5.7%	9.32 (0.009) **	NA < Alcohol 4.33 (0.037) *
Select all reasons why you use or may use EC										
Vapor is less harmful to others	186	29.5%	45	23.2%	81	27.4%	60	42.6%	15.92 (< 0.001) ***	NA < Alcohol 4.89 (0.027) * Moderate < Binge 9.40 (0.002) **
Save money	119	18.9%	30	15.5%	49	16.6%	40	28.4%	10.82 (0.004) **	Moderate < Binge 7.51 (0.006) **

	<u>Total sample N = 631</u>		<u>No alcohol</u>		<u>Moderate drinkers</u>		<u>Binge drinkers</u>		<u>Omnibus test</u>	<u>Group differences; direction and follow- up test</u>
	N	%	<u>N = 194 (30.7%)</u>		<u>N = 296 (46.9%)</u>		<u>N = 141 (22.3%)</u>		χ^2 (p)	χ^2 (p)
EC are better for my health	107	17.0%	25	12.9%	51	17.2%	31	22.0%	4.83 (0.089)	
Can use EC in non-smoking areas	95	15.1%	17	8.8%	44	14.9%	34	24.1%	15.06 (< 0.001) ***	NA < Alcohol 7.98 (0.004) **
										Moderate < Binge 4.96 (0.026) *
Less judgment by others	96	15.2%	22	11.3%	47	15.9%	27	19.1%	4.05 (0.132)	
EC taste better/flavor variety	94	14.9%	14	7.2%	47	15.9%	33	23.4%	3.13 (0.077)	
EC reduce other tobacco product use	57	9.0%	13	6.7%	29	9.8%	15	10.6%	1.94 (0.380)	
Friends/family prefer EC	49	7.8%	15	7.7%	15	5.1%	19	13.5%	9.43 (0.009) **	Moderate < Binge 8.27 (0.004) **
EC reduce the amount I smoke	44	7.0%	7	3.6%	22	7.4%	15	10.6%	6.40 (0.041) *	NA < Alcohol 4.17 (0.041) *
EC allowed me to quit smoking	29	4.6%	7	3.6%	16	5.4%	6	4.3%	0.91 (0.634)	
Should EC be regulated like cigarettes and other tobacco products? (Yes)	407	64.5%	130	67.0%	189	63.9%	88	62.4%	0.86 (0.651)	
Do you think ECs are as addictive as tobacco cigarettes? (Yes)	352	55.8%	116	59.8%	167	56.4%	69	48.9%	3.99 (0.136)	

Note regarding missing data: Percentages reflect the N in each column as a percentage of column/category total N (including non-responses to that item, rather than of the total number of responses on that particular item).

Note regarding multiple comparisons: Benjamini-Hochberg procedure was used to control the false discovery rate associated with multiple comparisons.

Bold text signifies the category of survey responses, indented beneath bold text.

* Significant at $p < .05$ level.

** Significant at $p < .01$ level.

*** Significant at $p < .001$ level.

Table 2

Smoking and E-cigarette use behavior while drinking alcohol (drinkers only).

	<u>All drinkers N = 437</u>		<u>Moderate drinkers N = 296 (67.7% of drinkers)</u>		<u>Binge drinkers N = 141 (32.3% of drinkers)</u>		χ^2 (p) Social vs. binge drinkers
	N	%	N	%	N	%	
Smoke cigarettes when drinking (Yes)	51	11.7%	25	8.4%	26	18.4%	8.31 (0.004)**
Number of cigarettes consumed when drinking							2.65 (0.266)
1–2	23	5.3%	14	4.7%	9	6.4%	
3–4	12	2.7%	4	1.4%	8	5.7%	
5 or more	16	3.7%	7	2.4%	9	6.4%	
Use EC when drinking (Yes)	21	4.8%	13	4.4%	8	5.7%	0.120 (0.729)
Smokers who use EC when drinking	6	1.4%	4	1.4%	2	1.4%	
Non-Smokers who use EC when drinking	15	3.4%	9	3.0%	6	4.2%	

**
Significant at p < .01 level.

Table 3

Alcohol and tobacco use by ever E-cigarette use.

	All drinkers N = 437		Never Tried EC		Tried EC		χ^2 (p)
			<i>N = 321 (73.5% of drinkers)</i>		<i>N = 116 (26.5% of drinkers)</i>		Never tried vs. tried
	N	%	N	%	N	%	
Quantity of alcohol consumed per episode							15.94 (0.001) **
1–2	147	33.6%	122	38.0%	25	21.6%	9.61 (0.002) **
3–4	149	34.1%	111	34.6%	38	32.8%	0.06 (0.810)
5–6	88	20.1%	56	17.4%	32	27.6%	4.84 (0.028) *
7 or more	53	12.1%	32	10.0%	21	18.1%	4.55 (0.033) *
Smoke cigarettes when drinking? (Yes)	51	11.7%	15	4.7%	36	31.0%	54.91 (< 0.001) ***

Bold text signifies the category of survey responses, indented beneath bold text.

* Significant at $p < .05$ level.** Significant at $p < .01$ level.*** Significant at $p < .001$ level.