



Cigarettes and e-cigarettes use among US adults with multimorbidity

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HIGHLIGHTS

- This study explored associations between tobacco use categories and multimorbidity.
- About a quarter of US adults reported multimorbidity.
- Those who reported cigarettes, e-cigarettes or both had higher odds of multimorbidity.
- Stronger associations were observed among younger adults, females and non-Hispanic Multiracial for current dual use.
- Further research is needed to explore if a causal relationship exists.

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ABSTRACT

Background: Tobacco use leads to multiple illnesses. Yet, the effects of different categories of tobacco use on multimorbidity remain understudied. We investigated the associations between tobacco use categories and multimorbidity and the potential moderating effects of age, sex, or race/ethnicity among adults in the United States.

Methods: We conducted a cross-sectional analysis using pooled data from the Behavioral Risk Factor Surveillance System for the years 2020–2022. Multimorbidity was ascertained through self-reported ≥ 2 chronic health conditions. We categorized tobacco use into nine derived from nonuse (did not use e-cigarettes or cigarettes), former cigarette or e-cigarette use, current (used on some days/everyday) cigarette use or e-cigarette use, or both (dual use). We used multinomial logistic regression to investigate the associations while accounting for potential confounding factors.

Results: Within the sample (N=1,080,257), 28.2% reported multimorbidity. For the categories examined (former exclusive e-cigarette, exclusive e-cigarette, former exclusive cigarette, former dual, former cigarette/current e-cigarette, exclusive cigarette, current cigarette/former e-cigarette and dual use), all reported higher odds of having multimorbidity compared to those who reported nonuse of both e-cigarettes and cigarettes. We found significant interactions for age, sex and race/ethnicity with the tobacco use categories for multimorbidity ($p < 0.01$), where stronger associations were observed among younger adults, females and non-Hispanic Multiracial for current dual use ($p < 0.05$).

Conclusions: The use of cigarettes, e-cigarettes, or both was associated with multimorbidity among adults, which was more pronounced among younger adults, females and non-Hispanic Multiracial. These findings underscore the importance of implementing targeted public health interventions to mitigate the health risks associated with using both products, particularly among specific demographics, to reduce the prevalence of multimorbidity.

1. Background

Multimorbidity, the coexistence of two or more chronic health

conditions, poses a significant and complex challenge to public health worldwide. (Moffat & Mercer, 2015) In the United States (US), its prevalence rose from 15.2% in 1999 to 22.7% in 2018 (Caraballo et al.,

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2022). This multifaceted health condition is associated with higher mortality, lower quality of life, increased healthcare utilization, (Marengoni et al., 2011) and healthcare costs (Marengoni et al., 2011; Salisbury et al., 2011). Multimorbidity is often associated with older age groups (≥ 65 years), (King et al., 2018) and is more prevalent among females, (King et al., 2018; Marengoni et al., 2011; Salisbury et al., 2011) though some other studies differ (Rizza et al., 2012). Additionally, studies have indicated racial/ethnic disparities in the prevalence of multimorbidity (Caraballo et al., 2022). For instance, prior research found that multimorbidity was more prevalent among Black individuals and less prevalent among Asian and Hispanic individuals compared to White individuals (Caraballo et al., 2022).

Several lifestyle behaviors (Tazzeo et al., 2023) are associated with multimorbidity, including tobacco use, (Alvarez-Galvez et al., 2023) a well-established risk factor for a range of chronic diseases. In recent years, the landscape of tobacco use has transformed with the emergence of electronic nicotine delivery systems (ENDS), commonly known as e-cigarettes (Mirbolouk et al., 2018; Osei et al., 2019). These devices introduced a dynamic element to the landscape, with potential implications for the prevalence and complexity of multimorbidity. E-cigarettes have increased in popularity as an alternative to traditional combustible tobacco products and are often considered less harmful (Fong et al., 2019; Popova & Ling, 2013). However, studies have provided evidence for exposure to toxic volatile chemicals in e-cigarettes (Rubinstein et al., 2018). Those who use e-cigarettes may transition to dual use, i.e., using both cigarettes and e-cigarettes, thereby increasing their risks of developing adverse effects (Osei et al., 2019). However, the long-term health effects of e-cigarettes are still evolving (Osei et al., 2019).

As e-cigarettes gain traction and dual use becomes common (Osei et al., 2019), understanding their relationship with multimorbidity is crucial. We aim to investigate the association between tobacco use categories, including traditional cigarettes and e-cigarettes, and multimorbidity. Sociodemographic characteristics like age, sex, and race/ethnicity can also influence how individuals respond to the health risks associated with tobacco use. (Arrazola et al., 2023; Higgins et al., 2019; Kingsbury et al., 2020) We will therefore explore potential interactions between tobacco use categories and these sociodemographic factors to provide a more comprehensive understanding of how cigarette-, e-cigarette-, and dual use relate to multimorbidity. Such insights may inform evidence-based policies and interventions to reduce the prevalence of chronic diseases and improve overall population health.

2. Methods

We used the STATA statistical software version 18 (StataCorp LLC, College Station, TX) for this cross-sectional analysis. We utilized pooled data from three years of the Behavioral Risk Factor Surveillance System (BRFSS) (2020–2022) (Centers for Disease Control and Prevention, 2020). The BRFSS is a nationally representative survey investigating health behaviors and risks, chronic conditions, and personal behaviors such as smoking and drinking among the noninstitutionalized US population. A detailed description of the BRFSS study's methodology and procedures can be found elsewhere (Centers for Disease Control and Prevention, 2020). This study uses de-identified publicly available data deemed exempt from review by the Florida International University Institutional Review Board.

2.1. Measures

2.1.1. Multimorbidity

We obtained multimorbidity, the dependent variable, from questions about chronic health conditions. This study's assessment of chronic health conditions included participants' self-reported history of receiving a medical diagnosis from a doctor, nurse, or other health professionals. Specifically, participants were asked whether a healthcare

provider had ever informed them about the presence of any of the following chronic health conditions: angina or coronary heart disease, arthritis, asthma, cancer, chronic obstructive pulmonary disease or emphysema or chronic bronchitis, depression, diabetes, heart attack (myocardial infarction), kidney disease and stroke. The response options were "Yes" or "No" for each condition, and a new variable was generated by summing the responses and categorizing them into three groups: 0 (reference), 1, and ≥ 2 (indicating the presence of multimorbidity) in line with prior research (Boyd & Fortin, 2010).

2.1.2. Tobacco use categories

The independent variable in this study was the categories of tobacco use, which was ascertained by the use of cigarettes and e-cigarettes. Current cigarette smokers were participants who reported smoking at least 100 cigarettes in their lifetime and smoking every day or some days at the time of the survey. Former cigarette users were participants who had smoked at least 100 cigarettes in their lifetime but not smoking now at the time of the survey. Never cigarette users were those who responded "No" to the question, "Have you smoked at least 100 cigarettes your entire lifetime?" Current e-cigarette users were participants who responded "Yes" to the question: "Do you now use e-cigarettes or other electronic "Vaping" product, every day or some days?" Former e-cigarette users responded "not at all" to the question. Never e-cigarette users were participants who responded "No" to the question, "Have you ever used an e-cigarette or electronic vaping product even just one time in your entire lifetime?" To conduct our analysis, we combined and coded the responses to the items, resulting in nine distinct categories: 1. nonuse (participants who have never used e-cigarettes and cigarettes), 2. former exclusive e-cigarette use, 3. current exclusive e-cigarette use, 4. former exclusive cigarette use, 5. former dual use, 6. former cigarette/current e-cigarette use, 7. current exclusive cigarette use, 8. current cigarette/former e-cigarette use, and 9. current dual use.

2.1.3. Moderators

We used the age categories provided in the BRFSS data: 18–24 years, 25–34 years, 35–44 years, 45–54 years, 55–64 years and ≥ 65 years. Biological sex was reported as males and females. Race/ethnicity was classified as non-Hispanic White, non-Hispanic Black, non-Hispanic Other, non-Hispanic Multiracial, and Hispanic.

2.1.4. Covariates

We obtained covariates, such as demographic characteristics of the study participants, from self-report questionnaires. We categorized the measures and included education (below high school, high school graduate, attended college/technical school and graduated college/technical school), income ($< \$25,000$, $\$25,000$ to $< \$50,000$, $\geq \$50,000$, and don't know/not reported), marital status (single, divorced/widowed/separated, and married/partnered). Mental health distress days was assessed from the question related to number of days in the past 30 days that mental health was not good (0, 1–13 days, and 14–30 days) and heavy alcohol consumption was assessed from adult men having more than 14 drinks per week and women having more than 7 drinks per week in the BRFSS and categorized as Yes or No. Current smokeless tobacco was assessed from the use of smokeless tobacco everyday, some days or not at all, while self-rated health was assessed on a 5-point Likert scale ranging from excellent to poor and regrouped as optimal (excellent/very good/good) and suboptimal (fair/poor).

2.2. Statistical analysis

We investigated the differences in demographic characteristics between the morbidity categories using chi-square tests. (McHugh, 2013) Then, we analyzed the relationship between tobacco use categories and multimorbidity using multinomial logistic regression. We also analyzed the interactions of age, sex, and race/ethnicity with the tobacco use categories while controlling for sociodemographic factors, mental

health distress days, heavy alcohol consumption, current smokeless tobacco, and physical activity. The steps in the analysis were as follows: Model 1 included the individual variable (tobacco use categories) and covariates, and Model 2 had the adjusted model with the interaction terms for sex*tobacco use categories, age*tobacco use categories, and race/ethnicity*tobacco use categories inserted separately. We conducted a stratified analysis for sex age and race/ethnicity following the interaction analysis. The regression models estimated the adjusted odds ratios (aOR) and 95% confidence intervals (CI). The statistical significance for this study was set at a p-value of <0.05. We conducted all analyses employing the BRFSS weighting methodology using the 'svy' procedures in the STATA statistical software.

3. Results

3.1. Participant characteristics

Overall, 28.2% of the study participants (N = 1,080,257; Weighted N= 202,129,317) reported multimorbidity. About half of the participants were female (51.3%). About a fifth of the study participants were 65 years and older (22.9%). The majority (61.7%) of the participants identified as non-Hispanic White, 11.8% as non-Hispanic Black, 7.2% as non-Hispanic Other, 2.1% as non-Hispanic Multiracial, and 17.1% as Hispanic. Additionally, 4.2% reported current exclusive cigarette use, 2.2% reported current exclusive e-cigarette use, and 2.1% reported current dual use. The characteristics of the study participants varied by multimorbidity. Females had a higher prevalence of multimorbidity compared to males (32.1% vs. 24.1%). Non-Hispanic Multiracial and non-Hispanic White participants had a higher prevalence of multimorbidity compared to other racial/ethnic groups. Older age groups had a higher prevalence of multimorbidity than younger age groups. Details of the study participants are in [Table 1](#).

3.2. Regression analysis

In the adjusted regression analysis, the results showed that individuals who reported current exclusive cigarettes (adjusted odds ratio [aOR]: 1.49 [95% CI: 1.40, 1.59]), e-cigarettes (1.55 [1.40, 1.72]), or dual use (2.58 [2.36, 2.82]) had higher odds of having multimorbidity compared to those who reported nonuse ([Table 2](#)). Although we observed these associations in individuals with single morbidity, the magnitude of associations was larger among those with multimorbidity.

Furthermore, the study found significant interactions between age*tobacco use categories and sex*tobacco use categories (p<0.001), where we observed stronger associations among younger adults and females (p<0.05) ([Tables 2 & 3](#)). However, we observed no significant interaction based on race/ethnicity for single morbidity (1 morbidity: p=0.179; ≥2: 0.003; [Table 4](#)).

4. Discussion

This nationally representative study in the US showed that about 1 in 4 adults reported multimorbidity in 2020–2022. Individuals who reported former or current exclusive cigarette or e-cigarette use and former or current dual use had higher odds of multimorbidity compared to those who reported nonuse. Notably, we observed stronger associations among younger adults, females and non-Hispanic Multiracial for current dual use. While these associations were evident in US adults with single morbidity, the strengths of the associations were more pronounced among those with multimorbidity, particularly among those who reported cigarette and dual use compared to those who reported nonuse. These findings highlight the urgent need for prospective studies that explore the impact of different cigarette/e-cigarette use on multimorbidity risk to decrease the prevalence of cigarette and e-cigarette use behaviors. Specifically concerning is the notably higher odds of dual use among younger adults, females and non-Hispanic Multiracial,

Table 1
Study sample characteristics, BRFSS 2020–2022.

Characteristics	Total	Morbidity		
		0	1	≥2
	N (%)	n (%)	n (%)	n (%)
Total	1,080,257 (100.0)	395,095 (43.3)	315,455 (28.5)	369,707 (28.2)
Age in years^a				
18–24	64,781 (12.0)	38,839 (60.1)	19,144 (29.4)	6798 (10.4)
25–34	114,616 (16.9)	66,791 (59.6)	32,228 (27.2)	15,597 (13.2)
35–44	141,401 (16.3)	76,930 (56.1)	38,926 (26.6)	25,545 (17.3)
45–54	162,689 (15.4)	73,180 (46.9)	46,913 (28.2)	42,596 (25.0)
55–64	205,588 (16.5)	65,754 (32.3)	62,264 (30.5)	77,570 (37.2)
≥65	391,182 (22.9)	73,601 (18.9)	115,980 (29.1)	201,601 (51.9)
Sex				
Female	579,011 (51.3)	186,271 (38.3)	173,853 (29.6)	218,887 (32.1)
Male	501,246 (48.7)	208,824 (48.6)	141,602 (27.4)	150,820 (24.1)
Race/ethnicity				
Non-Hispanic White	800,672 (61.7)	268,561 (38.0)	239,685 (29.8)	292,426 (32.2)
Non-Hispanic Black	80,246 (11.8)	31,341 (44.8)	22,753 (28.0)	26,152 (27.2)
Non-Hispanic Other	57,331 (7.2)	29,101 (59.6)	14,669 (24.4)	13,561 (16.0)
Non-Hispanic Multiracial	23,256 (2.1)	8363 (38.3)	6518 (28.3)	8375 (33.5)
Hispanic	92,896 (17.1)	47,509 (55.1)	24,641 (26.2)	20,746 (18.7)
Education				
Below high school	64,153 (11.7)	21,262 (40.7)	15,789 (24.9)	27,102 (34.4)
High school graduate	274,107 (27.7)	95,971 (43.1)	78,037 (28.3)	100,099 (28.6)
Attended college/technical school	297,524 (30.6)	98,945 (39.8)	86,630 (29.4)	111,949 (30.9)
Graduated college/technical school	440,407 (30.0)	176,915 (48.0)	133,992 (29.3)	129,500 (22.7)
Income				
<\$25,000	159,285 (15.4)	41,002 (33.8)	39,755 (25.6)	78,528 (40.6)
\$25,000- <\$50,000	224,966 (20.0)	72,005 (39.9)	64,796 (28.1)	88,165 (32.0)
≥\$50,000	497,239 (45.2)	209,901 (47.7)	152,634 (29.8)	134,704 (22.5)
Don't know/Missing/Not reported	198,767 (19.5)	72,187 (44.1)	58,270 (28.3)	68,310 (27.6)
Marital status				
Single	189,875 (24.6)	90,937 (53.8)	55,226 (28.7)	43,712 (17.4)
Divorced/widowed/separated	279,273 (20.0)	65,615 (28.3)	77,456 (27.1)	136,202 (44.6)
Married/partnered	602,024 (55.5)	234,166 (43.9)	180,332 (29.0)	187,526 (27.2)
Self-rated health				
Optimal	894,802 (83.1)	374,147 (48.9)	276,745 (29.5)	243,910 (21.6)
Suboptimal	182,968 (16.9)	20,360 (16.1)	38,049 (23.6)	124,559 (60.4)
Mental health distress days				
0	661,821 (58.9)	272,303 (49.5)	192,596 (27.1)	196,922 (23.4)
1–13	259,690 (26.0)	91,812 (41.9)	78,490 (30.5)	89,388 (27.6)
≥14	139,122 (15.0)	25,233 (22.5)	38,983 (30.8)	74,906 (46.8)

(continued on next page)

Table 1 (continued)

Characteristics	Total	Morbidity		
		0	1	≥2
Heavy alcohol consumption				
Yes	65,792 (6.3)	25,424 (43.2)	21,091 (31.6)	19,277 (25.2)
No	982,040 (93.7)	355,784 (43.1)	285,255 (28.4)	341,001 (28.6)
Current smokeless tobacco				
Yes	34,732 (3.3)	14,745 (45.9)	9819 (28.0)	10,168 (26.2)
No	1,044,641 (96.7)	379,987 (43.2)	305,399 (28.5)	359,255 (28.3)
Tobacco use categories				
Nonuse	404,067 (37.2)	167,867 (48.5)	119,856 (28.3)	116,344 (23.2)
Former exclusive e-cigarette use	224,389 (23.0)	98,586 (51.6)	67,041 (28.5)	58,762 (20.0)
Current exclusive e-cigarette use	14,090 (2.2)	6853 (50.2)	4658 (33.6)	2579 (16.3)
Former exclusive cigarette use	154,881 (11.5)	38,374 (28.6)	44,158 (28.2)	72,349 (43.2)
Former dual use	122,973 (10.2)	33,954 (33.3)	35,460 (29.4)	53,559 (37.3)
Former cigarette/current e-cigarette use	19,990 (2.4)	7058 (38.7)	6302 (32.5)	6630 (28.8)
Current exclusive cigarette use	45,966 (4.2)	14,153 (35.6)	12,383 (25.9)	19,430 (38.5)
Current cigarette/former e-cigarette use	77,101 (7.3)	22,962 (34.3)	20,711 (27.4)	33,428 (38.4)
Current dual use	16,800 (2.1)	5288 (34.6)	4886 (30.1)	6626 (35.4)

Abbreviations: BRFSS: Behavioral Risk Factor Surveillance System. Analytic ns (overall column numbers) do not always add to total in columns due to missing data. Ns are unweighted; percentages are weighted. Nonuse: no use of e-cigarettes or cigarettes; e-cigarette use: individuals reporting current/former use of e-cigarettes; cigarette use: individuals who report current/former use of traditional cigarettes; dual use: individuals who report both current e-cigarette and cigarette use. The characteristics of the study participants varied by multimorbidity ($p < 0.001$). ^aDistribution across morbidity are row percentages.

emphasizing the necessity for focused efforts to address these vulnerable populations and mitigate the potential public health impact.

In our study, we observed that using cigarettes or e-cigarettes, including former use, when compared to those reporting nonuse, was associated with morbidity, regardless of whether individuals had single morbidity or multimorbidity. Extensive literature shows that cigarette use is associated with a myriad of adverse health outcomes, (USDHHS, 2014) while emerging evidence suggests that e-cigarette use is associated with several adverse health effects, including cardiovascular disease, (Lee et al., 2019) cancer, (Canistro et al., 2017) mental health issues, (Kaplan et al., 2021) neurological diseases, (Faulcon et al., 2020) and oro-dental diseases (Jeong et al., 2020). The prevalence of e-cigarette use in the US is substantial, with many of those who report use also using cigarettes (Owusu et al., 2019). According to the US Centers for Disease Control and Prevention, in 2021, over 11 million US adults reported current use of e-cigarettes, (Romeh et al., 2023) and 28.3 million reported current cigarette use (Cornelius et al., 2023). In 2019, among adults who currently used e-cigarettes overall, 36.9% also reported current use of cigarettes (Cornelius et al., 2020). As previously mentioned, while e-cigarettes are not harmless and the long-term effects associated with e-cigarette use are limited, e-cigarettes have been promoted as a tool for smoking cessation (Abrams et al., 2018). Although randomized clinical trials suggest that e-cigarettes may show promise as a smoking cessation tool, real-world cohort studies, whether used as a cessation aid or as a cigarette substitute, have not consistently

Table 2

Association between multimorbidity and tobacco use categories, overall and by sex.

	Morbidity		
	1	≥2	
Overall	Adjusted OR (95% CI)		
Nonuse	Ref	Ref	
Former exclusive e-cigarette use	1.03 (1.00, 1.06)	1.01 (0.97, 1.04)	
Current exclusive e-cigarette use	1.41 (1.31, 1.53)	1.55 (1.40, 1.72)	
Former exclusive cigarette use	1.28 (1.24, 1.33)	1.77 (1.70, 1.84)	
Former dual use	1.36 (1.31, 1.42)	1.82 (1.74, 1.89)	
Former cigarette/current e-cigarette use	1.56 (1.45, 1.68)	2.17 (2.01, 2.35)	
Current exclusive cigarette use	1.11 (1.04, 1.18)	1.49 (1.40, 1.59)	
Current cigarette/former e-cigarette use	1.33 (1.27, 1.40)	1.95 (1.85, 2.05)	
Current dual use	1.56 (1.43, 1.69)	2.58 (2.36, 2.82)	
Female			
Nonuse	Ref	Ref	
Former exclusive e-cigarette use	0.99 (0.95, 1.03)	0.99 (0.94, 1.04)	
Current exclusive e-cigarette use	1.67 (1.48, 1.88)	1.79 (1.54, 2.08)	
Former exclusive cigarette use	1.29 (1.22, 1.36)	1.73 (1.64, 1.83)	
Former dual use	1.44 (1.36, 1.53)	1.96 (1.84, 2.09)	
Former cigarette/current e-cigarette use	1.84 (1.60, 2.10)	2.55 (2.25, 2.88)	
Current exclusive cigarette use	1.19 (1.08, 1.30)	1.55 (1.42, 1.68)	
Current cigarette/former e-cigarette use	1.47 (1.37, 1.58)	2.29 (2.13, 2.47)	
Current dual use	1.70 (1.49, 1.94)	2.90 (2.54, 3.31)	
Male			
Nonuse	Ref	Ref	
Former exclusive e-cigarette use	1.07 (1.02, 1.11)	1.03 (0.97, 1.09)	
Current exclusive e-cigarette use	1.27 (1.15, 1.41)	1.40 (1.20, 1.63)	
Former exclusive cigarette use	1.26 (1.19, 1.32)	1.72 (1.63, 1.82)	
Former dual use	1.31 (1.24, 1.38)	1.66 (1.57, 1.76)	
Former cigarette/current e-cigarette use	1.44 (1.32, 1.57)	2.00 (1.79, 2.24)	
Current exclusive cigarette use	1.05 (0.96, 1.14)	1.42 (1.29, 1.56)	
Current cigarette/former e-cigarette use	1.26 (1.18, 1.34)	1.69 (1.57, 1.81)	
Current dual use	1.51 (1.36, 1.69)	2.41 (2.11, 2.74)	

Adjusted model; adjusted for age, sex, race/ethnicity, education, income, marital status, general health status, mental health distress days, heavy alcohol consumption, and current smokeless tobacco use. Interaction by age and sex with morbidity: $p < 0.001$ for 1 and ≥ 2 . Interaction for race: 1:0.179; ≥ 2 : 0.003. The models for the sex variable adjusted for similar variables as the adjusted model without sex. Numbers in italics are not statistically significant ($p > 0.05$).

demonstrated their effectiveness in achieving smoking cessation (Wang et al., 2021). It is likely that adults diagnosed with multimorbidity may turn to e-cigarettes as a less harmful alternative to traditional cigarettes. Concerns about their health may motivate them to adopt such alternatives, as switching to e-cigarettes can be perceived as a step towards less harmful behavior than combustible cigarettes (Kosterman et al., 2022). This decision aligns with the understanding that chronic illnesses are not curable, and individuals may seek ways to mitigate their risks by reducing exposure to harmful substances like those found in cigarettes.

The dual use of both traditional cigarettes and e-cigarettes, as demonstrated in the current study, presents a significant concern due to its strong association with multimorbidity. This pattern of dual use remains prevalent among US adults (Mirbolouk et al., 2018). It is plausible that individuals who smoke cigarettes may initiate e-cigarette use as a potential pathway toward harm reduction or complete cessation (Glantz & Bareham, 2018). However, existing evidence remains conflicting. While some studies suggest benefits from e-cigarette use in reducing harm or achieving smoking cessation (Kalkhoran & Glantz, 2016), others indicate that those who report dual use may transition back to cigarette use or continue with dual use (Osibogun et al., 2022), potentially impeding cessation efforts (El Dib et al., 2017). This is particularly concerning because dual use of tobacco products may result in greater exposure to toxins and worse respiratory outcomes than using either product alone (Reddy et al., 2021). Conversely, a Cochrane review found high-certainty evidence that e-cigarettes with nicotine increase quit rates compared to nicotine replacement therapy. However, a limitation identified in the review is that the included studies primarily comprised

Table 3
Association between multimorbidity and tobacco use categories by age group.

	Morbidity	
	1 Adjusted OR (95% CI)	≥2
18–24 years		
Nonuse	Ref	Ref
Former exclusive e-cigarette use	<i>1.08 (0.99, 1.17)</i>	1.15 (1.01, 1.31)
Current exclusive e-cigarette use	1.53 (1.37, 1.72)	1.80 (1.52, 2.14)
Former exclusive cigarette use	1.85 (1.29, 2.66)	<i>1.52 (0.82, 2.82)</i>
Former dual use	1.52 (1.23, 1.88)	2.25 (1.68, 3.01)
Former cigarette/current e-cigarette use	1.94 (1.58, 2.39)	2.72 (2.15, 3.43)
Current exclusive cigarette use	<i>1.44 (0.92, 2.25)</i>	4.21 (2.02, 8.79)
Current cigarette/former e-cigarette use	1.68 (1.39, 2.03)	2.86 (2.23, 3.67)
Current dual use	2.05 (1.68, 2.50)	3.93 (3.15, 4.90)
25–34 years		
Nonuse	Ref	Ref
Former exclusive e-cigarette use	1.08 (1.01, 1.15)	<i>1.06 (0.96, 1.18)</i>
Current exclusive e-cigarette use	1.42 (1.21, 1.65)	1.35 (1.10, 1.66)
Former exclusive cigarette use	1.52 (1.30, 1.78)	1.70 (1.41, 2.05)
Former dual use	1.57 (1.42, 1.74)	1.74 (1.52, 1.98)
Former cigarette/current e-cigarette use	1.66 (1.47, 1.88)	2.07 (1.76, 2.43)
Current exclusive cigarette use	1.27 (1.08, 1.50)	1.80 (1.48, 2.20)
Current cigarette/former e-cigarette use	1.72 (1.55, 1.91)	2.31 (2.02, 2.64)
Current dual use	1.71 (1.46, 2.00)	2.53 (2.09, 3.06)
35–44 years		
Nonuse	Ref	Ref
Former exclusive e-cigarette use	<i>1.05 (0.98, 1.13)</i>	1.13 (1.01, 1.25)
Current exclusive e-cigarette use	1.48 (1.10, 1.98)	1.89 (1.36, 2.64)
Former exclusive cigarette use	1.23 (1.12, 1.35)	1.66 (1.43, 1.92)
Former dual use	1.32 (1.21, 1.44)	1.91 (1.70, 2.14)
Former cigarette/current e-cigarette use	1.56 (1.36, 1.79)	2.27 (1.94, 2.65)
Current exclusive cigarette use	1.23 (1.05, 1.45)	1.66 (1.42, 1.93)
Current cigarette/former e-cigarette use	1.39 (1.26, 1.53)	2.29 (2.03, 2.58)
Current dual use	1.57 (1.34, 1.84)	2.70 (2.27, 3.21)
45–54 years		
Nonuse	Ref	Ref
Former exclusive e-cigarette use	<i>0.99 (0.92, 1.06)</i>	<i>1.03 (0.94, 1.12)</i>
Current exclusive e-cigarette use	1.21 (0.87, 1.69)	<i>1.35 (0.88, 2.07)</i>
Former exclusive cigarette use	1.27 (1.16, 1.38)	1.65 (1.50, 1.82)
Former dual use	1.35 (1.22, 1.48)	1.65 (1.48, 1.85)
Former cigarette/current e-cigarette use	1.38 (1.09, 1.75)	1.91 (1.57, 2.32)
Current exclusive cigarette use	<i>1.06 (0.93, 1.20)</i>	1.31 (1.15, 1.50)
Current cigarette/former e-cigarette use	1.25 (1.11, 1.40)	1.73 (1.54, 1.94)
Current dual use	1.29 (1.03, 1.62)	2.05 (1.61, 2.61)
55–64 years		
Nonuse	Ref	Ref
Former exclusive e-cigarette use	<i>0.97 (0.90, 1.05)</i>	<i>0.91 (0.84, 0.99)</i>
Current exclusive e-cigarette use	<i>0.98 (0.62, 1.55)</i>	1.70 (1.15, 2.51)
Former exclusive cigarette use	1.22 (1.13, 1.32)	1.62 (1.50, 1.76)
Former dual use	1.27 (1.16, 1.38)	1.84 (1.68, 2.01)
Former cigarette/current e-cigarette use	1.34 (1.06, 1.69)	2.39 (1.89, 3.02)
Current exclusive cigarette use	<i>1.02 (0.90, 1.15)</i>	1.39 (1.24, 1.56)
Current cigarette/former e-cigarette use	<i>1.08 (0.97, 1.20)</i>	1.73 (1.55, 1.94)
Current dual use	<i>1.02 (0.75, 1.40)</i>	1.73 (1.26, 2.37)
≥65 years		
Nonuse	Ref	Ref
Former exclusive e-cigarette use	<i>0.97 (0.90, 1.03)</i>	<i>0.92 (0.86, 0.98)</i>
Current exclusive e-cigarette use	<i>1.01 (0.63, 1.60)</i>	<i>1.52 (0.97, 2.37)</i>
Former exclusive cigarette use	1.22 (1.15, 1.30)	1.72 (1.62, 1.82)
Former dual use	1.29 (1.19, 1.40)	1.68 (1.56, 1.81)
Former cigarette/current e-cigarette use	<i>0.91 (0.62, 1.34)</i>	1.54 (1.06, 2.24)
Current exclusive cigarette use	<i>0.91 (0.80, 1.04)</i>	1.15 (1.02, 1.30)
Current cigarette/former e-cigarette use	<i>0.90 (0.78, 1.03)</i>	1.14 (1.02, 1.29)
Current dual use	<i>0.78 (0.54, 1.14)</i>	1.64 (1.18, 2.27)

Model adjusted for sex, race/ethnicity, education, income, marital status, self-rated health, mental health distress days, heavy alcohol consumption, and current smokeless tobacco use. Numbers in italics are not statistically significant ($p > 0.05$).

Table 4
Association between multimorbidity and tobacco use categories by race/ethnicity.

	Morbidity	
	1 Adjusted OR (95% CI)	≥2
Non-Hispanic White		
Nonuse	Ref	Ref
Former exclusive e-cigarette use	1.03 (1.00, 1.07)	<i>1.01 (0.97, 1.04)</i>
Current exclusive e-cigarette use	1.30 (1.19, 1.42)	1.48 (1.30, 1.67)
Former exclusive cigarette use	1.27 (1.22, 1.32)	1.71 (1.64, 1.77)
Former dual use	1.34 (1.28, 1.39)	1.73 (1.66, 1.81)
Former cigarette/current e-cigarette use	1.45 (1.35, 1.56)	2.08 (1.91, 2.26)
Current exclusive cigarette use	<i>1.06 (1.00, 1.14)</i>	1.36 (1.27, 1.46)
Current cigarette/former e-cigarette use	1.27 (1.20, 1.34)	1.83 (1.73, 1.94)
Current dual use	1.51 (1.38, 1.65)	2.45 (2.21, 2.71)
Non-Hispanic Black		
Nonuse	Ref	Ref
Former exclusive e-cigarette use	<i>1.07 (0.98, 1.16)</i>	<i>1.05 (0.95, 1.16)</i>
Current exclusive e-cigarette use	1.61 (1.28, 2.04)	1.73 (1.29, 2.33)
Former exclusive cigarette use	1.39 (1.21, 1.60)	2.03 (1.76, 2.34)
Former dual use	1.33 (1.15, 1.54)	1.88 (1.61, 2.18)
Former cigarette/current e-cigarette use	1.99 (1.40, 2.84)	1.90 (1.31, 2.75)
Current exclusive cigarette use	<i>1.10 (0.93, 1.31)</i>	1.46 (1.23, 1.74)
Current cigarette/former e-cigarette use	1.31 (1.13, 1.50)	1.46 (1.26, 1.69)
Current dual use	1.42 (1.07, 1.89)	2.34 (1.70, 3.23)
Non-Hispanic Other		
Nonuse	Ref	Ref
Former exclusive e-cigarette use	<i>0.97 (0.85, 1.11)</i>	<i>0.95 (0.78, 1.17)</i>
Current exclusive e-cigarette use	1.50 (1.09, 2.06)	1.99 (1.16, 3.42)
Former exclusive cigarette use	1.41 (1.15, 1.73)	2.20 (1.74, 2.77)
Former dual use	1.65 (1.32, 2.06)	2.56 (2.05, 3.21)
Former cigarette/current e-cigarette use	1.74 (1.24, 2.44)	2.99 (2.06, 4.34)
Current exclusive cigarette use	<i>1.19 (0.88, 1.61)</i>	1.89 (1.37, 2.61)
Current cigarette/former e-cigarette use	<i>1.30 (0.99, 1.71)</i>	1.60 (1.23, 2.08)
Current dual use	1.87 (1.28, 2.75)	2.53 (1.62, 3.94)
Non-Hispanic Multiracial		
Nonuse	Ref	Ref
Former exclusive e-cigarette use	<i>0.88 (0.71, 1.08)</i>	<i>0.82 (0.63, 1.07)</i>
Current exclusive e-cigarette use	<i>1.33 (0.86, 2.06)</i>	<i>1.48 (0.84, 2.61)</i>
Former exclusive cigarette use	<i>1.20 (0.89, 1.63)</i>	1.74 (1.26, 2.39)
Former dual use	1.40 (1.07, 1.82)	1.72 (1.30, 2.27)
Former cigarette/current e-cigarette use	1.60 (1.10, 2.34)	1.74 (1.15, 2.65)
Current exclusive cigarette use	<i>1.11 (0.76, 1.63)</i>	1.68 (1.18, 2.41)
Current cigarette/former e-cigarette use	<i>1.23 (0.94, 1.62)</i>	2.21 (1.64, 2.96)
Current dual use	<i>1.42 (0.91, 2.20)</i>	2.80 (1.82, 4.33)
Hispanic		
Nonuse	Ref	Ref
Former exclusive e-cigarette use	<i>1.00 (0.91, 1.09)</i>	<i>1.03 (0.91, 1.16)</i>
Current exclusive e-cigarette use	1.57 (1.29, 1.90)	1.37 (1.03, 1.82)
Former exclusive cigarette use	1.24 (1.08, 1.44)	1.73 (1.46, 2.05)
Former dual use	1.31 (1.13, 1.52)	1.78 (1.50, 2.12)
Former cigarette/current e-cigarette use	1.66 (1.20, 2.29)	2.29 (1.66, 3.16)
Current exclusive cigarette use	<i>1.14 (0.92, 1.41)</i>	1.54 (1.25, 1.90)
Current cigarette/former e-cigarette use	1.49 (1.26, 1.75)	2.69 (2.21, 3.26)
Current dual use	1.53 (1.15, 2.02)	2.56 (1.87, 3.49)

Model adjusted for age, sex, education, income, marital status, self-rated health, mental health distress days, heavy alcohol consumption, and current smokeless tobacco use. Numbers in italics are not statistically significant ($p > 0.05$).

randomized clinical trials, and the estimates were imprecise (Hartmann-Boyce et al., 2022). Similarly, another study found that switching from cigarette use to e-cigarette or dual use appears to reduce biomarkers of potential harm (Hartmann-Boyce et al., 2023). This current study's findings raises significant concerns about the use of these tobacco products and underscores the importance of reducing their use.

Our study also reveals that multimorbidity is not confined to older age groups, although its prevalence tends to be higher among older individuals, consistent with prior studies (King et al., 2018). Notably, our findings highlight stronger associations between tobacco use categories

and multimorbidity among younger adults as well. Previous research on multimorbidity has primarily focused on older populations, leaving multimorbidity categories in younger individuals underrepresented and under-studied (Carrilero et al., 2020). Additionally, our study findings showed a higher prevalence of multimorbidity among females compared to males, which aligns with other study findings (Sharma et al., 2023). This sex difference is often attributed to higher healthcare utilization and longer life expectancy among females (Sharma et al., 2023).

The relationship between tobacco use and multimorbidity is undoubtedly complex. The well-documented adverse health consequences of tobacco have led to extensive public health efforts to curb its prevalence and mitigate its effects. To effectively reduce the prevalence of multimorbidity, a comprehensive approach is needed, addressing multiple risk factors, with tobacco use being a crucial target for prevention and intervention through various concerted public health policies. Quitting tobacco use is pivotal in improving overall health and reducing the risk of single or multimorbidity.

The primary strength of this study is the use of a three-year nationally representative dataset, which allows us to provide estimates applicable to the noninstitutionalized US civilian population. Another strength is the ability to categorize tobacco use into nine different groups that are mutually exclusive. However, some limitations should be taken into consideration. First, it is essential to acknowledge that this was a cross-sectional analysis, which restricts our ability to establish causal inferences or determine the temporal sequence of the observed associations. Reverse causation remains possible and cannot be excluded. It is also plausible that e-cigarettes are used as part of quit attempts among those who reported dual use. Therefore, while our findings have potential public health and regulatory implications, they should be considered exploratory rather than definitive and seen as a starting point for future research. Second, our analysis relied on a one-time assessment, and the impact of the tobacco use categories on multimorbidity likely evolved over time. Longitudinal research is needed to provide a more comprehensive understanding of these dynamics. Third, our measure of multimorbidity was based on a simple count of diseases, which may not fully capture the complexity of the relationship between tobacco use categories and specific combinations of conditions or the broader impact of multimorbidity on healthcare systems (Rizza et al., 2012). Next, our analysis did not explore the duration or intensity of cigarette/e-cigarette product use and its potential association with multimorbidity, as this information was unavailable in the BRFSS dataset. Consequently, we cannot rule out the possibility that dual use may represent a transitional phase in tobacco product use. Fourth, there is also the potential for the healthy survivor effect as a potential bias of the observed association; those who report dual use may likely have worse health due to pre-existing conditions that could increase their odds of additional morbidities or that those with more severe health consequences due to their tobacco use may be more likely to die prematurely preventing them from participating in the survey, thereby leading to an underestimation of the true association between the tobacco use categories and multimorbidity. Last, data for 2020 and 2021 BRFSS were collected during the COVID-19 pandemic, and results should be interpreted in light of the association between COVID-19 and tobacco use categories, which was explored in a previous study using the 2021 US National Health Interview Survey (Kalan et al., 2023).

The high prevalence of multimorbidity among adults who reported current use of cigarettes, e-cigarettes, or both in the US underscores the critical need for enhanced regulatory measures and targeted clinical interventions to address the substantial health risks associated with these products and to curb the prevalence of chronic diseases in this population, especially among certain demographics such as females. However, it's crucial to note that prospective studies are needed to establish a causal link between these products (e.g., exclusive e-cigarette/dual use) and their impact on health through long-term longitudinal studies. Additionally, more research is warranted to explore potential causal relationships between exclusive cigarette use, e-

cigarette use, and the dual use of cigarettes and e-cigarettes in relation to multimorbidity. This type of research can inform the development of tailored interventions to reduce the prevalence of multimorbidity, particularly among specific demographic groups exhibiting distinct tobacco use behaviors.

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The authors have nothing to disclose

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CRediT authorship contribution statement

Mohammad Ebrahimi Kalan: Conceptualization, Formal analysis, Investigation, Methodology, Writing – review & editing. **Rime Jebai:** Conceptualization, Formal analysis, Investigation, Methodology, Writing – review & editing. **Olatokunbo Osibogun:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Writing – original draft, Writing – review & editing. **Wei Li:** Conceptualization, Formal analysis, Investigation, Methodology, Writing – review & editing.

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.

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