



The association of current exclusive e-cigarette use and dual use of e-cigarettes and cigarettes with psychological distress among U.S. adults

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ABSTRACT

This observational study examines the association of current e-cigarette use and dual use of e-cigarettes and cigarettes (dual use) with psychological distress among U.S. adults. We differentiate dual use based on the smoking frequency and compare the relationship between dual use and psychological distress to that of exclusive cigarette smoking with the same smoking frequency.

Using data from the 2015–2018 National Health Interview Surveys, we analyzed adults aged 18+ (N = 55,780) who currently use e-cigarettes or/and cigarettes and have no history of using other tobacco products, and adults who never used any tobacco. Multinomial logistic regression models estimate the association of current e-cigarette use and dual use with psychological distress severity (no/mild, moderate, and severe). In the sample, 15.3% and 2.9% of adults experienced moderate and severe psychological distress. Compared to never tobacco users, current exclusive e-cigarette users and dual users who smoke daily had higher odds of moderate and severe psychological distress. Dual users who smoke nondaily had higher odds of moderate, but not severe psychological distress than never tobacco users. Compared to exclusive daily smokers, dual users with daily smoking had higher odds of moderate and severe psychological distress. Compared to exclusive nondaily smokers, dual users with nondaily smoking had higher odds of moderate but not severe psychological distress.

Our findings suggest that exclusive e-cigarette use is associated with psychological distress severity. Dual use is associated with higher odds of psychological distress severity compared to never tobacco users and exclusive cigarette smoking, and this association differs by smoking frequency.

1. Introduction

While there is extensive evidence of the adverse effects of cigarette smoking on mental health, (Carter et al., 2014; Boksa, 2017; Plurphanswat et al., 2017) research on e-cigarette use and mental health is relatively nascent. (Becker et al., 2021; Obisesan et al., 2019; Bandiera et al., 2016; Wiernik et al., 2019; Kaplan et al., 2021; Pham et al., 2020) Available evidence suggests that similar to cigarette smoking, e-cigarette use is associated with mental health concerns (compared to non-use) such as depression, (Becker et al., 2021; Obisesan et al., 2019; Bandiera et al., 2016; Wiernik et al., 2019) internalizing and externalizing disorders, (Becker et al., 2021; Kaplan et al., 2021) and other mental health conditions (Becker et al., 2021; Pham et al., 2020) in the

U.S. (Obisesan et al., 2019; Bandiera et al., 2016) and other countries. (Wiernik et al., 2019; Pham et al., 2020)

Psychological distress is a commonly used indicator of mental health symptoms, including feeling nervous, hopeless, restless/fidgety, depressed, as if everything was an effort, and worthless. (Kessler et al., 2003) Psychological distress correlates with diagnoses of poor mental health and mental disorders, (Kessler et al., 2003; Furukawa et al., 2003) and severe psychological distress is associated with premature mortality. (Muhuri, 2014) The prevalence of cigarette smoking and e-cigarette use is almost three times greater among adults with psychological distress than adults without psychological distress (Wang et al., 2018; Weinberger et al., 2020) In 2017, 39.5% of adults with psychological distress vs. 13.4% of adults without psychological distress reported

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smoking cigarettes and 7.7% of adults with psychological distress vs. 2.7% of adults without psychological distress reported current e-cigarette use. (Weinberger et al., 2020) Psychological distress is also associated with heavier cigarette consumption, nicotine dependence, and increased challenges in maintaining abstinence from cigarettes compared to smokers without psychological distress. (Forman-Hoffman et al., 2017; Kulik and Glantz, 2017; Streck et al., 2020; Hagman et al., 2008; Park et al., 2017).

Researchers have recently started to examine the associations between e-cigarette use and psychological distress among adults, and the results are inconsistent. (Adzrago et al., 2021; Meng et al., 2022; Spears et al., 2020; Park et al., 2017; Spears et al., 2019) Using the 2014 National Health Interview Survey (NHIS) data, Park and colleagues stratified e-cigarette users into three groups: ever e-cigarette users who had never smoked cigarettes, current dual users of e-cigarettes and cigarettes, and ever e-cigarette users who were former cigarette smokers, and they found that all three groups had higher odds of psychological distress than those who never used e-cigarettes or cigarettes. (Park et al., 2017) Spears and colleagues analyzed data from the 2017 and 2018 Tobacco Products and Risk Perceptions Surveys. They found positive associations between psychological distress and lifetime e-cigarette use, current e-cigarette use, and current daily e-cigarette use. (Spears et al., 2019; Spears et al., 2020) On the other hand, a study did not find any significant association between current e-cigarette use and psychological distress, using the California Health Interview Survey (CHIS) 2017–2018 data. (Meng et al., 2022) Adzrago and colleagues did not find any association between exclusive e-cigarette use and psychological distress among sexual and gender minorities in Texas. (Adzrago et al., 2021).

The inconsistent results from the above studies could be due to differing study designs. First, e-cigarette measures varied across studies in terms of ever use, (Park et al., 2017) current use, (Spears et al., 2019; Spears et al., 2020) daily use, (Spears et al., 2019; Spears et al., 2020) and exclusive current use. (Adzrago et al., 2021) Second, some studies analyzed the general population of adults nationally (Park et al., 2017; Spears et al., 2019; Spears et al., 2020) or specific states, (Meng et al., 2022; Adzrago et al., 2021) while other studies focused on subpopulations such as sexual and gender minorities in Texas. (Adzrago et al., 2021) Third, psychological distress was measured by either a dichotomous variable, (Spears et al., 2019; Spears et al., 2020; Adzrago et al., 2021) or a categorical variable. (Park et al., 2017; Meng et al., 2022).

Given that most adult e-cigarette users concurrently use cigarettes and other tobacco products such as cigars, smokeless tobacco, and pipes, (Creamer et al., 2019; Sung et al., 2018) and that cigarette smoking and other tobacco product use have been shown to be associated with poorer mental health, (Boksa, 2017; Carter et al., 2014; Forman-Hoffman et al., 2017; Hagman et al., 2008; King et al., 2018; Kulik and Glantz, 2017; Plurphanswat et al., 2017; Streck et al., 2020) it is important to tease out the potential confounding impact of cigarette smoking and other non-e-cigarette tobacco product use on the association between e-cigarette use and psychological distress. Furthermore, studies (Azagba et al., 2019; Borland et al., 2019) have found that nicotine dependence among dual users of e-cigarettes and cigarettes (hereafter “dual users”) varied by their use frequencies. Given that nicotine dependence is linked to psychological distress, (Prochaska et al., 2017) it is plausible that varying levels of nicotine dependence may contribute to different probabilities of psychological distress within subgroups of dual users. By excluding the potential impacts of other tobacco product use and taking into account the frequency of use among dual users, we can enhance our comprehension of the association between e-cigarette use and psychological distress. Furthermore, considering different levels of psychological distress can provide insights into how e-cigarette use is associated with escalating distress levels, ranging from mild to severe.

Furthermore, while e-cigarettes may be perceived as less harmful than traditional cigarettes, (Malt et al., 2020) it is important to note that

dual use of cigarettes and e-cigarettes may not necessarily be less harmful than exclusive cigarette smoking. Recent evidence suggests that dual use carries elevated health risks comparable to or as harmful as smoking cigarettes exclusively. (Kim et al., 2020; Wang et al., 2018) However, limited research has investigated whether dual use is associated with higher odds of psychological distress compared to exclusive cigarette smoking.

The objectives of this study are to (1) compare psychological distress severity for exclusive e-cigarette users, dual users, and subgroups of dual users who smoke cigarettes daily and who smoke cigarettes nondaily relative to never tobacco users among U.S. adults; (2) compare psychological distress severity between dual users and exclusive cigarette smokers, between dual users who smoke daily and exclusive daily cigarette smokers, and between dual users who smoke nondaily and exclusive nondaily cigarette smokers among adults in the U.S..

2. Methods

2.1. Data source

We analyzed data for adults aged 18 + from the National Health Interview Survey (NHIS). Data from the NHIS are publicly available and subjects cannot be identified; thus our study was found to qualify as exempt by the UCSF Institutional Review Board. We pooled cross-sectional data from the 2015–2018 NHIS to increase the sample size. (Kim and Keegan, 2022; Wang et al., 2022) The NHIS is a cross-sectional household interview survey of the civilian noninstitutionalized U.S. resident adult population. (National Center for Health Statistics. National Health Interview Survey, 2017) The 2015–2018 NHIS collected data on each respondent’s use of five tobacco products (e-cigarettes, cigarettes, cigars, pipes, and smokeless tobacco), mental health conditions, health status, other health conditions, health insurance coverage, other health risk behaviors such as alcohol consumption and socio-demographic characteristics. To create clear comparison groups, in this study, we focused on adults who currently use e-cigarettes or/and smoke cigarettes without any history of using other tobacco products (e.g., cigars, pipes, and smokeless tobacco) and adults who never used any tobacco products.

2.2. Measures

2.2.1. Outcome

We defined psychological distress using the K6 scale, which is widely used as a mental health screening tool in the general population. (Kessler et al., 2003) The K6 consists of six questions asking respondents to rate on a Likert scale how frequently they experienced the following feelings in the past 30 days: nervousness, hopelessness, restlessness or fidgetiness, worthlessness, sadness or depression, and that everything was an effort. For each question, responses of “none of the time”, “a little of the time”, “some of the time”, “most of the time”, or “all of the time” were scored as 0–4. Responses to the six items were summed to yield a K6 score between 0 and 24, with higher scores indicating a greater tendency toward mental illness. Following the literature, (Meng et al., 2022; Prochaska et al., 2012) we categorized K6 scores of 0–4 as indicating no or mild distress, 5–12 as indicating moderate distress, and 13 and above as indicating severe psychological distress.

2.2.2. Key covariates

Based on self-reported use of the five tobacco products from the 2015–2018 NHIS, we constructed a tobacco use status variable that categorizes adults into never tobacco users and five groups of tobacco users: (1) current exclusive e-cigarette users, (2) current exclusive daily cigarette smokers, (3) current exclusive nondaily cigarette smokers, (4) dual users who smoke cigarettes daily, and (5) dual users who smoke cigarettes nondaily. Current exclusive e-cigarette users were those who now use e-cigarettes every day or some days, or used e-cigarettes in the

past 30 days, and have never used tobacco products other than e-cigarettes. Current exclusive cigarette smokers were those who have smoked 100 cigarettes in their lifetime and currently smoke cigarettes daily or nondaily and have never used tobacco products other than cigarettes. Dual users were current e-cigarette users and current daily or nondaily cigarette smokers who had never used tobacco products other than cigarettes and e-cigarettes. Never tobacco users were those who had never used any tobacco products.

2.3. Other covariates

Based on previous reports of characteristics associated with psychological distress, (Alang et al., 2014; Grzywacz and Almeida, 2008; Isasi et al., 2015; Pelletier et al., 2016) we controlled for sociodemographic characteristics, heavy drinking status, body mass index (BMI), health insurance coverage, the number of smoking years, and survey year indicators.

Sociodemographic characteristics included sex, age (18–34, 35–64, and ≥ 65), race/ethnicity (Hispanic, non-Hispanic (NH) White, NH Black, NH Asian, and other NH race), educational attainment (<high school; high school graduate including general educational development; some college; college degree; and postgraduate degree), family income level (poor [$<100\%$ of the federal poverty level (FPL)], low-income [$100\%–199\%$ FPL], middle-income [$200\%–399\%$ FPL], high-income [$\geq 400\%$ FPL], and unknown income), marital status (married, separated/divorced/widowed, never married, and living with a partner), and region of residence (Northeast, Midwest, South, and West). We categorized income level by the ratio of family income to the FPL after considering the family size. We included the 5.7% of adults whose incomes were unknown as a separate category because we were concerned that data on income might not be missing at random.

We identified heavy drinkers as those who answered “one or more days” to the question: “In the past year, on how many days did you have ≥ 5 (for men) or ≥ 4 (for women) drinks of any alcoholic beverage?” (CDC NCFHS, 2018).

We categorized BMI into underweight (BMI < 18.5 kg/m²), normal (BMI 18.5–24.9 kg/m²), overweight (BMI 25.0–29.9 kg/m²), and obese (BMI ≥ 30.0 kg/m²). (CDC, 2021).

We stratified health insurance coverage as no, partial, and full based on the proportion of months without health insurance coverage in the past 12 months.

The number of smoking years is zero for current exclusive e-cigarette users and never tobacco users. For current exclusive cigarette smokers and dual users, the number of smoking years was derived by subtracting the age when first started to smoke fairly regularly from the respondent's age at the interview.

2.4. Study sample

The pooled 2015–2018 NHIS data contained 60,573 adults aged 18 + who were current exclusive e-cigarette users, current exclusive cigarette smokers, dual users, or never tobacco users. After excluding those with missing values for psychological distress, tobacco use status, and other covariates (except income, for which we included unknown income as a separate category), the final study sample was 55,780.

2.5. Statistical analysis

We examined the distribution of the study sample and the prevalence of no/mild, moderate, and severe psychological distress by tobacco use status and each other covariate. We also used bivariate chi-square tests to examine the independence between each covariate and psychological distress.

We used a multinomial logistic regression model to estimate the likelihood of reporting moderate and severe psychological distress (reference group: no/mild psychological distress) as a function of

tobacco use status (reference group: never tobacco users) and all other covariates. We hypothesized that compared to never tobacco users, exclusive e-cigarette users, dual users who smoke cigarettes daily, and dual users who smoke cigarettes nondaily were more likely to report moderate and severe psychological distress vs. no/mild psychological distress. Then, based on the multinomial logistic regression results, we used the F test to compare psychological distress severity across different groups. Specifically, we compared psychological distress severity in the following comparisons: a) dual users (who smoke daily and nondaily) vs. exclusive cigarette smokers, b) dual users who smoke daily vs. exclusive daily smokers, c) dual users who smoke nondaily vs. exclusive nondaily smokers, d) dual users (who smoke daily and nondaily) vs. never tobacco users, and e) current exclusive cigarette smokers (daily and nondaily) vs. never tobacco users.

We used survey data analysis procedures in all analyses to account for the complex multistage sample design of the NHIS. We conducted the study using SAS version 9.4. (SAS® 9.4 software. Copyright © 2013).

3. Results

Among 55,780 adults in the final study sample, 0.4% were current exclusive e-cigarette users ($n = 185$), 5.8% were current exclusive daily smokers ($n = 3,632$), 2.0% were current exclusive nondaily smokers ($n = 1,215$), 1.1% were dual users who smoke cigarettes daily ($n = 629$), 0.3% were dual users who smoke cigarettes nondaily ($n = 180$), and 90.5% were never tobacco users (Table 1). Table 1 also reports that 15.3% and 2.9% of adults in the study sample had moderate and severe psychological distress in the past 30 days.

Among different groups of tobacco users, moderate psychological distress was most often reported by dual users who smoke cigarettes nondaily (33.5%, $n = 63$), followed by dual users who smoke cigarettes daily (30.5%, $n = 193$). In contrast, severe psychological distress was most often reported by dual users who smoke cigarettes daily (12.4%, $n = 80$), and followed by current exclusive daily cigarette smokers (7.6%, $n = 289$). Never tobacco users reported the least moderate and severe psychological distress (14.6% and 2.4%). Bivariate chi-square test results indicated that the prevalence of psychological distress was statistically significantly different across all subgroups for every covariate (Table 2).

3.1. Results of multinomial logistic regression model

Table 3 indicated that compared to never tobacco users, current exclusive e-cigarette users had 1.86 times the odds of moderate psychological distress and 3.19 times the odds of severe psychological distress. Dual users who were daily smokers were 2.02 times the odds of reporting moderate psychological distress and 3.98 times the odds of reporting severe psychological distress than never tobacco users. Dual users who smoke nondaily were 2.09 times the odds of reporting moderate psychological distress than never tobacco users. Current exclusive daily and nondaily smokers had 1.89 and 1.69 times the odds of severe psychological distress, respectively, compared to never tobacco users. However, neither current exclusive daily nor nondaily smokers had a significant association with moderate psychological distress.

3.2. F test results

F-test results (Table 4) indicated that the odds of reporting moderate and severe psychological distress were statistically higher for dual users who were daily smokers than for exclusive daily smokers. And compared to exclusive nondaily smokers, dual users who were nondaily smokers had higher odds of reporting moderate psychological distress. However, dual users who were nondaily smokers did not have significantly different odds of reporting severe psychological distress compared to exclusive nondaily smokers. Moreover, dual users (who smoke daily and nondaily) had higher odds of reporting moderate and severe

Table 1
Distribution of study sample by psychological distress, tobacco use status, and other covariates: National Health Interview Survey, 2015–18 (n = 55,780).

| | | n | w%(SE) |
|------------------------|--|--------|---------------|
| All | | 55,780 | 100.0 |
| Psychological distress | No/mild | 45,224 | 81.8 (0.2) |
| | Moderate | 8,779 | 15.3 (0.2) |
| | Severe | 1,777 | 2.9(0.1) |
| Tobacco use status | Current exclusive e-cig use | 185 | 0.4(0.0) |
| | Current exclusive daily cigarette smokers | 3,632 | 5.8(0.1) |
| | Current exclusive nondaily cigarette smokers | 1,215 | 2.0(0.1) |
| | Dual users who smoke daily | 629 | 1.1(0.1) |
| | Dual users: who smoke nondaily | 180 | 0.3(0.0) |
| | Never tobacco use | 49,939 | 90.5 (0.2) |
| Sex | Male | 18,651 | 35.5 (0.3) |
| | Female | 37,129 | 64.5 (0.3) |
| Age | 18–34 | 14,385 | 27.8 (0.3) |
| | 35–64 | 27,187 | 51.2 (0.3) |
| | 65+ | 14,208 | 21.0 (0.3) |
| Race/ethnicity | Hispanic | 9,523 | 18.7 (0.6) |
| | NH White | 33,619 | 58.7 (0.7) |
| | NH Black | 7,782 | 13.2 (0.4) |
| | NH Asian | 4,135 | 8.4(0.3) |
| | NH Other Race | 721 | 1.0(0.1) |
| Education | <HS | 7,299 | 12.9 (0.3) |
| | HS | 13,183 | 23.6 (0.3) |
| | Some college | 16,514 | 28.9 (0.3) |
| | College | 11,419 | 21.1 (0.3) |
| | Postgraduate | 7,365 | 13.4 (0.3) |
| | Income level | Poor | 8,182 |
| | Low income | 10,346 | 17.0 (0.3) |
| | Middle-income | 14,702 | 26.5 (0.3) |
| | High-income | 19,202 | 38.6 (0.5) |
| Marital status | Unknown | 3,348 | 6.5(0.2) |
| | Married | 25,322 | 54.6 (0.3) |
| | S/D/W | 14,398 | 17.4 (0.2) |
| | Never married | 13,319 | 22.2 (0.3) |
| Region | Living with partner | 2,741 | 5.8(0.1) |
| | Northeast | 9,143 | 18.3 (0.6) |
| | Midwest | 11,500 | 20.0 (0.5) |
| | South | 20,671 | 37.4 (0.8) |
| | West | 14,466 | 24.3 (0.8) |
| BMI | Underweight | 1,130 | 2.1(0.1) |
| | Normal | 19,782 | 35.9 (0.3) |
| | Overweight | 18,303 | 32.8 (0.3) |

Table 1 (continued)

| | | n | w%(SE) |
|---------------------------|-------------------------|--------|---------------|
| | Obese | 16,565 | 29.1 (0.3) |
| Heavy drinking | No | 47,476 | 85.3 (0.2) |
| | Yes | 8,304 | 14.7 (0.2) |
| Health insurance coverage | Covered all 12 months | 48,654 | 87.1 (0.3) |
| | Partial covered | 1,904 | 3.3(0.1) |
| | Not covered at all | 5,222 | 9.6(0.2) |
| Survey year | 2015 | 16,217 | 27.9 (0.5) |
| | 2016 | 15,239 | 22.3 (0.3) |
| | 2017 | 12,373 | 24.6 (0.4) |
| | 2018 | 11,951 | 25.3 (0.4) |
| | Number of smoking years | 55,780 | 2.8(0.1) * |

Note: SE indicates standard error; NH indicates non-Hispanic; HS indicates high school; S/D/W indicates single, divorced, or widowed; BMI indicates body mass index; *indicates the mean(SE for mean).

psychological distress than exclusive cigarette smokers.

Compared to never tobacco users, F-test results indicated that dual users (who smoke daily and nondaily) had higher odds of reporting moderate and severe psychological distress, and exclusive cigarette smoking (both daily and nondaily) had higher odds of severe but not moderate psychological distress.

4. Discussion

This study aimed to understand the association between psychological distress and current e-cigarette and dual use among US adults. To eliminate the potential confounding effects of those products on the association, current e-cigarette users and dual users in this study did not have any other tobacco use history. Our findings revealed that exclusive e-cigarette use was associated with higher odds of reporting moderate or severe psychological distress when compared to never tobacco use. In contrast, exclusive cigarette smoking (both daily and nondaily) was associated with higher odds of severe psychological distress but not with moderate psychological distress compared to never tobacco use. These results highlight the importance of considering both the physical (Hajek et al., 2014) and mental health risks associated with e-cigarette use when assessing potential harm. Moreover, upon stratifying dual use into two subgroups based on cigarette smoking frequency, we identified different associations with psychological distress severity for dual users who smoke daily and dual users who smoke nondaily when compared to respective exclusive daily and nondaily smokers.

Our finding that current exclusive e-cigarette users who have never used other tobacco products had higher odds of reporting moderate and severe psychological distress differs from a previous study that did not find a significant association between exclusive e-cigarette use and psychological distress. (Adzrago et al., 2021) The inconsistency may be attributed to differences in study samples (sexual and gender minority in Texas vs. adults in the U.S.) and variations in the definitions of psychological distress (dichotomous variables for each diagnosis of panic/anxiety, depression, and PTSD in the past 12 months vs. a categorical variable based on K6 scales in the past 30 days).

Our finding that dual users had higher odds of psychological distress than never tobacco users aligns with previous research. (Park et al., 2017) However, it is worth noting that the definition of dual use varied across studies. In the previous study, (Park et al., 2017) dual use was defined as current use of both cigarettes and e-cigarettes, regardless of other tobacco product use. Our study specifically excluded individuals

Table 2
Prevalence of psychological distress by tobacco use, and other covariates pooled National Health Interview Survey 2015–18 (n = 55,780).

| | | Prevalence of No/mild psychological distress | | Prevalence of Moderate psychological distress | | Prevalence of Severe psychological distress | | P value from bivariate analysis |
|---------------------------|--|--|-------------|---|-------------|---|-------------|---------------------------------|
| | | n | row w% (SE) | n | row w% (SE) | n | row w% (SE) | |
| All | | 45,224 | 81.8* | 8,779 | 15.3* | 1,777 | 2.9* | |
| Tobacco use status | Current exclusive e-cig use | 117 | 67.3(4.5) | 53 | 25.9(4.0) | 15 | 6.8(2.1) | < 0.001 |
| | Current exclusive daily cigarette smokers | 2,561 | 72.0(1.0) | 782 | 20.4(0.9) | 289 | 7.6(0.6) | |
| | Current exclusive nondaily cigarette smokers | 889 | 74.1(1.6) | 245 | 19.6(1.5) | 81 | 6.3(0.9) | |
| | Dual users who smoke daily | 356 | 57.1(2.5) | 193 | 30.5(2.3) | 80 | 12.4(1.8) | |
| | Dual users: who smoke nondaily | 115 | 62.0(4.8) | 53 | 33.5(4.7) | 12 | 4.4(1.5) | |
| | Never tobacco use | 41,186 | 83.0(0.2) | 7,453 | 14.6(0.2) | 1,300 | 2.4(0.1) | |
| Sex | Male | 15,829 | 85.3(0.3) | 2,396 | 12.6(0.3) | 426 | 2.1(0.1) | < 0.001 |
| | Female | 29,395 | 79.9(0.3) | 6,383 | 16.8(0.3) | 1,351 | 3.4(0.1) | |
| Age | 18–34 | 11,541 | 81.0(0.4) | 2,483 | 16.5(0.4) | 361 | 2.5(0.2) | < 0.001 |
| | 35–64 | 21,768 | 81.5(0.3) | 4,360 | 15.2(0.3) | 1,059 | 3.3(0.1) | |
| | 65+ | 11,915 | 83.7(0.4) | 1,936 | 13.7(0.4) | 357 | 2.6(0.2) | |
| Race/ethnicity | Hispanic | 7,650 | 81.2(0.5) | 1,503 | 15.4(0.5) | 370 | 3.4(0.2) | < 0.001 |
| | NH White | 27,329 | 81.9(0.3) | 5,265 | 15.3(0.3) | 1,025 | 2.9(0.1) | |
| | NH Black | 6,197 | 80.8(0.6) | 1,320 | 16.2(0.6) | 265 | 3.0(0.2) | |
| | NH Asian | 3,507 | 85.1(0.7) | 559 | 13.3(0.7) | 69 | 1.6(0.3) | |
| | NH Other Race | 541 | 76.7(2.6) | 132 | 17.5(2.3) | 48 | 5.8(1.0) | |
| Education | <HS | 5,474 | 76.9(0.7) | 1,399 | 18.1(0.6) | 426 | 5.1(0.3) | < 0.001 |
| | HS | 10,440 | 79.8(0.5) | 2,242 | 16.6(0.4) | 501 | 3.7(0.2) | |
| | Some college | 13,123 | 80.0(0.4) | 2,815 | 16.9(0.4) | 576 | 3.2(0.2) | |
| | College | 9,755 | 86.1(0.5) | 1,482 | 12.4(0.4) | 182 | 1.5(0.1) | |
| | Postgraduate | 6,432 | 87.4(0.5) | 841 | 11.4(0.5) | 92 | 1.2(0.2) | |
| Income level | Poor | 5,616 | 70.1(0.7) | 1,927 | 22.5(0.6) | 639 | 7.4(0.4) | < 0.001 |
| | Low income | 7,813 | 75.8(0.5) | 2,064 | 19.8(0.5) | 469 | 4.3(0.3) | |
| | Middle-income | 12,074 | 81.8(0.4) | 2,268 | 15.7(0.4) | 360 | 2.5(0.2) | |
| | High-income | 16,866 | 87.5(0.3) | 2,113 | 11.2(0.3) | 223 | 1.3(0.1) | |
| Marital status | Unknown | 2,855 | 84.3(0.8) | 407 | 13.1(0.8) | 86 | 2.6(0.4) | < 0.001 |
| | Married | 21,602 | 85.2(0.3) | 3,215 | 12.9(0.3) | 505 | 1.9(0.1) | |
| | S/D/W | 11,106 | 76.4(0.5) | 2,595 | 18.5(0.5) | 697 | 5.0(0.2) | |
| | Never married | 10,367 | 78.4(0.5) | 2,478 | 18.0(0.5) | 474 | 3.5(0.2) | |
| Region | Living with partner | 2,149 | 78.6(0.9) | 491 | 17.7(0.9) | 101 | 3.7(0.4) | 0.044 |
| | Northeast | 7,407 | 82.6(0.5) | 1,458 | 14.7(0.4) | 278 | 2.7(0.2) | |
| | Midwest | 9,305 | 81.0(0.5) | 1,856 | 16.2(0.5) | 339 | 2.8(0.2) | |
| | South | 16,784 | 82.3(0.4) | 3,186 | 14.7(0.3) | 701 | 3.0(0.2) | |
| BMI | West | 11,728 | 81.2(0.5) | 2,279 | 15.8(0.5) | 459 | 3.0(0.2) | < 0.001 |
| | Underweight | 859 | 76.5(1.7) | 208 | 17.4(1.5) | 63 | 6.1(1.1) | |
| | Normal | 16,558 | 84.5(0.3) | 2,764 | 13.5(0.3) | 460 | 2.0(0.1) | |
| | Overweight | 15,101 | 83.1(0.4) | 2,726 | 14.4(0.3) | 476 | 2.5(0.2) | |
| Heavy drinking | Obese | 12,706 | 77.4(0.4) | 3,081 | 18.3(0.4) | 778 | 4.3(0.2) | < 0.001 |
| | No | 38,672 | 82.2(0.2) | 7,276 | 14.9(0.2) | 1,528 | 2.9(0.1) | |
| Health insurance coverage | Yes | 6,552 | 79.9(0.6) | 1,503 | 17.4(0.6) | 249 | 2.7(0.2) | < 0.001 |
| | Covered all 12 months | 39,815 | 82.5(0.2) | 7,402 | 14.8(0.2) | 1,437 | 2.7(0.1) | |
| | Partial covered | 1,341 | 71.9(1.4) | 455 | 22.7(1.3) | 108 | 5.4(0.7) | |
| Survey year | Not covered at all | 4,068 | 79.2(0.7) | 922 | 16.7(0.7) | 232 | 4.1(0.3) | 0.0252 |
| | 2015 | 13,180 | 82.2(0.4) | 2,526 | 14.9(0.4) | 511 | 2.8(0.2) | |
| | 2016 | 12,393 | 82.6(0.5) | 2,345 | 14.5(0.4) | 501 | 2.9(0.2) | |
| | 2017 | 10,043 | 81.8(0.4) | 1,964 | 15.5(0.4) | 366 | 2.6(0.2) | |
| Number of smoking years | 2018 | 9,608 | 80.7(0.5) | 1,944 | 16.1(0.4) | 399 | 3.2(0.2) | |
| | | 45,224 | 2.4(0.1)** | 8,779 | 4.1(0.2)** | 1,777 | 7.9(0.4)** | |

Note: SE indicates standard error. *indicates the 4-year average prevalence. NH indicates non-Hispanic; HS indicates high school; S/D/W indicates single, divorced, or widowed; BMI indicates body mass index; **indicates the mean(SE for mean).

with a history of using other tobacco products. Our results provide further confirmation that dual use is associated with higher odds of psychological distress than never tobacco use.

Furthermore, our findings revealed that dual users had higher odds of experiencing moderate or severe psychological distress compared to exclusive cigarette smokers. The reasons underlying this association between dual use and higher odds of psychological distress can be multifaceted. On the one hand, cigarette smokers who already experience psychological distress may be more inclined to use e-cigarettes as a coping mechanism or to alleviate stress, leading to the adoption of dual use. (Miller et al., 2017) On the other hand, e-cigarette use itself could contribute to this increased risk of reporting psychological distress. E-

cigarettes contain toxic chemicals such as nicotine, lead, and aluminum, which can potentially affect the central and peripheral nervous systems, thus potentially increasing the odds of psychological distress among dual users compared to exclusive cigarette smokers. (Badea et al., 2018; Gaur and Agnihotri, 2019; Zhao et al., 2018; National Center for Chronic Disease Prevention and Health Promotion (US), 2016; Parrott, 2015) Additionally, a recent study has shown that dual users exhibit higher total nicotine use and nicotine dependence than exclusive cigarette smokers. (Martínez et al., 2020) The increased total nicotine intake and dependence among dual users may further contribute to the elevated odds of psychological distress observed in this group. Moreover, our results demonstrated distinct associations between severe psychological

Table 3

Estimated association of tobacco use status with moderate and severe psychological distress vs. no/mild psychological distress from the multinomial logistic regression models among the sample adults, pooled National Health Interview Survey 2015–2018 (n = 55,780).

| | | Moderate psychological distress | | | Severe psychological distress | | | | |
|--------------------|--|---------------------------------|--------|----------|-------------------------------|--------|----------|------|----------|
| | | AOR | 95% CI | P values | AOR | 95% CI | P values | | |
| Tobacco use status | Current exclusive e-cigarette users | 1.86 | 1.19 | 2.92 | 0.007 | 3.19 | 1.55 | 6.56 | 0.002 |
| | Current exclusive daily cigarette smokers | 1.08 | 0.87 | 1.35 | 0.468 | 1.89 | 1.33 | 2.69 | 0.000 |
| | Current exclusive nondaily cigarette smokers | 1.08 | 0.85 | 1.38 | 0.538 | 1.69 | 1.15 | 2.47 | 0.007 |
| | Dual users who smoke daily | 2.02 | 1.51 | 2.69 | < 0.0001 | 3.98 | 2.57 | 6.15 | < 0.0001 |
| | Dual users who smoke nondaily | 2.09 | 1.26 | 3.46 | 0.004 | 1.27 | 0.58 | 2.81 | 0.548 |
| | Never tobacco users | | | | | | | | |

Note: The model controls all other covariates: sociodemographic characteristics, BMI status, heavy drinking, health insurance coverage, year dummies, and the number of smoking years,

Table 4

Comparison of the association with moderate and severe psychological distress across different groups, results from F tests, pooled National Health Interview Survey 2015–2018 (n = 55,780).

| | Moderate psychological distress | | Severe psychological distress | |
|---|---------------------------------|-------------------|-------------------------------|-------------------|
| | F value | P-value | F value | P-value |
| Compared to current exclusive cigarette smokers | | | | |
| a) Dual users (who smoke daily and nondaily) vs. current exclusive daily and nondaily cigarette smokers | 10.33 | < 0.001 | 13.38 | < 0.001 |
| b) Dual users who smoke daily vs. current exclusive daily cigarette smokers | 22.16 | < 0.001 | 13.11 | 0.000 |
| c) Dual users who smoke nondaily vs. current exclusive nondaily cigarette smokers | 6.52 | 0.011 | 0.48 | 0.489 |
| Compared to never tobacco users | | | | |
| d) Dual users (who smoke daily and nondaily) vs. never tobacco users | 12.72 | < 0.001 | 19.76 | < 0.001 |
| e) Current exclusive cigarette smokers (daily and nondaily) vs. never tobacco users | 0.29 | 0.748 | 6.64 | 0.001 |

distress and dual users who smoke daily versus nondaily, compared to never tobacco users. Specifically, dual users who smoke daily had higher odds of severe psychological distress than exclusive daily smokers. In contrast, no significant association was observed between dual users who smoke nondaily and severe psychological distress compared to exclusive nondaily smokers. These findings highlight the complex association between psychological distress severity and different subgroups of dual users. These findings emphasize the importance of considering the mental health implications of dual use and the need for further research to better understand the mechanisms involved. Additionally, these findings call for targeted interventions to support individuals who engage in dual use and may be at risk for psychological distress.

This study has several limitations. Data on tobacco use and psychological distress outcomes were self-reported, which might lead to nonrandom misclassification and recall bias. Due to data limitations, we could not account for some confounders, such as nicotine content, years of vaping, and nicotine dependence. In addition, due to the small sample size, we could not differentiate between daily vs. nondaily use of e-cigarettes. Similarly, the small sample size of dual users who smoke nondaily might explain why we did not detect a significant difference in psychological distress between dual users who smoke nondaily and exclusive nondaily cigarette smokers. Last, this is an observational and cross-sectional study, so we cannot establish causality. Given the reinforcing effects of psychological distress on cigarette smoking, such that individuals with psychological distress smoke more cigarettes, (Hagman et al., 2008; McClave et al., 2010; Streck et al., 2020) future studies that

investigate the causal relationship between e-cigarette use and psychological distress and the impact of e-cigarette use on successful quitting among smokers with psychological distress are needed.

5. Conclusion

Our findings suggest that current exclusive e-cigarette use is associated with psychological distress severity. Dual use was associated with higher odds of psychological distress severity compared to never tobacco users and exclusive cigarette smoking, and this association differs by smoking frequency. Given the popularity of e-cigarettes (Hall et al., 2016) and the high prevalence of psychological distress worldwide, (Nochaiwong et al., 2021) our findings regarding the association of current exclusive and dual e-cigarette use with psychological distress in the U.S. may also have meaningful implications for other countries.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

NHIS data is available at <https://www.cdc.gov/nchs/nhis/data-questionnaires-documentation.htm>.

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Ethical Approval

This study uses publicly available secondary data and is certified as exempt by the UCSF IRB committee.

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