HHS Public Access

Author manuscript

J Sleep Res. Author manuscript; available in PMC 2021 June 01.

Published in final edited form as:

J Sleep Res. 2020 June ; 29(3): e12902. doi:10.1111/jsr.12902.

Electronic Cigarette Use and Sleep Health in Young Adults

Emma I Brett, MS[1], **Mary Beth Miller, PhD**[2], **Eleanor L.S. Leavens, MS**[1,3], **Susanna V Lopez, MS**[1], **Theodore L. Wagener, PhD**[3,4], **Thad R Leffingwell, PhD**[1]

[1]Department of Psychology, Oklahoma State University, Stillwater, OK, USA

[2]University of Missouri School of Medicine, Columbia, MO

[3]Oklahoma Tobacco Research Center, Oklahoma City, OK

[4]Department of Pediatrics, University of Oklahoma Health Sciences Center, Oklahoma City, Oklahoma, USA

Summary

Poor sleep health is associated with numerous health concerns, and sleep problems are exacerbated by cigarette smoking. While rates of traditional tobacco use are declining, rates of electronic cigarette (e-cigarette) use are comparatively high and growing. Given that nicotine is a primary mechanism by which smoking negatively impacts sleep health, e-cigarette use may also be linked to poor sleep health; however, no research has investigated this association.

Participants were 1,664 college students, 40.9% of whom reported ever trying or currently using an e-cigarette. Questionnaires assessed demographic information, sleep health, and e-cigarette use status and patterns. All measures were completed remotely via a secure online survey. Analysis of covariance was used to compare the sleep health of daily/non-daily e-cigarette users to (a) non-users and (b) users of combustible cigarettes. Gender and drinks per week were included as covariates in analyses.

Current combustible and e-cigarette users reported significantly more sleep difficulties than never users. Users of e-cigarettes reported greater use of sleep medication than combustible cigarette users.

Similar to combustible cigarette smoking, e-cigarette use (vs. non-use) was associated with worse sleep health, even among nondaily e-cigarette users. These findings may indicate a need for assessment of and education on the role of e-cigarette use in sleep health among individuals who report experimentation with or current use of e-cigarettes. Future research should examine these relationships prospectively.

Corresponding author: Emma I. Brett, M.S., Oklahoma State University, Department of Psychology, 116 North Murray, Stillwater, OK 74078, emma.brett@okstate.edu, 773-981-3662.

Contributors: EB and MM conceptualized the study. EL oversaw data collection. EB conducted data analyses. EB, MM, EL, SL, and TW wrote sections of the manuscript and TL provided final edits. All authors contributed to interpretation of results and revisions of the manuscript and approve the final manuscript.

Conflict of Interest: Emma I. Brett has none to declare. Mary Beth Miller has none to declare. Eleanor L. S. Leavens has none to declare. Susanna V. Lopez has none to declare. Theodore L. Wagener has none to declare but would like to acknowledge that part of his salary support is provided by the Oklahoma Tobacco Research Center, which is provided funding from the Oklahoma Tobacco Settlement Endowment Trust. Thad R. Leffingwell has none to declare.

Keywords

ENDS; nicotine; college students; sleep quality; insomnia

INTRODUCTION

While current (past 30 day) use of cigarette smoking is at a historic low among young adults in the United States, use of electronic cigarettes has risen in recent years to comparatively high rates (Schulenberg, Johnston, O'Malley, Bachman, Miech, & Patrick, 2017). Typical electronic cigarettes, or "e-cigarettes," deliver nicotine to the user by heating a combination of nicotine, flavorants, and propylene glycol and vegetable glycerine. Their safety and utility has been debated, inciting both support and opposition (Hajek, Etter, Benowitz, Eissenberg, & McRobbie, 2014; Wagener, Siegel, & Borrelli, 2012; Wagener, Meier, Tackett, Matheny, & Pechacek, 2015). This is due in part to a lack of empirical evidence regarding the long-term risk and safety of e-cigarettes, particularly among adolescents and young adults. Indeed, less than one in three young adults between 18–30 years (16–28%) indicates that regular use of e-cigarettes places the user at "great risk." In contrast, 50–85% agree that regular use of smokeless tobacco or combustible cigarettes incurs great risk (Schulenberg et al., 2017), demonstrating that young adults perceive e-cigarattes as less risky than other forms of tobacco use. Additional research documenting the risks and benefits of e-cigarette use among young adults are needed to inform prevention and intervention efforts within this population.

One potential consequence of e-cigarette use that has not been examined in the literature is poor sleep health. Poor sleep health – defined as sleep of inadequate quality, timing, efficiency, or duration to prevent daytime sleepiness – has been identified as a public health issue in the United States (Barnes & Drake, 2015; Buysse, 2014). Regularly sleeping fewer than seven hours, for example, has been associated with consequences ranging from increased risk of motor vehicle accidents to hypertension and depression (Watson et al., 2015). Poor sleep health is particularly common among college students, 60% of whom report "poor quality" sleep and 10% of whom meet diagnostic criteria for insomnia disorder (Lund, Reider, Whiting, & Prichard, 2010; Taylor, Bramoweth, Grieser, Tatum, & Roane, 2013).

The effect of combustible cigarette use on sleep has been well-established. Cigarette use has been associated with poor sleep health in national samples of adolescents (Terry-McElrath, Maslowsky, O'Malley, Schulenberg, & Johnston, 2016) and adults (McNamara et al., 2014; Sabanayagam & Shankar, 2011), including college students (Boehm, Lei, Lloyd, & Prichard, 2016). A population-based case-control study using the Pittsburgh Sleep Quality Index (PSQI; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) found significant differences in global sleep score between smokers and non-smokers, with current smokers exhibiting more sleep disturbance (Cohrs et al., 2014). Studies examining the effect of nicotine on sleep measured using polysomnography indicate increases in sleep onset latency, reductions in rapid eye movement sleep, and decreases in total sleep time (Jaehne, Loessl, Barkai, Riemann, & Hornyak, 2009). Moreover, compared to non-smokers, current smokers (~21

cigarettes per day) demonstrate shorter sleep times, longer sleep onset latency, more sleep apneas, and more leg movements during sleep (Jaehne et al., 2012). Sleeping difficulties can also exacerbate nicotine withdrawal symptoms, leading to potential increased risk for relapse among those trying to quit smoking (Jaehne et al., 2009), though findings also indicate that sleep disturbance related to nicotine withdrawal subsides after 10 days (Shiffman et al., 2006). The pharmacological effects of nicotine are purported to drive these associations, as nicotine has detrimental effects on the neurotransmitters that regulate the sleep-wake cycle (Sabanayagam & Shankar, 2011; Zhang, Samet, Caffo, & Punjabi, 2006). Given this proposed mechanism, nicotinized e-cigarettes, which deliver cigarette-like levels of nicotine (Ramôa et al., 2015; Wagener et al., 2016; Goniewicz, Kuma, Gawron, Knysak, & Kosmider, 2013; Stiles et al., 2018), may also be linked to poor sleep health. However, the effects of e-cigarette use on sleep health remain unknown.

The current study aimed to determine the impact of e-cigarette use on self-reported sleep health among young adults in college. Given the negative effect of nicotine on sleep architecture (Jaehne et al., 2009), we hypothesized that daily and nondaily e-cigarette users would report similar sleep health compared to combustible cigarette smokers, but worse sleep health than non-users. To determine the specific components of sleep health that are impacted by e-cigarette use (e.g., difficulties with sleep onset, sleep disturbance in the middle of the night, poor subjective sleep quality), group differences in both global sleep score and component sleep scores on the Pittsburgh Sleep Quality Index (PSQI) were examined.

METHODS

Participants and procedures

Undergraduate students from a large, Midwestern university self-selected into the study from a list of other studies through the university's online research recruitment system. Eligible participants were at least 18 years of age. They completed the online study anonymously after providing informed consent; all measures were self-report and completed remotely. Participants were compensated with course credit(s). All study procedures were approved by the university's Institutional Review Board of Human Subjects Research (#AS1584).

Measures

Demographics.—Participants responded to demographic questions assessing gender, age, race/ethnicity, class standing, student status (i.e., full-time or part-time), marital status (i.e. never married, married or engaged, divorced, separated, common law marriage, domestic partnership, widowed, live with same sex partner, live with opposite sex partner), income level, and current living situation (i.e. residence hall/dorm, Fraternity/Sorority house, off campus, with parents, and other). Affiliation with Greek organizations, which are social organizations for male and female college students where members often live in Greek-specific housing, organize social events, and participate in community service, was also assessed given that Greek status has been associated with e-cigarette use (Sutfin, McCoy, Morrell, Hoeppner, & Wolfson, 2013).

Sleep patterns and quality.—Participants reported quality and patterns of sleep via the Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989). This self-report measure contains 19 items assessing sleep health through seven components with scores ranging from 0–3: (1) subjective sleep quality, (2) sleep latency, (3) sleep duration, (4) habitual sleep efficiency, (5) sleep disturbances, (6) use of sleeping medication, and (7) daytime dysfunction. Items from all components were summed to create a global score with values ranging from 0–21, with higher scores indicating worse sleep health. Scores greater than 5 demonstrate 99% sensitivity and 84% specificity among patients with primary insomnia (Backhaus et al., 2002). This measure also assessed past-month experience of sleeping problems, such as difficulties sleeping due to pain, difficulty breathing, and nighttime awakenings. The PSQI has demonstrated reliability across a four week time period and has been frequently used within college student samples (Lund, Reider, Whiting, & Prichard, 2010; Becker et al., 2018).

Tobacco/nicotine product use.—Participants responded to self-report items about e-cigarette and combustible cigarette use. These items assessed product ever use (“Have you ever tried [product]?”) with the response options of “never tried,” “tried before, but never used regularly,” “at least once each year, but not monthly,” “at least once each month, but not weekly,” “at least once each week, but not daily,” and “at least once each day, or most days each month.” Products assessed included cig-a-like (looks like a cigarette) and tank style (looks like a pen) e-cigarettes as well as combustible cigarettes. Images of products were also presented to increase clarity. For analyses, cig-a-like and tank style e-cigarettes were collapsed to create a general e-cigarette category. Daily e-cigarette users were classified as those who reported using either a cig-a-like and/or tank style e-cigarette at least once each day while nondaily users were classified as those who reported regular weekly or monthly use. Regular combustible cigarette smokers were those who reported smoking daily or weekly given established associations between daily and non-daily cigarette use and sleep disturbance (McNamara et al., 2014). Participants who reported using both combustible and e-cigarettes (n = 525) were excluded from primary analyses to avoid confounding results. Additionally, those who reported trying but not currently using a product were also excluded from primary analysis groups.

Alcohol use.—To assess alcohol use, one set of items from the Daily Drinking Questionnaire (DDQ; Collins, Parks, & Marlatt, 1985) was used to assess the number of standard drinks consumed for each day in a typical week. The seven values were then summed to create a total score indicating number of drinks consumed per week. The DDQ has been a widely used self-report measure of alcohol use among college students (e.g., Lindren, Neighbors, Wiers, Gasser, & Teachman, 2015; Larimer et al., 2007).

Validity Items.—At the end of the survey, participants were asked to respond to two face valid self-report items that asked if they responded randomly or dishonestly (“I answered items randomly without reading the items,” and “I answered all items honestly and accurately”). Participants who selected “true” to the first item and “false” to the second item were excluded from analyses.

Data Analytic Plan

Prior to analyses, data were screened for missingness and outliers. Participants who admitted random (n = 94) or dishonest (n = 37) responding and those who did not complete the outcome measure (n = 85) were excluded. Outliers (n = 19) for drinks per week were replaced with the value three standard deviation and one integer above the mean (Tabachnick & Fidell, 2007). A one-way analysis of covariance (ANCOVA) was conducted to examine group differences in global sleep score between current daily, nondaily, and never users of e-cigarettes. Then, a multivariate analysis of covariance (MANOVA) was conducted to examine differences in specific components of sleep health between the above groups. Next, both analyses were replicated for examining differences in sleep between never users, regular e-cigarette users (e.g., daily or weekly users), and regular (daily or weekly) combustible cigarette users All analyses included gender and drinks per week as covariates based on research suggesting that associations between cigarette use and sleep may be partially explained by alcohol use (Hayley, Stough, & Downey, 2017). Planned comparisons were conducted to determine the nature of group differences.

RESULTS

Participant demographics

The final sample included 1,664 college students with a mean age of 19.7 (SD = 2.5) years. The majority of participants were Caucasian (76.2%), female (66.3%), and underclassmen (72.7%; see Table 1). Nine hundred eighty four participants (59%) reported never using an e-cigarette. Five hundred forty-six participants (33%) reported ever trying an e-cigarette, while 134 (8%) reported e-cigarette use at least once each month. A number of participants reported trying or using combustible cigarettes (n = 482; see Table 1). Participants reported consuming an average of 4.1 alcoholic drinks per week. They reported an average global sleep score of 5.8, indicating overall poor sleep quality.

Primary Analyses

To determine the extent to which global sleep health may differ among e-cigarette users and never users, a one-way ANCOVA compared the global sleep scores of current daily and nondaily users of e-cigarettes to that of never users. There were significant differences in global sleep scores between groups, $F(2, 928) = 5.25$, $p = .005$, partial $\eta^2 = .01$. Planned pairwise comparisons revealed significantly lower global sleep scores (indicating better sleep health) among never users compared to both nondaily ($p = .018$) and daily ($p = .015$; see Table 2 for group means). No significant differences emerged between nondaily and daily users. Given significant group differences in global sleep scores, we conducted a MANCOVA to determine group differences in the specific aspects of sleep disturbance (e.g., difficulty with sleep onset latency, short sleep duration, poor subjective sleep quality; see Table 2) that drive global sleep scores. Using Wilks' Lambda, there were significant overall differences in component scores between groups [$\lambda = 0.97$, $F(14, 1{,}844) = 1.92$, $p = .020$, partial $\eta^2 = 0.01$]. Univariate ANOVAs indicated significant group differences for subjective sleep quality [$F(2, 928) = 6.51$, $p = .002$, partial $\eta^2 = .014$] and use of sleep medication [$F(2, 928) = 5.19$, $p = .006$, partial $\eta^2 = .011$] such that never users demonstrated lower scores (indicating better sleep help) than comparison groups.

A second one-way ANCOVA was conducted comparing global sleep scores of never users, regular e-cigarette (e.g., daily and weekly), and regular combustible cigarette users. There were significant differences in global sleep scores between groups, $F(2, 925) = 10.34$, $p < .00$, partial $\eta^2 = 02$. Global sleep scores were significantly lower (indicating better sleep health) among never users compared to both e-cigarette ($p < .00$) and cigarette ($p = .01$; see Table 3 for group means) users. Again, using MANCOVA to determine group differences in component scores, significant differences were found between groups [$\lambda = 0.96$, $F(14, 1,838) = 2.62$, $p = .001$, partial $\eta^2 = 0.02$]. Univariate ANOVAs indicated significant group differences for subjective sleep quality [$F(2, 925) = 5.92$, $p = .003$, partial $\eta^2 = .013$], sleep disturbances [$F(2, 925) = 7.72$, $p < .00$, partial $\eta^2 = .016$], and use of sleep medication [$F(2, 925) = 6.80$, $p = .001$, partial $\eta^2 = .014$] such that never users demonstrated better scores than comparison groups and for use of sleep medication, both never users and combustible users demonstrated lower scores than e-cigarette users. See Tables 2 and 3 for values for all mean values and pairwise comparisons.

DISCUSSION

The current study is the first to examine the association between e-cigarette use and sleep health among college students. This area of research is particularly important, given the growing prevalence of e-cigarette use and potential co-occurrence with sleep difficulties within this population. Across all groups, mean global sleep score was well above 5, suggesting generally poor sleep as consistent with prior research documenting clinically significant sleep problems in college student populations (Becker et al., 2018). Global sleep health differed between never users, nondaily users, and daily e-cigarette users, such that nondaily and daily users of e-cigarettes reported significantly worse sleep health than never users. As predicted, combustible cigarette smokers also reported significantly worse global sleep health than never users, suggesting that combustible smokers (similar to e-cigarette users) experience more sleep difficulties than never users. In terms of the specific sleep patterns that drive global sleep health, never users reported fewer sleep disturbances (e.g., waking up throughout the night, difficulty breathing, bad dreams) and better subjective sleep quality than e-cigarette and combustible cigarette groups as well as less use of sleep medication than regular e-cigarette users. Collectively, these data suggest that both e-cigarette and combustible cigarette use are linked to worse sleep health among young adults in college.

Similar to combustible cigarette smoking, e-cigarette use may have a negative impact on sleep health, even among individuals who use e-cigarettes irregularly. Nondaily users of e-cigarettes reported worse global sleep, subjective sleep quality, and increased use of sleep medication than never users, suggesting that even such occasional exposure to nicotine may contribute to the development of disruptions in sleep. Therefore, it is possible that any use of e-cigarettes is a risk factor for the development of sleep problems through greater exposure to nicotine, with even sporadic use being disruptive enough to establish problematic sleep patterns, including relying on sleep medication to aid sleep. Prospective data including assessment of sleeping medications/aids are needed to test this hypothesis.

Surprisingly, e-cigarette users reported greater use of sleep medication than combustible cigarette smokers in the current sample. Since e-cigarette use could result in nicotine exposure at levels comparable to combustible cigarettes (Vansickel & Eissenberg, 2012), this could be because regular users of e-cigarettes may be able to use their devices more frequently due to ease and convenience of use and decreased likelihood of being impacted by campus smoking bans. Findings indicate that e-cigarette use may differentially impact certain components of sleep, with differences seen in sleep quality, nighttime sleep disturbance, and use of sleep medication. Future research using longitudinal designs can determine which aspects of sleep health are most negatively impacted by tobacco use over time. Also, research has shown relationships between psychiatric concerns and other substances, such as alcohol, and poor sleep (Bandiera, Loukas, Li, Wilkinson, & Perry, 2017; Van Reen, Roane, Barker, McGeary, Borsari, & Carskadon et al., 2016; Pieters et al., 2015), with some finding that alcohol use may partially explain associations between cigarette smoking and poor sleep (Hayley, Stough, & Downey, 2017). The results of the current study remained after controlling for alcohol use, suggesting an association between e-cigarette use and sleep independent of alcohol consumption. Future research should replicate this finding and examine associations by varying levels of drinking severity. Finally, the current study did not assess psychiatric diagnoses, which may be an important variable for understanding how e-cigarette use and sleep disturbance are related.

Given the association between e-cigarette use and poor sleep health, assessment of and education on sleep health in individuals who report e-cigarette use may be warranted. Information on relationships between e-cigarette use and sleep can be incorporated into prevention efforts as well as interventions that encourage switching to e-cigarette use as an alternative to combustible smoking. Providing such information to those who are considering transitioning from cigarettes to e-cigarettes may help promote behavior changes consistent with sleep health or prevent future sleep difficulties from occurring.

While the current study begins to fill an important gap in the literature, it is not without limitations. First, the sample consisted of college students who were primarily Caucasian and female. Therefore, it is unclear whether the findings will generalize to other, more diverse populations, such as individuals in the community or heavy-smoking groups. Second, less than 10% of the sample reported current e-cigarette use. Future research should examine these relations in a sample with a greater proportion of established e-cigarette users as well as regular e-cigarette users who have quit smoking. Also, the study was cross-sectional in design, which precludes examination of causal relationships; it is possible that other factors, such as poorer general health, may partially explain these associations. Research within the combustible cigarette literature posits that sleeping deficits impact executive functioning, which prospectively contributes to substance use (Pasch, Latimer, Cance, Moe, & Lytle, 2012; Pieters et al., 2015). Given the cross-sectional nature of the current study, temporal relationships cannot be determined; thus, it is possible that sleep difficulties are predictive of e-cigarette use.

Future studies examining the temporal, prospective associations between e-cigarette use and sleep disturbance are encouraged. Shifts in sleep rhythm, such as social jet lag, impact a variety of health factors (Beauvalet, Quiles, & Braga de Oliveira, 2017) and may also be an

important factor to consider in evaluating e-cigarette use and sleep. Additionally, studies should further evaluate sleep health and e-cigarette use in the context of other substance use, such as marijuana, alcohol, caffeine, and illicit drugs, as all of these drugs may also impact sleep quality. Likewise, the current study did not assess e-cigarette nicotine concentration or include biomarkers of nicotine. Rates of non-nicotinized e-liquid use continue to decline and were therefore likely very low in the current study (Morean, Kong, Cavallo, Camenga, & Krishnan-Sarin, 2016); however, given the effect of nicotine on sleep, objective assessment of the nicotine concentrations of e-liquids is a critical step for future research. In particular, research examining the magnitude and dose-response of relationships between various e-liquid concentrations and sleep is encouraged. Further, the assessment of other conditions related to sleep, such as obstructive sleep apnea and restless leg syndrome along with more information on the use of sleep medication and broad health factors should be incorporated in future research. Finally, the current study did not assess for psychiatric comorbidities, such as depression and anxiety, though research has demonstrated associations between e-cigarette use and psychiatric concerns within college students (Boehm et al., 2016; Bandiera et al., 2017). It is possible the mental health status could partially explain the reported relations between e-cigarette use and sleep disturbance.

The current study is the first to investigate the relation between e-cigarette use and sleep disturbance among college students and begins to fill an important gap in the literature. Similar to combustible cigarette smokers, e-cigarette users reported worse sleep that never users. Research examining the temporal associations between these variables, as well as their mechanisms of effect, are needed. Additional variables, such as psychiatric comorbidities and e-liquid nicotine concentration, will be important to include in future studies examining relationships between sleep and e-cigarette use in college student populations. Future research should also incorporate objective measures of nicotine exposure and alcohol use. Given the prevalence and negative impact of poor sleep health among young adults, tobacco prevention and intervention efforts may highlight the negative impact of e-cigarette use on sleep health within this population.

Acknowledgements:

Part of Dr. Wagener’s salary support is provided by the Oklahoma Tobacco Research Center, which is provided funding from the Oklahoma Tobacco Settlement Endowment Trust.

References

Backhaus J, Junghanns K, Broocks A, Riemann D, & Hoghagen F (2002). Test-retest reliability and validity of the Pittsburgh Sleep Quality Index in primary insomnia. Journal of Psychosomatic Research, 53(3), 737–740. 10.1016/S0022-3999(02)00330-6 [PubMed: 12217446]

Bandiera FC, Loukas A, Li X, Wilkinson AV, & Perry CL (2017). Depressive symptoms predict current e-cigarette use among college students in texas. Nicotine & Tobacco Research, 19(9), 1102–1106. [PubMed: 28199689]

Barnes CM, & Drake CL (2015). Prioritizing sleep health: public health policy recommendations. Perspectives on Psychological Science, 10(6), 733–737. [PubMed: 26581727]

Beauvalet JC, Luísa Quiles C, & Alves Braga de Oliveira M (2017). Social jetlag in health and behavioral research: a systematic review. ChronoPhysiology and Therapy, 7, 19–31.

Becker SP, Jarrett MA, Luebbe AM, Garner AA, Burns GL, & Kofler MJ (2018). Sleep in a large, multi-university sample of college students: sleep problem prevalence, sex differences, and mental health correlates. Sleep Health, 4(2), 174–181. [PubMed: 29555131]

Boehm MA, Lei QM, Lloyd RM, & Prichard JR (2016). Depression, anxiety, and tobacco use: Overlapping impediments to sleep in a national sample of college students. Journal of American College Health, 64(7), 565–574. [PubMed: 27347758]

Buysse DJ (2014). Sleep health: can we define it? Does it matter?. Sleep, 37(1), 9–17. [PubMed: 24470692]

Buysse DJ, Reynolds CF III, Monk TH, Berman SR, & Kupfer DJ (1989). The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatry Research, 28(2), 193–213. [PubMed: 2748771]

Cohrs S, Rodenbeck A, Riemann D, Szagun B, Jaehne A, Brinkmeyer J, Gründer G, Wienker T, Diaz-Lacava A, Mobascher A, & Dahmen N (2014). Impaired sleep quality and sleep duration in smokers—results from the German Multicenter Study on Nicotine Dependence. Addiction Biology, 19(3), 486–496. [PubMed: 22913370]

Collins RL, Parks GA, & Marlatt GA (1985). Social determinants of alcohol consumption: The effects of social interaction and model status on the self-administration of alcohol. Journal of Consulting and Clinical Psychology, 53(2), 189. [PubMed: 3998247]

Goniewicz ML, Kuma T, Gawron M, Knysak J, & Kosmider L (2013). Nicotine levels in electronic cigarettes. Nicotine & Tobacco Research, 15(1), 158–166. [PubMed: 22529223]

Hajek P, Etter JF, Benowitz N, Eissenberg T, & McRobbie H (2014). Electronic cigarettes: review of use, content, safety, effects on smokers and potential for harm and benefit. Addiction, 109(11), 1801–1810. [PubMed: 25078252]

Hayley AC, Stough C, & Downey LA (2017). DSM-5 Tobacco Use Disorder and Sleep Disturbance: Findings from the National Epidemiologic Survey on Alcohol and Related Conditions-III (NESARC-III). Substance Use & Misuse, 52(14), 1859–1870. [PubMed: 28777674]

Jaehne A, Loessl B, Bárkai Z, Riemann D, & Hornyak M (2009). Effects of nicotine on sleep during consumption, withdrawal and replacement therapy. Sleep Medicine Reviews, 13(5), 363–377. [PubMed: 19345124]

Jaehne A, Unbehaun T, Feige B, Lutz UC, Batra A, & Riemann D (2012). How smoking affects sleep: a polysomnographical analysis. Sleep Medicine, 13(10), 1286–1292. [PubMed: 23026505]

Larimer ME, Lee CM, Kilmer JR, Fabiano PM, Stark CB, Geisner IM, & … Neighbors C (2007). Personalized mailed feedback for college drinking prevention: A randomized clinical trial. Journal Of Consulting And Clinical Psychology, 75(2), 285–293. [PubMed: 17469886]

Lindgren KP, Neighbors C, Wiers RW, Gasser ML, & Teachman BA (2015). Evaluating implicit drinking identity as a mediator of drinking motives and alcohol consumption and craving. Addictive Behaviors, 4333–38.

Lund HG, Reider BD, Whiting AB, & Prichard JR (2010). Sleep patterns and predictors of disturbed sleep in a large population of college students. Journal of Adolescent Health, 46(2), 124–132. [PubMed: 20113918]

McNamara JP, Wang J, Holiday DB, Warren JY, Paradoa M, Balkhi AM, Fernandez-Baca J, & McCrae CS (2014). Sleep disturbances associated with cigarette smoking. Psychology, Health & Medicine, 19(4), 410–419.

Morean ME, Kong G, Cavallo DA, Camenga DR, & Krishnan-Sarin S (2016). Nicotine concentration of e-cigarettes used by adolescents. Drug and Alcohol Dependence, 167, 224–227. [PubMed: 27592270]

Pasch KE, Latimer LA, Cance JD, Moe SG, & Lytle LA (2012). Longitudinal bi-directional relationships between sleep and youth substance use. Journal of youth and adolescence, 41(9), 1184–1196. [PubMed: 22752878]

Pieters S, Burk WJ, Van der Vorst H, Dahl RE, Wiers RW, & Engels RC (2015). Prospective relationships between sleep problems and substance use, internalizing and externalizing problems. Journal of youth and adolescence, 44(2), 379–388. [PubMed: 25385390]

Ramôa CP, Hiler MM, Spindle TR, Lopez AA, Karaoghlanian N, Lipato T, Breland AB, Shihadeh A, & Eissenberg T (2015). Electronic cigarette nicotine delivery can exceed that of combustible cigarettes: a preliminary report. Tobacco control, tobaccocontrol-2015.

Sabanayagam C, & Shankar A (2011). The association between active smoking, smokeless tobacco, second-hand smoke exposure and insufficient sleep. Sleep Medicine, 12(1), 7–11. [PubMed: 21144798]

Schulenberg JE, Johnston LD, O'Malley PM, Bachman JG, Miech RA, & Patrick ME (2017). Monitoring the Future national survey results on drug use, 1975–2016: Volume II, college students and adults ages 19–55.

Shiffman S, Patten C, Gwaltney C, Paty J, Gnys M, Kassel J, Hickcox M, Waters A, & Balabanis M (2006). Natural history of nicotine withdrawal. Addiction, 101(12), 1822–1832. [PubMed: 17156182]

Stiles MF, Campbell LR, Jin T, Graff DW, Fant RV, & Henningfield JE (2018). Assessment of the abuse liability of three menthol Vuse Solo electronic cigarettes relative to combustible cigarettes and nicotine gum. Psychopharmacology, 1–10. [PubMed: 29178009]

Sutfin EL, McCoy TP, Morrell HE, Hoeppner BB, & Wolfson M (2013). Electronic cigarette use by college students. Drug and Alcohol Dependence, 131(3), 214–221. [PubMed: 23746429]

Tabachnick BG, & Fidell LS (2007). Using multivariate statistics (5th Ed.). New York, NY: Haper and Row.

Taylor DJ, Bramoweth AD, Grieser EA, Tatum JI, & Roane BM (2013). Epidemiology of insomnia in college students: relationship with mental health, quality of life, and substance use difficulties. Behavior Therapy, 44(3), 339–348. [PubMed: 23768662]

Terry-McElrath YM, Maslowsky J, O'Malley PM, Schulenberg JE, & Johnston LD (2016). Sleep and substance use among US adolescents, 1991–2014. American Journal of Health Behavior, 40(1), 77–91. [PubMed: 26685816]

Wagener TL, Floyd EL, Stepanov I, Driskill LM, Frank SG, Meier E, Leavens EL, Tackett AP, Molina N, & Queimado L (2016). Have combustible cigarettes met their match? The nicotine delivery profiles and harmful constituent exposures of second-generation and third-generation electronic cigarette users. Tobacco control, tobaccocontrol-2016.

Wagener TL, Meier E, Tackett AP, Matheny JD, & Pechacek TF (2015). A proposed collaboration against big tobacco: common ground between the vaping and public health community in the United States. Nicotine & Tobacco Research, 18(5), 730–736. [PubMed: 26508399]

Wagener TL, Siegel M, & Borrelli B (2012). Electronic cigarettes: achieving a balanced perspective. Addiction, 107(9), 1545–1548. [PubMed: 22471757]

Watson NF, Morgenthaler T, Chervin R, Carden K, Kirsch D, Kristo D, Malhotra R, Martin J, Ramar K, Rosen I, & Weaver T (2015). Confronting drowsy driving: the american academy of sleep medicine perspective. Journal of Clinical Sleep Medicine, 11(11), 1335–1336. [PubMed: 26414989]

Van Reen E, Roane BM, Barker DH, McGeary JE, Borsari B, & Carskadon MA (2016). Current alcohol use is associated with sleep patterns in first-year college students. Sleep, 39(6), 1321–1326. [PubMed: 27070138]

Vansickel AR, & Eissenberg T (2012). Electronic cigarettes: effective nicotine delivery after acute administration. Nicotine & Tobacco Research, 15(1), 267–270. [PubMed: 22311962]

Zhang L, Samet J, Caffo B, & Punjabi NM (2006). Cigarette smoking and nocturnal sleep architecture. American Journal of Epidemiology, 164(6), 529–537. [PubMed: 16829553]

Table 1.

Participant demographic information (N = 1664).

	M/N	SD/%
Age	19.69	2.48
Drinks Per Week	4.10	6.33
Global PSQI Score	5.78	3.22
Sleeping Problems		
Long Sleep Latency	1.22	1.08
Nighttime Awakenings	0.62	0.77
Nocturia	0.42	0.69
Difficulty Breathing	0.11	0.38
Coughing or Snoring	0.12	0.42
Felt Too Cold	0.28	0.57
Felt Too Hot	0.44	0.67
Had Bad Dreams	0.21	0.51
Had Pain	0.12	0.41
Use of Sleep Medication	0.33	0.74
Gender		
Male	560	33.7%
Female	1104	66.3%
Class Standing		
Freshman	714	42.9%
Sophomore	496	29.8%
Junior	256	15.4%
Senior	190	11.4%
Student Status		
Full-Time	1623	97.5%
Part-Time	41	2.5%
Race/Ethnicity		
Caucasian or White	1268	76.2%
American Indian	124	7.5%
African American	88	5.3%
Hispanic or Latino	71	4.3%
Asian	50	3.0%
Biracial	44	2.6%
Pacific Islander/Other	19	1.2%
Living Situation		
Residence hall/dorm	780	46.9
Fraternity/sorority house	268	16.1
Off campus	548	32.9
With parents	57	3.4
Other	11	0.7

	M/N	SD/%
Greek Affiliation		
Currently Affiliated	568	34.1%
Never Affiliated	989	59.4%
Marital Status		
Never Married	1533	92.1%
Married or engaged	56	3.4%
Live with partner/Domestic Partnership	68	4.0%
Income		
$0–19,999	173	10.4
$20,000–39,000	212	12.7
$40,000–59,000	230	13.8
$60,000–79,000	260	15.7
$80,000+	789	47.4
E-cigarette Use – cig-a-like		
Never tried	1,307	78.5%
Trier	317	19.0%
Nondaily user	32	1.9%
Daily user	8	0.5%
E-cigarette Use – tank style		
Never tried	1,058	63.6%
Trier	483	29.0%
Nondaily user	88	5.2%
Daily user	35	2.1%
Cigarette Use		
Never tried	1,182	71.0%
Trier	351	21.0%
Nondaily user	89	5.4%
Daily user	42	2.5%

Note. Sleeping Problems item responses ranged from 0 (Not experienced during the past month) to 3 (Experienced three or more times per week).

Table 2.

Differences in sleep health between never users (n = 827), nondaily e-cigarette users (n = 78), daily e-cigarette users (n = 28).

Group	M	SE	F	*p*	η_p^2
Global Score	6.26	0.25	5.25	.005	.011
Never user	5.51[a,b]	0.12			
Nondaily e-cig user	6.34[a]	0.37			
Daily e-cig user	6.90[b]	0.62			
Subjective sleep quality	1.12	0.05	6.51	.002	.014
Never user	0.93[c,d]	0.02			
Nondaily e-cig user	1.13[c]	0.08			
Daily e-cig user	1.32[d]	0.13			
Sleep latency	1.27	0.07	1.11	.330	.002
Never user	1.18	0.03			
Nondaily e-cig user	1.17	0.11			
Daily e-cig user	1.45	0.18			
Sleep duration	0.78	0.06	1.65	.193	.004
Never user	0.69	0.03			
Nondaily e-cig user	0.84	0.08			
Daily e-cig user	0.80	0.14			
Habitual sleep efficiency	0.59	0.06	1.47	.232	.003
Never user	0.47	0.03			
Nondaily e-cig user	0.56	0.10			
Daily e-cig user	0.73	0.16			
Sleep disturbances	1.23	0.05	2.63	.073	.006
Never user	1.12	0.02			
Nondaily e-cig user	1.22	0.07			
Daily e-cig user	1.34	0.11			
Use of sleeping medication	0.41	0.05	5.19	.006	.011
Never user	0.26[e]	0.03			
Nondaily e-cig user	0.53[e]	0.08			
Daily e-cig user	0.43	0.14			
Daytime dysfunction	0.87	0.06	1.24	.291	.003
Never user	0.79	0.03			
Nondaily e-cig user	0.93	0.09			
Daily e-cig user	0.91	0.15			

Note. Analyses control for gender and alcohol use. “Never user” refers to individuals who have never tried an e- or combustible cigarette, “nondaily e-cig user” refers to those who report regular weekly or monthly e-cigarette use but do not use daily, “daily e-cig user” refers to those who use e-cigarettes every day on most days, and “cigarette user” refers to someone who reports daily or weekly combustible cigarette use. Global score differences tested via ANCOVA while the components of sleep disturbance were tested using MANCOVA. Matching superscripts within each global and component score indicates significant pairwise comparisons at $p \leq .01$ for component scores (range from 0–3) and $p \leq .05$ for global score (range from 0–21).

Table 3.

Differences in sleep health between never users (n = 827), e-cigarette users (n = 54), and combustible cigarette smokers (n = 49).

Group	M	SE	F	*p*	η_p^2
Global Score	5.62	0.22	10.34	.000	.022
Never user	5.45[a,b]	0.11			
E-cig user	7.17[a]	0.44			
Cigarette user	6.73[b]	0.47			
Subjective sleep quality	1.08	0.05	5.92	.003	.013
Never user	0.98[c]	0.02			
E-cig user	1.24[c]	0.09			
Cigarette user	1.07	0.10			
Sleep latency	1.35	0.07	3.08	.046	.007
Never user	1.18	0.03			
E-cig user	1.39	0.13			
Cigarette user	1.49	0.14			
Sleep duration	0.81	0.05	2.64	.072	.006
Never user	0.69	0.03			
E-cig user	0.86	0.10			
Cigarette user	0.89	0.11			
Habitual sleep efficiency	0.66	0.06	4.32	.014	.009
Never user	0.48	0.03			
E-cig user	0.73	0.12			
Cigarette user	0.76	0.12			
Sleep disturbances	1.29	0.04	7.72	.000	.016
Never user	1.12[d,e]	0.02			
E-cig user	1.37[d]	0.08			
Cigarette user	1.37[e]	0.09			
Use of sleeping medication	0.39	0.05	6.80	.001	.014
Never user	0.26[f]	0.02			
E-cig user	0.63[f,g]	0.10			
Cigarette user	0.28[g]	0.10			
Daytime dysfunction	0.89	0.05	3.08	.046	.007
Never user	0.79[h]	0.03			
E-cig user	1.07[h]	0.11			
Cigarette user	0.82	0.11			

Note. Analyses control for gender and alcohol use. “Never user” refers to individuals who have never tried an e- or combustible cigarette, “e-cig user” refers to those who report regular daily or weekly e-cigarette use, and “cigarette user” refers to someone who reports regular daily or weekly combustible cigarette use. Global score differences tested via ANCOVA while the components of sleep disturbance were tested using MANCOVA. Matching superscripts within each global and component score indicates significant pairwise comparisons at $p \leq .01$ for component scores (range from 0–3) and $p \leq .05$ for global score (range from 0–21).