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Patterns and trends of dual use of e-cigarettes and cigarettes among U.S. adults, 2015–2018

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ABSTRACT

Introduction: If dual use of cigarettes and e-cigarettes is a transition state to tobacco and nicotine use cessation, it may be a tolerable temporary condition. But, if a long-term behavior, dual use may increase tobacco harm to the population as a whole, and efforts should aim to reduce it as much as possible. To develop effective tobacco control policy, the changes in dual use of e-cigarettes and cigarettes need to be better understood.

Methods: National probability samples of U.S. adults in 2015 (n = 6051), 2016 (n = 6014), 2017 (n = 5992), and 2018 (n = 5989) reported their smoking and e-cigarette use status, including frequency of use. Weighted multinomial logistic regression models were used to examine temporal trends and patterns of cigarette and e-cigarette use.

Results: Between 2015 and 2018, the prevalence of current e-cigarette use (29.8% in 2015, 22.3% in 2016, 29.1% in 2017, and 27.7% in 2018) did not change significantly among current smokers. This result was consistent among light, moderate, and heavy smokers, and did not change when stratified by sex, age and race. However, the prevalence of cigarette smoking in current e-cigarette users declined from 56.9% in 2015 to 40.8% in 2018 ($p < 0.001$). Among never ($p = .012$) and former ($ps < 0.001$) smokers the prevalence of current e-cigarette use increased significantly.

Conclusion: The continued high prevalence of dual use and increased prevalence of current e-cigarette use among never smokers highlight the need for better communication about the risks of prolonged dual use for e-cigarette users, and the risks of nicotine initiation and addiction for nonusers.

1. Introduction

Electronic cigarette (e-cigarette) use among U.S. adults was estimated at 1.9% in 2012/2013 [1] and 2.8% in 2017 [2]. The popularity and uptake of e-cigarettes may result in increased conventional smoking among never smokers [3,4], increased cessation among current smokers [5,6], relapse among former smokers [7], and continued dual use of e-cigarettes and conventional cigarettes [8,9]. From a population-level public health perspective, dual use of cigarettes and e-cigarettes could provide an opportunity to reduce the burden of tobacco use if it represents a temporary stage in which smokers switch to e-cigarettes or quit tobacco product use entirely [10,11]; however, dual use could also pose a significant public health risk if it prolongs and sustains nicotine addiction, and consequently inhibits smoking cessation among those who might otherwise quit. For dual users, in addition to continued harms to health that stem from continued smoking [12,13], recent research indicates there may be an increased risk of heart disease [14] for those who use both cigarettes and e-cigarettes. Because of its potential significant public health impact and implications, dual use of cigarettes and e-cigarettes is a behavior that needs to be better understood to help identify the most appropriate and effective public health and policy response.

Previous studies have shown that dual use of cigarettes and e-cigarettes is common [15,16] among those using e-cigarettes. For example, more than half of e-cigarette users were current smokers in 2015 [17,18]. Among the myriad of possible poly tobacco-use patterns, the combination of e-cigarettes and cigarettes is the most common among both adults and youth [19].

Smokers commonly indicate that they use e-cigarettes to aid smoking cessation or reduce consumption of cigarettes [20–25]. However, evidence has been mixed with regard to whether e-cigarette use is effective as a smoking cessation aid [26]. Some studies found that the use of nicotine containing e-cigarettes was associated with a significant increase in smoking cessation compared with using non-nicotine containing e-cigarettes or using nicotine replacement therapy [5,6,27]. However, others found that, compared to smokers who did not use e-cigarettes, the odds of quitting smoking were significantly decreased in participants who used e-cigarettes [28–31]. If e-cigarettes were found to be ineffective in helping smokers quit smoking, smokers who initiate use of e-cigarettes with the intention to quit may inadvertently prolong

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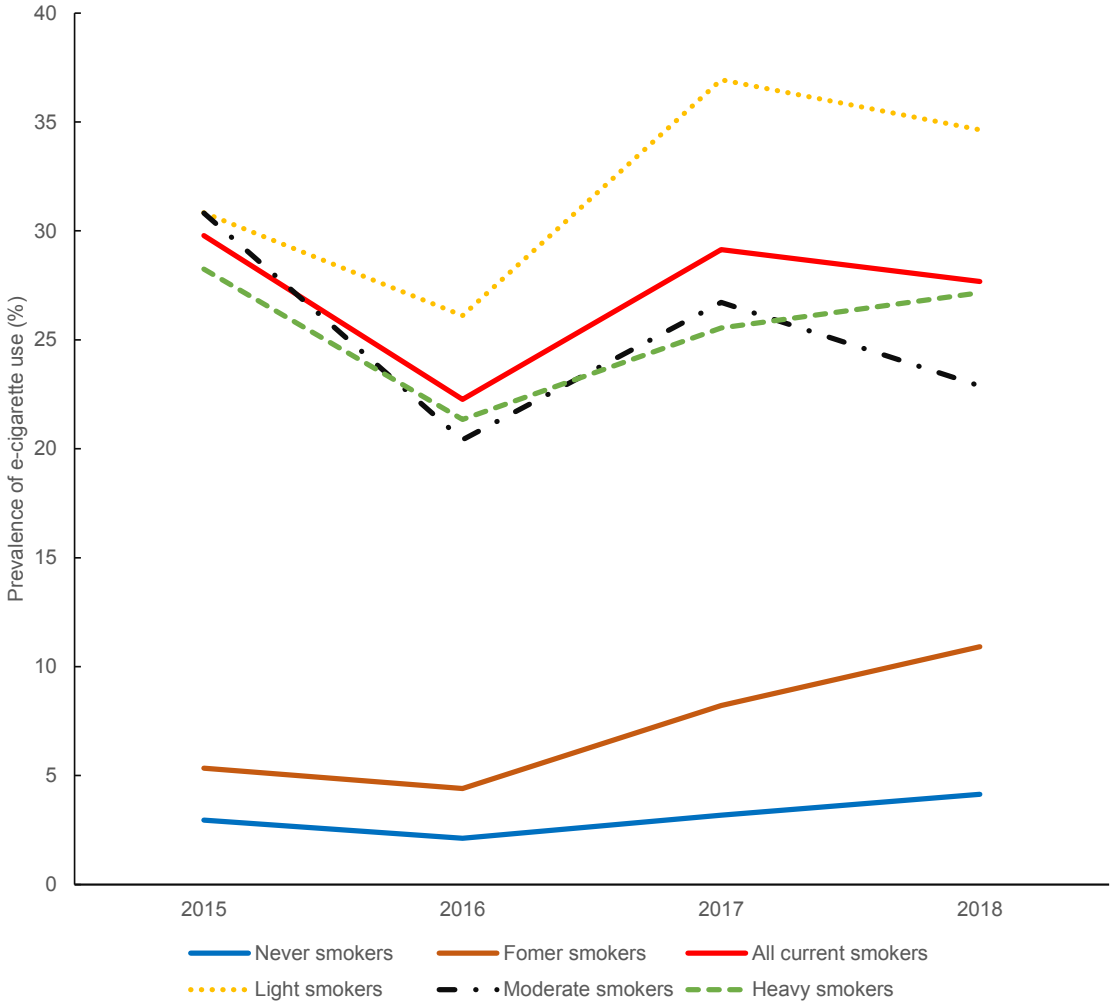


Note: All current smokers included light, moderate, and heavy smokers. Light smokers smoked 1-4 cigarettes per day, moderate smokers smoked 5-14 cigarettes per day and heavy smokers smoked >14 cigarettes per day. Between 2015 and 2018, prevalence of current e-cigarette use increased significantly in never (p = .012) and former (p < .001) smokers. Quadratic trend was significant in never (p = .029) and former (p = .040) smokers. Cubic trend was significant in former smokers (p = .032) and moderate smokers (5-14 cigarettes per day) (p =.024).

Fig. 1. Trends in prevalence of current e-cigarette use by smoking status. Note: All current smokers included light, moderate, and heavy smokers. Light smokers smoked 1–4 cigarettes per day, moderate smokers smoked 5–14 cigarettes per day and heavy smokers smoked > 14 cigarettes per day. Between 2015 and 2018, prevalence of current e-cigarette use increased significantly in never (p = .012) and former (p < .001) smokers. Quadratic trend was significant in never (p = .029) and former (p = .040) smokers. Cubic trend was significant in former smokers (p = .032) and moderate smokers (5–14 cigarettes per day) (p = .024).

and/or sustain their nicotine addiction. Alternatively, smokers may initiate e-cigarette use in order to reduce cravings for nicotine in places or under circumstances in which smoking may not be permitted or advisable. Indeed, e-cigarettes have been promoted for use in such places by the e-cigarette companies [32–34], and smokers consistently mentioned this as one of the reasons for using e-cigarettes [23,24]. Using e-cigarettes as a complement to cigarettes may lead to an increased likelihood of sustained dual use of e-cigarettes and cigarettes among smokers.

A more nuanced understanding of the patterns of dual use of e-cigarettes and cigarettes calls for continued monitoring and surveillance to better inform public health policies and interventions that would encourage a complete switch to e-cigarettes and/or a complete quit of all tobacco products. Studies conducted following the initial introduction of e-cigarettes to the U.S. reported increased dual use among adults. One study found that past 30-day e-cigarette use among current smokers increased from 4.9% (3.4–6.4) in 2010/2011 to 9.4% (7.1–11.6) in 2012/2013 [35], and another study reported that the prevalence of current e-cigarette use in nondaily smokers increased from 1.4% (0.0–3.3) in 2010 to 34.1% (26.0–42.2) in 2013 [36]. Among daily smokers, the prevalence of current e-cigarette use also increased from 1.4% (0.3–2.5) in 2010 to 30.3% (25.2–35.4) in 2013 [36]. Although limited data indicate that e-cigarette use among adults may have increased since 2013 [1,2,37], to the best of our knowledge, no published research has examined temporal trends in dual use of e-cigarettes and cigarettes among U.S. adults since 2013. To address this gap, this study examined trends in dual use of e-cigarettes and cigarettes among U.S. adults from 2015 to 2018. This study also reports on trends in e-cigarette use among never and former smokers.

2. Methods

Data were obtained from the Georgia State University Tobacco Products and Risk Perceptions Survey (GSU TPRPS) in 2015 (n = 6051), 2016 (n = 6014), 2017 (n = 5992), and 2018 (n = 5989) with study completion rates of 74.3%, 74.0%, 72.8%, and 74.9%, respectively. Participants of the GSU TPRPS were recruited from the GfK KnowledgePanel [38], an online national probability panel designed to

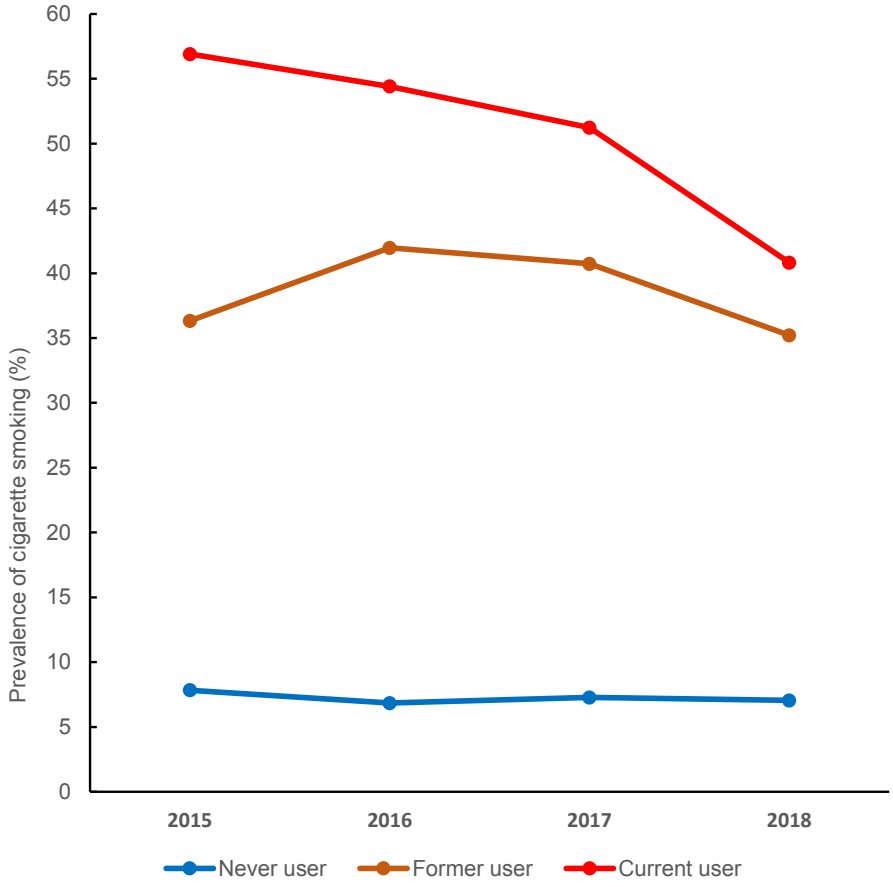


Fig. 2. Trends in prevalence of current cigarette smoking by e-cigarette use. Note: There was a significant decrease in the prevalence of cigarette smoking in current e-cigarette users ($p < 0.001$). Quadratic trend was significant in former e-cigarette users ($p = 0.010$).

be representative of non-institutionalized U.S. adults aged 18 years and older. Demographic and geographic distributions from the Current Population Survey [39] for each year were employed as benchmarks for computing final study sampling weights, and included sex, age, race/ethnicity, education, household income, census region, and metropolitan area. An iterative proportional fitting procedure was used to compute a study-poststratification weight to account for sampling and non-sampling errors. This study was approved by Georgia State University's Institutional Review Board.

2.1. Measures

2.1.1. Cigarette smoking

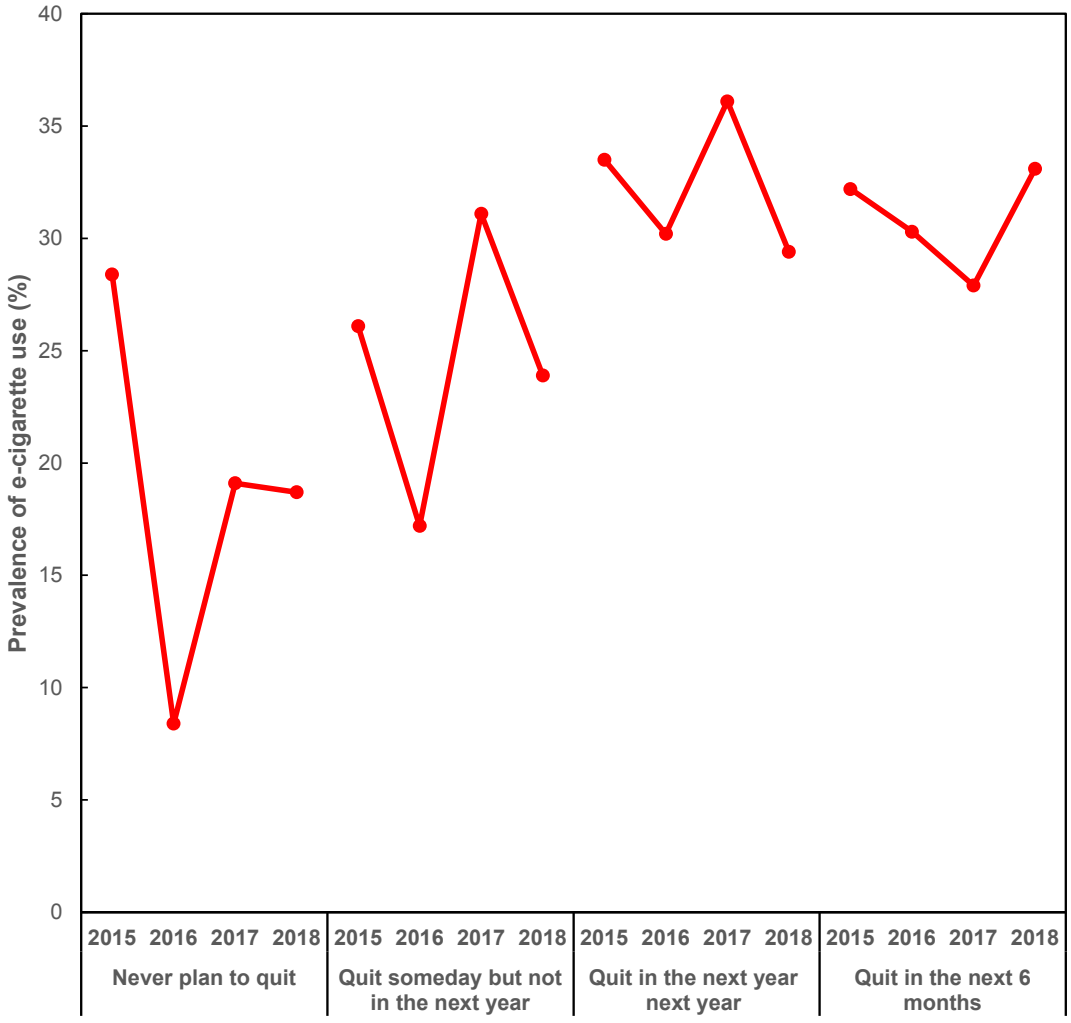
Participants who reported smoking < 100 cigarettes in their life or had never smoked cigarettes were considered never smokers. Participants who had smoked ≥100 cigarettes in their life were classified as current smokers if they reported that they currently smoked cigarettes "every day" or "some days," and as former smokers if they reported that they did not currently smoke at all. For current smokers, the number of cigarettes smoked per day (CPD) was calculated using responses to: "During the past 30 days, on how many days did you smoke cigarettes?" and, "On the days you smoked, how many cigarettes did you smoke each day?" For "some days" smokers, responses to both items were multiplied and then divided by 30. We categorized CPD into three smoking intensity levels: light smokers (1–4 CPD), moderate smokers (5–14 CPD), and heavy smokers (≥15 CPD) [40].

2.1.2. E-cigarette use

E-cigarette use status was assessed by the question, "Have you ever used electronic vapor products, even one or two times?" Participants who answered "no" were classified as never users. Those who indicated they had ever used were then asked, "Do you now use electronic vapor products every day, some days, rarely, or not at all? Participants who reported being every day, some days, or rarely users were further asked, "On how many of the past 30 days have you used electronic vapor products?" We examined the distribution for number of days e-cigarettes were used in the past 30-days for "rarely" and "somedays" users found a nontrivial number of users who report using on more days than the average "someday" user. Because of this overlap in the reported number of days of e-cigarette use in the past 30 days between "rarely" and "some days" users, we classified "every day", "some days", or "rarely" as current users of e-cigarettes. Those participants who had ever used e-cigarettes but did not currently use e-cigarettes at all were considered former e-cigarette users. Dual use of e-cigarettes and conventional cigarettes was defined as current cigarette smokers who were also current e-cigarettes users. Because the majority of dual users (67.6%, see Supplementary Fig. 1) indicated using cigarettes less than 10 days in the past 30 days, we dichotomized the number of days of e-cigarette use in the past 30 days into < 10 days and ≥10 days in order to identify the more frequent users in the study participants.

2.1.3. Intention to quit smoking

Participants' intentions to quit smoking were assessed by the question, "What best describes your plans regarding quitting smoking



Note: Prevalence of current e-cigarette use did not decrease or increase from 2015 to 2018.
Prevalence of current e-cigarette use showed significant quadratic trend in smokers who plan to quit someday but not in the next year (p = .013). Significant cubic trends in the prevalence of current e-cigarette use were seen among smokers who never plan to quit (p = .003) and smokers who plan to quit someday but not in the next year (p = .009).

Fig. 3. Trends in prevalence of e-cigarette use by intentions to quit smoking. Note: Prevalence of current e-cigarette use did not decrease or increase from 2015 to 2018. Prevalence of current e-cigarette use showed significant quadratic trend in smokers who plan to quit someday but not in the next year (p = 0.013). Significant cubic trends in the prevalence of current e-cigarette use were seen among smokers who never plan to quit (p = 0.003) and smokers who plan to quit someday but not in the next year (p = 0.009).

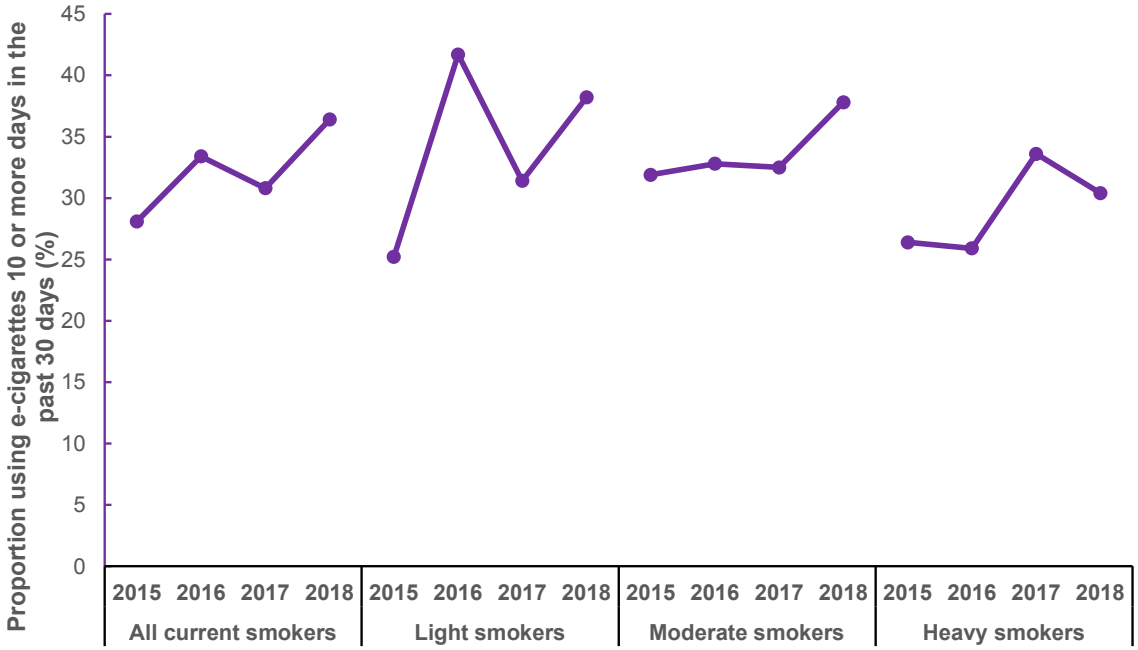
cigarettes?" Responses were 1) Intend to quit in the next 7 days, 2) Intend to quit in the next month, 3) Intend to quit in the next 6 months, 4) Intend to quit in the next year, 5) Intend to quit someday but not in the next year, 6) Never plan to quit. For analyses, the first three categories were combined into "Intend to quit in the next 6 months." Therefore, smokers' intentions to quit smoking were classified into four categories: 1) never plan to quit, 2) intention to quit someday but not in the next year, 3) intention to quit in the next year, and 4) intention to quit the next six months.

2.1.4. Demographic characteristics

Demographic variables included sex, age, race/ethnicity and education level.

2.2. Data analysis

We estimated the weighted proportions for categorical variables. Weighted logistic regression models with orthogonal polynomial trend contrasts were used to estimate and test changes in tobacco product use, either e-cigarettes or cigarettes, overall and among subgroups (e.g., e-cigarette use among cigarette smokers) during 2015–2018. Polynomial trend contrasts were conducted to assess linear as well as non-linear changes in the log-odds of product use, and orthogonal weights were used to reduce non-essential multicollinearity among the contrasts and aid interpretation. This approach avoids model misspecification that would occur if the relationship between year and log-odds of product use was not linear. To estimate the linear change in log odds of product use between 2015 and 2018, we computed a predictor variable with a value (weight) of −3 if the observation was in 2015, −1 if in 2016, +1 if in 2017, and +3 if in 2018. To estimate non-linear trends in the log-



No significant trend was observed. Light smokers smoked 1-4 cigarettes per day, moderate smokers smoked 5-14 cigarettes per day, and heavy smokers smoked >14 cigarettes per day.

Fig. 4. Trends in prevalence of 10 or more days of e-cigarettes use in the past 30 days among dual users. No significant trend was observed. Light smokers smoked 1–4 cigarettes per day, moderate smokers smoked 5–14 cigarettes per day, and heavy smokers smoked > 14 cigarettes per day.

odds of product use, we include variables with values assigned to capture quadratic and cubic trends in product use using weights +1, −1, −1, +1 (quadratic) and −1, +3, −3, +1 (cubic) assigned for the survey year. A significant linear effect of year would indicate that the log-odds of use either increased (if positive) or decreased (if negative) between 2015 and 2018, while significant quadratic and cubic effects would indicate non-linear changes in the log-odds of product use (e.g., log odds of e-cigarette use steeply increases between 2015 and 2016, but holds steady in the subsequent survey years). Some participants of the 2015 and 2016 survey were re-sampled in 2017 (n = 1100) and 2018 (n = 1129), respectively. Therefore, robust standard errors that allowed for correlated residuals between observations from re-sampled participants were obtained using the Taylor series linearization method [41,42]. All analyses were conducted using the SAS version 9.4 (SAS Institute, Cary, NC, USA).

3. Results

The demographic characteristics of the study participants are reported in Supplementary Table 1. Prevalence of e-cigarette use among the participants was 7.4% (95% CI = 6.6%, 8.3%) in 2015; 5.4% (95% CI = 4.7%, 6.1%) in 2016; 8.5% (95% CI = 7.7%, 9.4%) in 2017; and 9.2% (95% CI = 8.2, 10.1) in 2018 (Supplementary Table 1). Of the total sample, prevalence of dual use was 4.2% (95% CI = 3.6%, 4.8%) in 2015, 2.9% (95% CI = 2.5%, 3.4%) in 2016, 4.5% (95% CI = 3.7%, 5.0%) in 2017, and 3.7% (95% CI = 3.2%, 4.3%) in 2018 (p = 0. 0.959). Among all current smokers, prevalence of current e-cigarette use was 29.8% (95% CI = 26.1%, 33.4%), 22.3% (95%CI = 19.3%, 25.3%), 29.1% (95% CI = 25.8%, 32.5%), and 27.7% (95% CI = 24.3%, 31.1%) in 2015, 2016, 2017, and 2018, respectively. Between 2015 and 2018, the prevalence of current e-cigarette use among all current smokers, including light, moderate, and heavy smokers, did not show any evidence of significant linear change (ps > 0.05) (Fig. 1 and Supplementary Table 2). For example, the prevalence of e-cigarette use in heavy smokers was 28.2% (95% CI = 22.7%, 33.8%), 21.3% (95% CI = 16.6%, 26.1%), 25.5% (95% CI = 20.2%, 30.9%), and 27.2% (95% CI = 21.7%, 32.6%) in 2015, 2016, 2017, and 2018, respectively. This result did not change when we stratified the trend analysis by sex, race, and age of participants (online Supplementary Figs. 2–4).

Further examination of the trends in the prevalence of current e-cigarette use by current cigarette smokers' intentions to quit smoking revealed no statistically significant decreasing or increasing linear change in the log odds of the prevalence of current e-cigarette use in any of the categories of intentions to quit smoking (Fig. 2). Prevalence of current e-cigarette use in smokers with no intention to quit smoking was 28.4% (95% CI = 17.7%, 39.0%) in 2015, 8.4% (95% CI = 3.8%, 13.1%) in 2016, 19.1% (95% CI = 11.1%, 27.1%) in 2017, and 18.7% (95% CI = 9.6%, 27.8%) in 2018 (p = 0.567). Among smokers who planned to quit in the next 6 months, prevalence of current e-cigarette use was 32.2% (95% CI = 25.7%, 38.6%) in 2015, 30.3% (95% CI = 24.7%, 35.9%) in 2016, 27.9% (95% CI = 22.4%, 33.4%) in 2017, and 33.1% (95% CI = 27.1%, 39.0%) in 2018 (p = 0.996) (Fig. 2 and Supplementary Table 4).

We conducted additional trend analyses to examine the prevalence of cigarette smoking among current e-cigarette users and found that the prevalence of current smoking had decreased significantly from 56.9% (95% CI = 50.7%, 63.1%) in 2015 to 40.8% (95% CI = 35.8%, 45.8%) in 2018 in the total sample (p < .001) (Fig. 3), and among both males (p = .034) and females (p < .001) (Supplementary Fig. 5). However, this trend depended on smoking heaviness. Specifically, the proportion of moderate smokers decreased (p < .001), whereas the prevalence of light and heavy smoking among current e-cigarette users remained stable (ps > 0.05) (Supplementary Table 3). The decreasing trend in the prevalence of current smoking among current e-cigarette users was seen in participants aged 31–64 years (p < .001) and those identifying as non-Hispanic white (p = 0.002) (Supplementary Figs. 6&7). In heavy smokers who used e-cigarettes, 26.4% (95% CI = 17.4%, 35.3%),

25.9% (95% CI = 15.7%, 36.0%), 33.6% (95% CI = 21.8%, 45.5%), and 30.4% (95% CI = 19.2%, 41.5%) reported e-cigarette use on 10 or more days in the past 30 days in 2015, 2016, 2017, and 2018, respectively (Supplementary Table 5). Among all dual users, the number of days of e-cigarette use in the past 30 days remained stable between 2015 and 2018 ($ps > 0.05$) (Fig. 4). Among past 30-days e-cigarette users, the proportion of moderate smokers decreased significantly ($ps < 0.02$) (Supplementary Fig. 8).

Never smokers exhibited an increase in prevalence of current e-cigarette use (3.0%, 95% CI = 2.1%, 3.8% in 2015 to 4.1%, 95% CI = 3.3%, 5.0% in 2018, $p = 0.012$). An increase in the prevalence of current e-cigarette use was also observed among former smokers (5.3%, 95% CI = 3.8%, 6.9% in 2015 to 10.9%, 95% CI = 8.9%, 12.9% in 2018, $p < .001$) (Fig. 1 and Supplementary Table 2).

4. Discussion

This study contributes to the literature on dual use of cigarettes and e-cigarettes by providing an in-depth, detailed and more nuanced examination of dual use behavior among U.S. adults from 2015 to 2018, a period when newer generations of e-cigarettes proliferated. We found about one in four smokers were current e-cigarette users in the study period, and this rate did not change significantly over the four-year study period. This suggests that dual use of e-cigarettes and cigarettes continues to be common among adult smokers in the US, in agreement with previous studies [2,19]. Dual use could have positive public health impact if it leads to smoking cessation [8,15,43]. However, the findings from several recent studies have cast doubt on the effectiveness of e-cigarettes for smoking cessation under real-world situations, raising concerns that e-cigarette use may even inhibit smoking cessation [29,31,44]. For example, using data from the Population Assessment on Tobacco and Health Survey, Coleman et al. found that, after one year follow-up, 44.3% of dual users were still using both e-cigarettes and cigarettes, 43.5% stopped using e-cigarettes but continued smoking, 5.1% stopped smoking but continued to use e-cigarettes, and 7.0% stopped using both products [8]. We previously reported that after one year, 53% of baseline dual users of e-cigarettes and cigarettes remained dual users, 37% returned to exclusive combusted product use, 2% switched to exclusive e-cigarette use, and 7% quit using both products [31]. “Prolonged dual use of cigarettes and e-cigarettes has been associated with increased risk of heart disease that is greater than the risk associated with either exclusive cigarette smoking or exclusive e-cigarette use [14,45].

Smokers have consistently indicated that an important reason for using e-cigarettes is to aid quitting [20,21,46]. It is therefore expected that e-cigarettes use would be more common among smokers who intend to quit smoking. In each year from 2015 to 2018, we found that approximately three in 10 smokers who plan to quit in the next 6 months were e-cigarette users. However, we also found that about one in five smokers with no plan to quit smoking were using e-cigarettes during our study period with the exception of 2016. Among smokers who have no plan to quit, e-cigarette use is often linked to non-cessation related reasons, including using in situations when/where smoking is not allowed and/or conforming with social norms [47]. To the extent that use of e-cigarettes with no intentions to quit smoking may likely result in long-term dual use, public health communication campaigns to educate about the dangers of sustained/prolonged dual use, as well as interventions that encourage smokers who are unwilling to quit to switch to exclusive use of e-cigarettes are needed.

Evidence suggests that a significant number of e-cigarette users initiate e-cigarette use with the intention to reduce consumption of cigarettes [20–24] instead of quitting entirely. In all four years during our study period, we found that a high proportion of light and moderate smokers were current e-cigarette users (Fig. 1). We also found that about one in four heavy smokers was a current e-cigarette user, and more than a quarter of heavy smokers who used e-cigarettes reported using them on 10 or more days in the past 30 days. These findings suggest that dual users consist of not only infrequent users of one product or the other, but also a substantial number of heavy users of both products. Although more longitudinal studies are needed to understand how long smokers continue to use e-cigarettes together with cigarette smoking, the persistent high proportion of smokers who continue to use e-cigarettes from our cross-sectional surveys indicate the duration of dual use of cigarettes and e-cigarettes may be much longer than that optimal for public health.

While current smokers continue to be the largest subgroup among current e-cigarette users, their proportions have been declining while the proportions of never smokers or former smokers have increased during our study period. The increasing prevalence of e-cigarette use among never smokers raises a serious concern regarding the potential impact of e-cigarettes on smoking initiation in adults. Previous studies evaluating e-cigarettes’ role in tobacco use initiation have focused on children and adolescents, a subgroup that had the highest rate of increase in use of e-cigarettes since 2011 [48,49]. Although about 90% of smokers initiate smoking prior to age 18 years [49], current data suggest that the age of smoking initiation may be increasing [50] and exclusive e-cigarettes use is predictive of cigarette smoking initiation in young adults [3,51]. Given our finding that the use of e-cigarettes has increased among never smokers from 2015 to 2018, it is important to monitor e-cigarettes use among never smoking adults and its impact on smoking initiation in adulthood.

In addition to the increase among never smokers, an increase in current use of e-cigarettes was found in former smokers. The increasing share of current e-cigarette users that are former smokers may reflect a growing population of adults who quit smoking with the help of e-cigarettes. However, it may also reflect, at least partially, the relapse of former smokers to nicotine use [7]. Additional research is needed to better understand the degree to which e-cigarettes may increase relapse among former smokers versus help preventing relapse among recent quitters.

Limitations necessitate that the results presented in this research should be interpreted with caution. First, while our surveys were designed to be representative of the civilian noninstitutionalized adults in the U.S., the generalizability of our results may be limited due to potential panel conditioning as a result of the use of a web-panel often used in tobacco research. Second, our sample size did not permit an assessment of more nuanced e-cigarette use patterns among subgroups of current smokers such as type of e-cigarette devices used, factors that may influence the patterns, and length of dual use. Lastly, this study focused on e-cigarette and cigarette use and did not consider the use of e-cigarettes with other tobacco products. Never and former smokers who use e-cigarettes may also use other tobacco products at the same time. Future studies should examine patterns of e-cigarette and other tobacco product use. Despite these limitations, this study provides more detailed analysis with recent data on the patterns and trends in dual use of e-cigarettes and cigarettes among American adults.

5. Conclusion

This study uses four representative cross-sectional surveys to examine the dual use patterns among American adults from 2015 to 2018. Our study results show the prevalence of e-cigarette use among current smokers did not significantly change between 2015 and 2018. While this study cannot determine the proportion of long-term dual users versus dual users who were transitioning away from cigarette use, the high prevalence of dual use, especially among heavy smokers and smokers with no intention to quit smoking, calls for continued monitoring of dual use behaviors, and increased efforts to communicate to the public the dangers of prolonged dual use of e-cigarettes and cigarettes, and the risks of nicotine addiction among never users.

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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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2019.101009.

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