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Combustible and Electronic Cigarette Use and Insufficient Sleep among U.S. High School Students

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Abstract

The study aimed to investigate the relationships between current exclusive e-cigarette use, exclusive combustible cigarette smoking, and dual use of e-cigarettes and combustible cigarettes, and insufficient sleep among U.S. adolescents. We conducted a secondary data analysis of the 2017 Youth Risk Behavior Survey including 11,296 U.S. high school students. Current (past 30-day) tobacco use groups included exclusive e-cigarette users, exclusive combustible cigarette smokers, and dual-product users. We performed weighted unadjusted and adjusted logistic regression analyses. Insufficient sleep was defined as <8 hours/night and <7 hours/night. Overall, 73.4% of adolescents reported insufficient sleep <8 hours/night. Compared with non-tobacco users, exclusive e-cigarette users were more likely to report insufficient sleep <8 hours/night (odds ratio [OR]=1.55, 95%CI=1.12–2.14; adjusted OR [aOR]=1.57, 95%CI=1.01–2.43) and <7 hours/night (OR=1.55, 95%CI=1.19–2.01; aOR=1.61, 95%CI=1.16–2.24). Dual-product users were at increased odds to report insufficient sleep <8 hours/night (OR=3.15, 95%CI=1.87–5.32) and <7 hours/night (OR=2.64, 95%CI=1.87–3.72; aOR=1.73, 95%CI=1.14–2.62) than non-tobacco users.

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Conflicts of Interest: None

Exclusive combustible cigarette smokers were less likely to report insufficient sleep <8 hours/night (aOR=0.49, 95%CI=0.29–0.84) than non-tobacco users, but no differences were found based on insufficient sleep <7 hours/night. When comparing current use groups, exclusive e-cigarette users were at 3.20 increased odds (95%CI=1.65–6.22) and dual-product users were at 3.26 increased odds (95%CI=1.51–7.03) to report insufficient sleep <8 hours/night when compared with exclusive combustible cigarette smokers after covariate adjustment. Dual-product users were 1.89 times more likely (95%CI=1.01–3.51) to report insufficient sleep <7 hours/night when compared with exclusive combustible cigarette smokers. School-based prevention efforts for tobacco use may promote sufficient sleep in youth.

Keywords

sleep; electronic nicotine delivery systems; combustible cigarette smoking; adolescent; Youth Risk Behavior Survey

INTRODUCTION

Electronic cigarettes (e-cigarettes) remain the most widely used tobacco product (past 30-day use: 27.5%) among U.S. adolescents followed by combustible cigarettes (past 30-day use: 5.8%).^{1,2} While these trends illustrate combustible cigarette smoking is at an all-time low, adolescent e-cigarette use is increasing despite reaching epidemic levels in 2018.³ Among adolescent current (past 30-day) e-cigarette users, 34.2% reported using on 20 days.² Dual use of e-cigarettes and combustible cigarettes is also prevalent.^{1,4}

Combustible cigarettes contain nicotine, which is an unsafe and addictive chemical that has long-term effects on the developing adolescent brain and behavior.⁵ Most e-cigarettes contain varying nicotine amounts.^{6,7} Concerning adolescent current users, about 6-in-10 report their usual brand device is JUUL,² which delivers high nicotine concentrations of about 56mg/mL per pod in salt form.⁸ The health effects of combustible cigarette smoking are well documented.⁹ Contrarily, consequences of e-cigarettes remained understudied.⁷ Reviews of longitudinal studies indicate that adolescent e-cigarette users are more likely to progress to subsequent use of combustible cigarettes.^{6,10} Reasons for this progression include: accessibility of combustible cigarettes from friends or family members who smoke or retailers that sell both products; increased risk of substituting combustible cigarettes for e-cigarettes when unavailable or inaccessible; and sensation seeking due to the pharmacological effect of nicotine that e-cigarette users may expect from combustible cigarettes.^{6,10}

Adolescent combustible cigarette smoking is associated with poor sleep health.^{11–15} Consequently, over 7-in-10 students report insufficient sleep on school nights,¹⁶ with 8–10 hours per 24 hours recommended to promote optimal health in 13–18-year-olds.¹⁷ Insufficient sleep has its own health consequences such as obesity, diabetes mellitus, and mental health and behavioral problems.¹⁸ Poor sleep can negatively affect cognitive development and functioning and school performance.^{19,20} Polysomnographic studies indicate nicotine use can have a negative impact on sleep including decreased sleep time, and increased sleep onset latency and rapid eye-movement sleep latency.²¹ Studies suggest

e-cigarette use is associated with sleep-related complaints and difficulties (e.g., short duration) in adolescents²² and young adults.²³ E-cigarette and combustible cigarette induced oxidative stress may affect sleep quality during adolescence.²⁴ Other research demonstrates mixed findings between adolescent tobacco use and sleep problems.^{25–27} Given that e-cigarettes and combustible cigarettes are the most commonly reported combination of tobacco products used among adolescents,¹ clarifying the relationship between combustible cigarette smoking, e-cigarette use, and dual-product use may inform the potential benefits of programming to promote tobacco prevention and cessation on sleep sufficiency in this population.

This study investigated the association of current exclusive e-cigarette use, exclusive combustible cigarette smoking, and dual use of e-cigarettes and combustible cigarettes, with insufficient sleep among U.S. high school students. We hypothesized that e-cigarette users, combustible cigarette smokers, and dual-product users would be at increased odds of reporting insufficient sleep compared to non-tobacco users. We also posited that dual-product users would be at increased odds of reporting insufficient sleep compared with e-cigarette users and combustible cigarette smokers.

METHODS

Participants and Procedures

We conducted a secondary analysis of the 2017 Youth Risk Behavior Survey (YRBS) national data.²⁸ The national YRBS is a school-based survey conducted among a U.S. representative sample of high school students by the Centers for Disease Control and Prevention (CDC).²⁹ The national YRBS, along with state and large urban school district level YRBSs, is included in the CDC's Youth Risk Behavior Surveillance System to monitor priority health behaviors including tobacco use. An institutional review board (IRB) exempted this study from review due to using publicly available, de-identified data.

YRBS details are available elsewhere.²⁹ In brief, the 2017 YRBS used a three-stage cluster sample design to select and recruit students enrolled in grades 9–12 at public and private schools. CDC IRB-approved parental permission procedures were followed prior to student survey completion.²⁹ The overall 2017 YRBS response rate was 60%, including the overall school (75%) and student (81%) response rates.²⁹

We included 11,296 students in our main analyses after excluding those with missing information on age and past 30-day e-cigarette and combustible cigarette use ($n=1,583$). We yielded an analytic sample of 12,879 in our sensitivity analyses while imputing missing data. For all analyses, we excluded the 1,886 participants 12 years old or missing information on or who used cigars and/or smokeless tobacco. We limited our study to 13–18-year-olds due to varying sleep recommendations for other ages.¹⁷ We excluded participants who engaged in other current tobacco product use to focus exclusively on e-cigarette and combustible cigarette use. We performed a sensitivity analysis between those excluded and included based on sleep and participant characteristics, and no significant differences were found.

Measures

E-cigarette and Combustible Cigarette Variables—Adolescents reported how many days they used e-cigarettes and combustible cigarettes: 0, 1–2, 3–5, 6–9, 10–19, 20–29, and 30 days. Due to the categorical nature of original responses, we used YRBS-recoded variables³¹ that dichotomized use into no (0 days) and yes (≥ 1 day) to classify adolescents as: non-tobacco users, exclusive e-cigarette users, exclusive combustible cigarette smokers, and dual-product users.

Insufficient Sleep—Adolescents reported how many hours of sleep they got on an average school night with response options ranging from 4 hours to 10 hours. Based on the American Academy of Sleep Medicine's¹⁷ sleep duration recommendations for 13–18-year-olds, we dichotomized the variable into: ≥ 8 hours/night (sufficient sleep) and <8 hours/night (insufficient sleep). We considered variability in recommendations by performing sensitivity analyses using the National Sleep Foundation's³⁰ recommendations for 18-year-olds: ≥ 7 hours/night (sufficient sleep) and <7 hours/night (insufficient sleep).

Covariates—Demographics included sex, grade, and race/ethnicity (non-Hispanic white, black or African American, Asian, other race, Hispanic). Other race included American Indian/Alaska Native, Native Hawaiian/Other Pacific Islander, and multiple races.

Since electronic media and mental health issues have been associated with insufficient sleep,^{18,20} we included television watching and computer use for games or something other than school work on an average school day as covariates. We used YRBS-provided variables³¹ that dichotomized response options to align with recommended screen-time limits:³² <3 hours/day, ≥ 3 hours/day. We included a variable on whether adolescents had serious difficulty concentrating, remembering, or making decisions because of a current physical, mental, or emotional problem. Since alcohol^{18,26} and marijuana^{14,20,25} use have been associated with sleep disturbances, we included current alcohol and marijuana use as covariates.

Statistical Analysis

We performed analyses using R version 4.0.2., and followed the 2017 YRBS Data User Guide.³¹ We used the R “weights” package to apply appropriate weights to account for the sample design and obtain generalizable estimates to the U.S. student population. We calculated descriptive statistics for all variables of interest, which are presented as raw sample sizes with weighted percentages. We assessed differences between covariates and e-cigarette use and combustible cigarette smoking via χ^2 tests.

In order to assess the relationship between exclusive e-cigarette use, exclusive combustible cigarette smoking, and dual-product use and insufficient sleep, we fitted an unadjusted logistic regression model, using non-tobacco users as the reference category. Covariates were then entered into the model to better understand how they attenuated crude associations. To assess differences between current user groups in the same adjusted regression model, we used the R matrix of user-defined contrasts to assess three contrasts: exclusive e-cigarette users versus exclusive combustible cigarette smokers; exclusive e-

cigarette users versus dual users; and exclusive combustible cigarette smokers versus dual-product users. We conducted similar models with insufficient sleep defined as <7 hours/night. We used the R GLM function to conduct all weighted regression analyses. We present adjusted odds ratios and 95% confidence intervals. We set the *P*-value to 0.05 for statistical significance.

We tested the sensitivity of our findings by including missing data on e-cigarette use, combustible cigarette smoking, and the covariates in refitted regression models with the response variables as insufficient sleep <8 hours/night and <7 hours/night. We employed the R MICE function to use multiple imputation by chained equations with 10 imputations to account for missing data.³³ Polynomial regression was used in predictive mean matching due to the categorical nature of the imputed variables, and we present pooled estimates by averaging estimates from the 10 imputations.

RESULTS

Of the 11,296 adolescents in our main analysis, 53.6% were female, 53.4% were non-Hispanic white, and 22.1% were Hispanic (Table 1). Slightly more adolescents were in 9th grade (28.8%) than 12th grade (22.0%). One-fifth (20.0%) watched TV, and 43.9% used a computer for gaming or non-school related work for 3 hours/school day. About 3-in-10 adolescents (29.8%) had a physical, mental, or emotional problem that attributed to serious difficulty concentrating, remembering, or making decisions. One-in-five (20.1%) used alcohol and 12.1% used marijuana.

A total of 4.3% (*n*=566) were exclusive e-cigarette users, 1.4% (*n*=157) were exclusive combustible cigarette smokers, and 2.3% (*n*=235) were dual-product users. Among exclusive e-cigarette users, 81.3% (*n*=489) were non-frequent users (used 1–19 days), 6.5% (*n*=27) were frequent users (used 20–29 days), and 12.2% (*n*=50) were daily users (used 30 days). Among exclusive combustible cigarette smokers, 63.4% (*n*=117) were non-frequent smokers, 9.6% (*n*=10) were frequent smokers, and 27.0% (*n*=30) were daily smokers. Among dual-product users, 79.7% (*n*=185) and 78.5% (*n*=193) were non-frequent users, 6.1% (*n*=16) and 3.0% (*n*=9) were frequent users, and 14.2% (*n*=34) and 18.5% (*n*=33) were daily users of e-cigarettes and combustible cigarettes, respectively.

Sex, grade, race/ethnicity, alcohol use, marijuana use, and having a physical, mental, or emotional problem differed by exclusive e-cigarette use, exclusive combustible cigarette smoking, and dual-product use (Table 1). Females reported higher rates of combustible cigarette smoking and dual-product use. As grade increased, combustible cigarette smoking and dual-product use increased, while e-cigarette use varied. A high proportion of non-Hispanic white and Hispanic adolescents reported e-cigarette use, combustible cigarette smoking, and dual-product use. Physical, mental, or emotional problem rates varied with highest rates among combustible cigarette smokers and dual-product users. Alcohol and marijuana users had high rates of e-cigarette use, combustible cigarette smoking, and dual-product use.

Overall, 73.4% ($n=6,687$) of adolescents reported insufficient sleep <8 hours/night; 7.4% ($n=710$) slept 4 hours, 12.1% ($n=1,140$) slept five hours, 23.9% ($n=2,237$) slept six hours, 30.0% ($n=2,600$) slept seven hours, 20.6% ($n=1,803$) slept eight hours, 4.7% ($n=408$) slept nine hours, and 1.3% ($n=115$) slept 10 hours. High rates of insufficient sleep were reported among exclusive e-cigarette users (78.8%) and dual-product users (86.7%) (Table 2). Unadjusted results indicated exclusive e-cigarette users and dual-product users were 1.55 times (95% confidence interval [CI]=1.12–2.14) and 3.15 times (95%CI=1.87–5.32) more likely, respectively, to report insufficient sleep than non-tobacco users. Sensitivity analyses including participants with missing data yielded similar results (Supplement Table 1).

Adjusted model results, with non-tobacco users as the reference group, indicated exclusive e-cigarette users were 1.57 times more likely (95%CI=1.01–2.43) to report insufficient sleep than non-tobacco users. Exclusive combustible cigarette smokers were less likely to report insufficient sleep (adjusted odds ratio [aOR]=0.49, 95%CI=0.29–0.84) than non-tobacco users, while adjusting for covariates. Results from this adjusted model, with current user groups as the reference groups, indicated that exclusive e-cigarette users were 3.20 times more likely (95%CI=1.65–6.22) to report insufficient sleep than exclusive combustible cigarette smokers (Table 3). Dual-product users were 3.26 times more likely (95%CI=1.51–7.03) to report insufficient sleep than combustible cigarette smokers.

Sensitivity analyses including participants with missing data yielded varying significant results (see Supplement Table 1). Effect sizes remained similar, but significance was no longer detected among exclusive e-cigarette users or exclusive combustible cigarette smokers compared with non-users. Dual-product users were more likely (aOR=1.80, 95%CI=1.03–3.16) to report insufficient sleep <8 hours than non-tobacco users. Sensitivity analysis results, however, were similar when current user groups were the reference groups (Supplement Table 2)

Exclusive e-cigarette users (52.8%), exclusive cigarette smokers (51.1%) and dual-product users (61.0%) reported higher rates of insufficient sleep <7 hours/night than non-users (42.4%) (Table 4). Exclusive e-cigarette users (OR=1.55, 95%CI=1.19–2.01) and dual-product users (OR=2.64, 95%CI=1.87–3.72) were at increased odds to report insufficient sleep <7 hours/night than non-users, while no differences were found based on combustible cigarette smokers (OR=1.28, 95%CI=0.84–1.97). For the adjusted model, compared to non-users, exclusive e-cigarette users remained at increased odds to report insufficient sleep <7 hours (aOR=1.61, 95%CI=1.16–2.24), but no differences were found among exclusive combustible cigarette smokers. Dual-product users were 1.73 times more likely (95%CI=1.14–2.62) to report insufficient sleep <7 hours/night than non-users. For differences among current user groups, dual-product users were 1.89 times more likely (95%CI=1.01–3.51) to report insufficient sleep <7 hours/night than exclusive combustible cigarette smokers, but no difference was found between dual-product users and exclusive e-cigarette users (Table 5).

Sensitivity analyses including participants with missing data and insufficient sleep defined as <7 hours/night yielded similar results, with the exceptions of: exclusive e-cigarette users versus non-tobacco users (Supplement Table 3), and dual-product users versus exclusive

combustible cigarette smokers (Supplement Table 4). Sensitivity analysis results had similar effect sizes to the main results, but were no longer significant.

DISCUSSION

This study found that exclusive e-cigarette use is consistently associated with insufficient sleep among U.S. adolescents defined by the American Academy of Sleep Medicine (<8 hours)¹⁷ and National Sleep Foundation (<7 hours).³⁰ When compared with non-tobacco users, dual-product users showed: a positive, non-significant association with insufficient sleep <8 hours in the main adjusted model; a positive, significant association with insufficient sleep <8 hours in the sensitivity adjusted model including missing data; and significant positive associations in the main and sensitivity adjusted models with insufficient sleep defined as <7 hours. Our research fundamentally expands on prior mixed findings,^{11,22,26,27,34} by assessing current e-cigarette use and combustible cigarette smoking and insufficient sleep patterns. Another study using 2017 YRBS data also found that current alcohol users and marijuana users were more likely to report insufficient sleep.²⁵ Contrary to our results, the study reported no differences between current e-cigarette use, combustible cigarette smoking, and insufficient sleep.

There are several explanations for our varied findings. First, we used a different set of inclusion and exclusion criteria from the previous study. To exclude the potential confounding effect by other tobacco product use, we excluded students who used tobacco products other than e-cigarettes and combustible cigarettes. The previous study did not exclude these students, nor adjusted for other tobacco product use. Second, we examined e-cigarette use, combustible cigarette smoking, dual-product use, and non-tobacco use. The previous study did not examine the interaction of e-cigarette use and combustible cigarette smoking but adjusted for them in their analyses, i.e., averaged the e-cigarette use and sleep deficiency association across combustible cigarette smokers and non-smokers. Further, compared with combustible cigarette smokers, e-cigarette users had lower rates of TV watching, computer use, experiencing a physical, mental, or emotional problem, and marijuana use, but higher rates of alcohol use. Mental health issues and substance use are associated with sleep issues during adolescence, including reduced sleep durations.^{18,25,26}

We found that dual-product users had high prevalence of engaging in frequent and daily use, and combustible cigarette smokers had disproportionately high rates of frequent use, with nearly 3-in-10 reporting daily use. One potential reason for this finding is that combustible cigarette smokers may have greater exposure to nicotine than e-cigarette users. The varying nicotine content found in e-cigarettes may increase adolescents' frequency and intensity of e-cigarette use and subsequent combustible cigarette smoking.³⁵ Adolescents may use e-cigarettes to self-medicate and improve their mood, without knowing that nicotine may interrupt their sleep-wake cycle and decrease their sleep time. While this study was unable to determine brands used, JUUL Laboratories had a 515% increase in their average annual market share from 2016–2017, resulting in the largest share by end of 2017.³⁶ Since 2017, a great proportion of adolescents use JUUL, which has escalated quickly to epidemic rates.^{2,8} JUULs and other vape pod systems have high nicotine content resulting in higher median cotinine values than combustible cigarettes among adolescent users (245ng/ml⁸ vs.

155ng/ml,³⁷ respectively). While data on product type and nicotine content were not available, it is possible that the insufficient sleep differences observed in this study were due to higher nicotine exposure in the e-cigarette and dual-product use groups than combustible cigarette smokers. This is because nicotine, a stimulant, inhibits neurons in the ventrolateral preoptic area that is responsible for promoting sleep.³⁸

Overall, 73.4% of adolescents, irrespective of tobacco use, reported insufficient sleep with crude rates similar among non-tobacco users (72.8%) and combustible cigarette smokers (72.6%). Thus, we found high rates of insufficient sleep reported across groups, but also found combustible cigarette smokers had the lowest insufficient sleep rates compared with e-cigarette users and dual-product users. It is worth noting we found no differences between combustible cigarette smokers and non-tobacco users based on insufficient sleep, with the exception of combustible cigarette smokers being at decreased odds of reporting insufficient sleep <8 hours/night in the main adjusted model. Another explanation for our findings that vary from prior research^{11,22,25–27,34} is that sleep sufficiency is only one of many dimensions of sleep behavior, and it is important to consider sleep quality.¹⁸ Prior work found past year e-cigarette use and dual use of e-cigarettes and combustible cigarettes increased the odds of past year sleep complaints (e.g., sleeping restlessly), but no differences were detected based on combustible cigarette smoking after adjustment for sociodemographics, history of e-cigarette and cigarette use, sleep-related complaints, and emotional (depression, anxiety symptoms) and behavioral (alcohol use, marijuana use, social media use) health factors.²² Other research indicates a relationship between recent combustible cigarette smoking and sleep issues including chronic difficulty falling asleep.¹¹

Our findings suggest that school-based tobacco control programs may promote sleep health among adolescents. A frequent direct consequence of insufficient sleep is excessive daytime sleepiness, which has been associated with poor academic outcomes, behavioral health issues, and substance use.²⁰ Current tobacco use, especially e-cigarette and dual-product use, and insufficient sleep could be key targets of school prevention programming for students. Adolescents could be educated about the consequences of insufficient sleep and given guidance on increasing healthy sleep practices, such as: avoiding tobacco and other substance use; avoiding daytime naps; limiting TV/computer use before bedtime; developing a consistent bedtime routine that includes quiet and relaxing activities; and developing and adhering to a consistent bedtime schedule on school and weekend nights.²⁰ Prevention education starting as early as kindergarten through 12th grade is encouraged on the health dangers of combustible cigarette smoking on adolescent health including increased respiratory illness and impaired lung growth and function.⁵ Proactive education is encouraged on the addictive nature of e-cigarettes and combustible cigarettes, and the potential for use to act as a gateway to a sequence of substance use ranging from alcohol, marijuana,^{39,40} to harder illicit drugs.⁵ Students could be educated on accurate social norms of tobacco use and taught refusal skills. Programs that are supported by school policies, personnel, and families have more sustainable effects on preventing adolescent tobacco use.⁵ A comprehensive approach should be considered for adoption to teach students healthy behaviors such as avoiding tobacco use and getting sufficient sleep.

This study has strengths, including addressing an important gap on the association between the two most commonly used tobacco products, e-cigarettes and combustible cigarettes, and insufficient sleep among a large, nationally representative sample of students. Limitations of using these YRBS secondary data should be considered. We assessed cross-sectional relationships between current e-cigarette and combustible cigarette use, and longitudinal or causal relationships cannot be determined. We used YRBS-provided, self-reported items, and were unable to objectively measure sleep duration or tobacco use. Since YRBS asked one categorical question on average sleep quantity on school nights, we were unable to assess sleep hours continuously or during non-school nights, or sleep quality. We used the minimum recommended hours of sleep as cut-points, but were unable to consider and/or exclude adolescents with long sleep duration. Future research should consider excess sleep above the maximum recommended hours. Additionally, we were unable to account for other potential covariates that affect sleep such as caffeine intake and school start times.¹⁸ Variables on past 30-day e-cigarette and combustible cigarette use were categorical, thus we were unable to assess use continuously. Data were not collected on e-cigarette brand, device type, or device ingredients. The nicotine intake amount from e-cigarette use could not be assessed. Studies should consider using objective biochemical measures of current tobacco use with cotinine⁴¹ and sleep quantity and quality with actigraphy.⁴²

Conclusion

We investigated the associations between current exclusive e-cigarette use, exclusive combustible cigarette smoking, and dual-product use and insufficient sleep among U.S. students. Compared to non-tobacco users and combustible cigarette smokers, we report that e-cigarette users were at increased odds of reporting insufficient sleep, while taking into consideration important covariates. We report that dual-product users were at increased likelihood of reporting insufficient sleep than non-users and combustible cigarette smokers. Combustible cigarette smokers were at reduced likelihood to report insufficient sleep <8 hours/night after covariate adjustment in our main analysis. As outlined by the U.S. FDA,⁴³ prevention efforts are critically needed to reduce the rise in adolescent tobacco use trends due to the surge in e-cigarette use. School-based prevention initiatives for tobacco use may improve sleep health, which is a Healthy People 2020 goal.⁴⁴ Families should be included in these efforts, since they can play a key role in promoting ideal sleep health at home. Families should be educated on how to talk to their children about tobacco use and how to intervene when their child is using tobacco. Longitudinal studies may provide insight into how tobacco use influences sleep health over time.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights

- Tobacco use and insufficient sleep are prevalent problems facing adolescents.
- Insufficient sleep is more prevalent in e-cigarette users than non-tobacco users.
- Insufficient sleep is prevalent in dual users of e-cigarettes and cigarettes.
- E-cigarette users are more likely to have insufficient sleep than cigarette users.
- Dual-product users are more likely to have insufficient sleep than cigarette users.

Table 1.

Characteristics of U.S. High School Students According to Current Exclusive E-Cigarette Use, Exclusive Combustible Cigarette Smoking, and Dual-Product Use, 2017 YRBS

Participant Characteristics	Current E-Cigarette Use and Combustible Cigarette Smoking				P-Value
	Overall (N=11,296) n (%) ^a	Non-Tobacco Users (n=10,388) n (%) ^a	Exclusive E-Cigarette Users (n=566) n (%) ^a	Exclusive Combustible Cigarette Smokers (n=157) n (%) ^a	
Sex					
Male	5,173 (46.4)	4,764 (46.7)	272 (52.9)	49 (23.2)	88 (35.5)
Female	6,094 (53.6)	5,548 (53.3)	293 (47.1)	107 (76.8)	146 (64.5)
Grade Level					
9th	3,167 (28.8)	2,962 (29.5)	143 (24.7)	22 (15.9)	40 (16.1)
10th	2,884 (26.0)	2,649 (26.1)	143 (23.3)	35 (22.4)	57 (26.9)
11th	2,713 (23.2)	2,465 (23.1)	139 (24.6)	39 (24.7)	70 (24.5)
12th	2,506 (22.0)	2,238 (21.3)	140 (27.4)	61 (37.0)	67 (32.5)
Race/Ethnicity					
Non-Hispanic White	4,748 (53.4)	4,194 (52.7)	297 (54.3)	97 (73.4)	160 (70.2)
Non-Hispanic Black	2,227 (13.8)	2,124 (14.1)	79 (12.5)	16 (9.1)	8 (3.5)
Non-Hispanic Asian	567 (4.0)	553 (4.2)	9 (1.2)	1 (0.7)	4 (1.3)
Non-Hispanic Other	809 (6.7)	747 (6.7)	41 (7.9)	5 (2.5)	16 (6.7)
Hispanic	2,758 (22.1)	2,547 (22.3)	132 (24.1)	35 (14.3)	44 (18.3)
TV Watching on Average					
<3 hours/day	8,362 (80.0)	7,678 (80.1)	398 (81.0)	110 (75.6)	176 (77.0)
3 hours/day	2,301 (20.0)	2,102 (19.9)	114 (19.0)	39 (24.4)	46 (23.0)
Computer Use on Average					
<3 hours/day	5,957 (56.1)	5,460 (55.9)	293 (59.2)	81 (56.2)	123 (58.3)
3 hours/day	4,688 (43.9)	4,299 (44.1)	220 (40.8)	70 (43.8)	99 (41.7)
Current Physical, Mental, Emotional Problem					
No	5,668 (70.2)	5,365 (71.5)	166 (62.0)	59 (50.7)	78 (47.8)
Yes	2,501 (29.8)	2,237 (28.5)	118 (38.0)	60 (49.3)	86 (52.2)
Current Alcohol Use					

Participant Characteristics	Current E-Cigarette Use and Combustible Cigarette Smoking				P-Value
	Overall (N=11,296) n (%) ^a	Non-Tobacco Users (n=10,388) n (%) ^a	Exclusive E-Cigarette Users (n=566) n (%) ^a	Exclusive Combustible Cigarette Smokers (n=157) n (%) ^a	
No	8,176 (79.9)	7,918 (83.9)	184 (36.4)	50 (39.1)	24 (11.0)
Yes	2,099 (20.1)	1,522 (16.1)	312 (63.6)	85 (60.9)	180 (89.0)
Current Marijuana Use					
No	9,744 (87.9)	9,259 (91.2)	316 (55.2)	81 (48.6)	88 (38.3)
Yes	1,411 (12.1)	960 (8.8)	239 (44.8)	73 (51.4)	139 (61.7)

Abbreviation: e-cigarette use, electronic cigarette use.

^a n refers to raw sample size and % refers to weighted column percent. Missing values excluded.

Table 2.

Associations of Current Exclusive E-Cigarette Use, Exclusive Combustible Cigarette Smoking, and Dual-Product Use with Insufficient Sleep <8 Hours among U.S. High School Students, 2017 YRBS

Participant Characteristics	Insufficient Sleep (<8 hours/ night)	Unadjusted Logistic Regression	Adjusted Logistic Regression
	<i>n</i> (%) ^a	OR (95% CI)	aOR (95% CI) ^b
Current E-Cigarette and Combustible Cigarette Use			
Non-tobacco users	6,195 (72.8)	Ref	Ref
Exclusive e-cigarette users	247 (78.8)	1.55 (1.12–2.14)	1.57 (1.01–2.43)
Exclusive combustible cigarette smokers	101 (72.6)	0.87 (0.55–1.39)	0.49 (0.29–0.84)
Current dual-product users	144 (86.7)	3.15 (1.87–5.32)	1.60 (0.88–2.91)
Sex			
Male	2,997 (72.4)	-	Ref
Female	3,673 (74.2)	-	1.02 (0.89–1.16)
Grade Level			
9th	1,581 (63.7)	-	Ref
10th	1,688 (72.9)	-	1.63 (1.38–1.93)
11th	1,710 (77.0)	-	1.90 (1.59–2.28)
12th	1,700 (82.6)	-	3.12 (2.55–3.81)
Race/Ethnicity			
Non-Hispanic White	2,714 (71.5)	-	Ref
Non-Hispanic Black	1,158 (75.4)	-	1.28 (1.01–1.62)
Non-Hispanic Asian	400 (81.5)	-	1.25 (0.81–1.93)
Non-Hispanic Other	508 (80.5)	-	1.63 (1.20–2.21)
Hispanic	1,816 (73.7)	-	0.96 (0.80–1.15)
TV Watching on Average			
<3 hours/day	5,055 (73.2)	-	Ref
3 hours/day	1,391 (74.6)	-	0.91 (0.77–1.08)
Computer Use on Average			
<3 hours/day	3,404 (69.9)	-	Ref
3 hours/day	3,029 (78.0)	-	1.58 (1.38–1.81)
Current Physical, Mental, Emotional Problem			
No	4,031 (70.6)	-	Ref
Yes	1,978 (79.7)	-	1.46 (1.24–1.71)
Current Alcohol Use			
No	4,699 (70.7)	-	Ref
Yes	1,311 (82.0)	-	1.55 (1.27–1.90)
Current Marijuana Use			
No	5,745 (72.3)	-	Ref
Yes	900 (81.0)	-	1.07 (0.83–1.39)

Abbreviations: Ref, reference category; e-cigarette use, electronic cigarette use; aOR, adjusted odds ratio; CI, confidence interval.

^a n refers to raw sample size and % refers to weighted row percent. Missing values excluded.

^b Logistic regression adjusting for sex, grade level, race/ethnicity, TV watching, computer use, alcohol use, marijuana use, and physical, mental or emotional problem.

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Table 3.

Associations of Current Exclusive E-Cigarette Use, Exclusive Combustible Cigarette Smoking, and Dual-Product Use with Insufficient Sleep <8 Hours among U.S. High School Student Current Tobacco Users, 2017 YRBS

	Adjusted Logistic Regression Insufficient Sleep (<8 hours/ night)
	aOR (95% CI) ^a
Current E-Cigarette and Combustible Cigarette Use	
Exclusive e-cigarette users (vs. exclusive combustible cigarette smokers)	3.20 (1.65–6.22)
Dual-product users (vs. exclusive combustible cigarette smokers)	3.26 (1.51–7.03)
Dual-product users (vs. exclusive e-cigarette users)	1.02 (0.50–2.06)

Abbreviations: e-cigarette use, electronic cigarette use; aOR, adjusted odds ratio; CI, confidence interval.

^aLogistic regression adjusting for sex, grade level, race/ethnicity, TV watching, computer use, alcohol use, marijuana use, and physical, mental or emotional problem. The current use group reference category is in parentheses. The non-tobacco user group was included in this adjusted model with results presented in Table 2.

Table 4.

Associations of Current Exclusive E-Cigarette Use, Exclusive Combustible Cigarette Smoking, and Dual-Product Use with Insufficient Sleep <7 Hours among U.S. High School Students, 2017 YRBS

Participant Characteristics	Insufficient Sleep (<7 hours/ night)	Unadjusted Logistic Regression	Adjusted Logistic Regression
	<i>n</i> (%) ^a	OR (95% CI)	aOR (95% CI) ^b
Current E-Cigarette and Combustible Cigarette Use			
Non-tobacco users	3,749 (42.4)	Ref	Ref
Exclusive e-cigarette users	169 (52.8)	1.55 (1.19–2.01)	1.61 (1.16–2.24)
Exclusive combustible cigarette smokers	72 (51.1)	1.28 (0.84–1.97)	0.91 (0.56–1.51)
Current dual-product users	97 (61.0)	2.64 (1.87–3.72)	1.73 (1.14–2.62)
Sex			
Male	1,767 (41.9)	-	Ref
Female	2,307 (44.6)	-	0.98 (0.87–1.11)
Grade Level			
9th	851 (32.9)	-	Ref
10th	1,024 (43.7)	-	1.76 (1.50–2.08)
11th	1,085 (48.2)	-	2.12 (1.79–2.52)
12th	1,122 (51.6)	-	2.47 (2.07–2.94)
Race/Ethnicity			
Non-Hispanic White	1,498 (38.8)	-	Ref
Non-Hispanic Black	799 (52.6)	-	1.72 (1.40–2.12)
Non-Hispanic Asian	255 (51.2)	-	1.75 (1.21–2.52)
Non-Hispanic Other	346 (53.6)	-	1.56 (1.21–1.99)
Hispanic	1,129 (45.1)	-	1.21 (1.02–1.43)
TV Watching on Average			
<3 hours/day	3,058 (42.6)	-	Ref
3 hours/day	873 (46.7)	-	1.04 (0.89–1.21)
Computer Use on Average			
<3 hours/day	1,995 (39.7)	-	Ref
3 hours/day	1,927 (48.1)	-	1.43 (1.27–1.62)
Current Physical, Mental, Emotional Problem			
No	2,265 (38.0)	-	Ref
Yes	1,393 (55.1)	-	1.84 (1.61–2.11)
Current Alcohol Use			
No	2,789 (40.5)	-	Ref
Yes	870 (52.3)	-	1.11 (0.94–1.30)
Current Marijuana Use			
No	3,426 (41.5)	-	Ref
Yes	626 (55.6)	-	1.17 (0.95–1.44)

Abbreviations: ref, reference category; e-cigarette use, electronic cigarette use; aOR, adjusted odds ratio; CI, confidence interval.

^a n refers to raw sample size and % refers to weighted row percent. Missing values excluded.

^b Logistic regression adjusting for sex, grade level, race/ethnicity, TV watching, computer use, alcohol use, marijuana use, and physical, mental or emotional problem.

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Table 5.

Associations of Current Exclusive E-Cigarette Use, Exclusive Combustible Cigarette Smoking, and Dual-Product Use with Insufficient Sleep <7 Hours among U.S. High School Student Current Tobacco Users, 2017 YRBS

	Adjusted Logistic Regression Insufficient Sleep (<7 hours/ night)
	aOR (95% CI) ^a
Current E-Cigarette and Combustible Cigarette Use	
Exclusive e-cigarette users (vs. exclusive combustible cigarette smokers)	1.77 (0.99–3.13)
Dual-product users (vs. exclusive combustible cigarette smokers)	1.89 (1.01–3.51)
Dual-product users (vs. exclusive e-cigarette users)	1.07 (0.65–1.76)

Abbreviations: e-cigarette use, electronic cigarette use; aOR, adjusted odds ratio; CI, confidence interval.

^aLogistic regression adjusting for sex, grade level, race/ethnicity, TV watching, computer use, alcohol use, marijuana use, and physical, mental or emotional problem. The current use group reference category is in parentheses. The non-tobacco user group was included in the adjusted model with results presented in Table 4.

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