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Vaping and smoking behaviors among adolescents: Associations with demographic factors and mental health symptoms

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Abstract. *Objectives:* Vaping behaviors are highly prevalent among adolescents. However, additional research is necessary to identify common risk factors associated with vaping and smoking. This study sought to identify current prevalence rates of vaping and smoking among adolescents while identifying whether rates of engagement in these behaviors differ by gender, age and the presence of mental health symptoms. *Methods:* 6,393 U.S. adolescents (50.4% male; M_{age} = 14.74, SD = 1.76) recruited from a representative sample of high schools in Wood County, Ohio, completed a self-report survey in 2019. Using chi-square and logistic regression analyses, the cross-sectional associations between various vaping (nicotine, non-nicotine, cannabis), smoking (cigarettes and cannabis), and multiple product use (smoking and vaping) were investigated by gender, age, and the presence of mental health symptoms (aggression, delinquency, depression and anxiety). *Results:* Overall, 17.4% of adolescents reported having vaped during the past month. No gender differences were noted among those reporting nicotine and flavor vaping. Males reported higher rates of cannabis vaping. Older adolescents reported higher rates of cannabis vaping while younger adolescents reported higher rates of flavor vaping. Logistic regression analyses revealed that greater levels of delinquency were associated with all forms of vaping, smoking and multiple product use. Whereas greater aggressive symptoms were associated with nicotine and flavor vaping, depressive symptoms were associated with cigarette smoking. *Conclusion and Implication:* A significant proportion of adolescents report past month vaping, cannabis and cigarette smoking, with the use of these substances being associated with greater mental health symptomatology.

Background

Vaping or the use of electronic cigarettes (e-cigarettes) was initially introduced in 2006 to replace traditional cigarette smoking and has itself turned into an epidemic (Farzal et al., 2019). E-cigarettes are battery-operated devices used to vaporize liquid solutions that may contain nicotine, added flavors, and other chemicals (Bold et al., 2018). While the sale of e-cigarettes and e-liquids is illegal for minors to purchase in the United States, they are still widely accessible to youth (Hammond et al., 2019). Starting in September 2019, various states including Michigan, New York, and Ohio announced their intent to limit the sales of vaping products to minors and even adults due to potential health hazards (Ducharme, 2019). E-cigarette use has rapidly increased among high-school students, with evidence that rates of use grew by 10% from 2017 to 2018 (Kirby, 2019; Miech et al., 2019) and reached 27.5% in 2019 (Cullen et al., 2019). Among adolescents, vaping of nicotine-free flavored liquids and cannabis also increased significantly (Dai, 2020; Johnston et al., 2018). As of 2019, Cullen and colleagues noted that approximately 4.1 million American high school students and 1.2 million middle school students used e-cigarettes, with an estimated 970,000 students reporting daily use.

Adolescence marks an important period of psychological and social development which is often accompanied by both positive and negative transitional events. During adolescence, youth often have more responsibility, autonomy and freedom, which can lead to increased experimentation with a variety of risky behaviors (e.g., cigarette, e-cigarette, and substance use). Despite the potential health risks associated with vaping (Bjurlin et al, 2020; Rubinstein et al., 2018; St. Helen & Eaton, 2018; Wang et al., 2016), roughly 80% of 12th grade students who report vaping believe that electronic vapor products (EVPs) are safer than traditional cigarettes (Evans-Polce et al., 2017). Multiple reasons have been suggested as to why adolescents vape, with findings suggesting that more than 50% engage in vaping purely for experimental reasons, over 36% for the taste, and around 8% as a means to quit cigarette smoking (Evans-Polce et al., 2017; Patrick et al., 2016).

Over the past few years, considerable research has investigated the association between the use of e-cigarettes, cigarettes and cannabis smoking. In a recent meta-analysis, Soneji et al. (2017) noted that e-cigarette use may be a risk-factor for the initiation and maintenance of traditional cigarette smoking beyond other psychosocial risk factors. These findings have been replicated in recent longitudinal studies, with Goldenson et al. (2017) and Barrington-Trimis et al. (2018) indicating that youth who report vaping were more likely to initiate and progress to more frequent vaping and cigarette smoking over a six-month period. Over longer periods

of time, Bold and colleagues (2018) reported that e-cigarette use was prospectively associated with a greater risk of cigarette use up to three years later. As for e-cigarette, cigarette and cannabis use, Evans-Polce and colleagues (2020) reported that among 12th graders, those who used e-cigarettes and/or cigarettes were more likely to have used cannabis during the past 30 days.

When examining the associations between vaping and smoking among adolescents, the products youth are consuming (i.e., vaping nicotine, flavoring, or cannabis products) are critical to consider. In a review of the research published on vaping between 2014 to 2016, Greenhill et al. (2016) found that a majority of studies failed to report whether nicotine or non-nicotine products were being consumed. This omission has significant implications given the stronger associations noted for nicotine vaping in the transition to later cigarette use (Goldenson et al., 2017). Moreover, the co-occurrence of cannabis and nicotine use has similarly been reported (Kristman-Valente et al., 2017), with 3.9 to 8.9% of youth in the United States reporting vaping both nicotine and cannabis (Fataar & Hammond, 2019; Morean et al., 2015; Trivers et al., 2018).

Presently, research investigating gender differences in vaping and concurrent smoking behaviors among youth appear to have mixed results. Of note, Kwon and colleagues (2018) failed to find significant differences between male and female vapers while Yu et al. (2018) reported that males were 1.8 times more likely to be lifetime multiple tobacco users (through vaping and cigarettes) when compared to females. Moreover, males have been found to report higher rates of cannabis vaping when compared to females (Morean et al., 2015). As for age, older adolescents appear to be at a greater likelihood of e-cigarette and dual-use when compared to younger adolescents (Kwon et al., 2018; Yu et al., 2018). As such, gender and age appear to be significant demographic variables to consider when investigating the risk of vaping and smoking behaviors.

Other risk factors may be associated with vaping and smoking, including the presence of various mental health symptoms. Although research with college-aged and adult participants indicate that individuals who regularly use e-cigarettes are at a greater likelihood of reporting mental health problems (e.g., depressive symptoms, anxiety, attention problems, low self-esteem, impulsivity; Bandiera et al., 2016; Grant et al., 2018; Hiler et al., 2020; Li et al., 2019; Saeed et al., 2020), a dearth of research has investigated which mental health symptoms are related to e-cigarette and/or dual-use among adolescents. Due to the limited research, a call for action has been launched highlighting the need to investigate whether mental health problems are one of the factors responsible for the transition from e-cigarette to dual-use among adolescents (Gaiha & Halpern-Felsher, 2020). Of the available literature, Leventhal and colleagues (2016) reported that depression, panic disorder, and anhedonia were higher in adolescent e-cigarette users compared to non-users. Moreover, for various externalizing problems, an ordered pattern was observed whereby these symptoms were

lowest in non-users, moderate in single product users (conventional cigarette or e-cigarette only), and highest among dual users (Leventhal et al., 2016). In a longitudinal study, Kwon and colleagues (2018) reported that youth with high externalizing and internalizing disorders were at an increased risk of e-cigarette use one year later when controlling for sociodemographic variables and substance use behaviors. Lastly, Staff and colleagues (2020) identified that dual-users at age 14 reported the least positive adjustment and the most delinquent and substance use behaviors at age 11, followed by e-cigarette users and non-users.

A number of media reports have highlighted potential significant health concerns associated with vaping along with ease of access of vaping products. As such, a fresh look at those using e-cigarettes and other EVPs is important. Based on previous studies and the gaps remaining within the adolescent vaping literature, the present study has three objectives: (1) to identify prevalence rates of vaping (nicotine, non-nicotine, and cannabis), smoking (cigarette and cannabis), and multiple product use among adolescents while examining whether these rates differ by gender and age; (2) to identify whether youth who report vaping more frequently are more likely to also engage in cigarette or cannabis smoking; and (3) to identify whether adolescents reporting vaping, smoking, or the use of multiple products differ with regards to self-reported mental health symptoms.

Methods
Participants and Procedure

The present study used data collected from the 2019 Alcohol, Drug Addiction and Mental Health Services (ADAMHS) Board/Wood County Educational Service Centre survey on alcohol and other drug use.

A total of 7,573 students (grades 7 to 12) from 10 public schools in Wood County, Ohio participated in completing the survey. Participants provided information concerning a variety of mental health issues, vaping, and smoking behaviors. Of these, 763 were excluded due to insincere responses (i.e., reporting the use of fake drugs or use of all drugs at all times; providing inconsistent responses; reporting having participated in all gambling activities daily). As age was a variable of interest in the study, the low number of participants under 12 ($n = 15$) and over 18 ($n = 6$) years of age were removed. Moreover, as gender was also of interest, 396 participants were eliminated due to missing data. The final sample comprised 6,393 participants, with a mean age of 14.74 years ($SD = 1.76$). Demographic characteristics of the sample are presented in Table 1.

Table 1

Participant Characteristics

	N	%
Sociodemographic data		
Gender (male)	3223	50.4
Ethnicity		
White	5131	80.3
Black	146	2.3
Hispanic	310	4.8
Asian	137	2.1
Multicultural	252	3.9
Other/Missing	417	6.6
Age		
12-14 years	2902	45.4
15-17 years	3213	50.3
18 years	278	4.3
Past month cigarette smoking (yes)	144	2.3
Past month cannabis smoking (yes)	541	8.5
Past month nicotine vaping		
0-9 days	574	9.0
10+ days	293	4.6
Past month flavoring vaping		
0-9 days	440	6.9
10+ days	92	1.4
Past month cannabis vaping		
0-9 days	352	5.5
10+ days	138	2.2
Past month dual-user (cigarette and vaping; yes)	123	1.9
Past month dual-user (cannabis and vaping; yes)	463	7.2
Past month tri-user (cigarette, cannabis, vaping; yes)	85	1.3

Note. Past month vaping was only assessed in those reporting having ever vaped.

Students completed an anonymous paper-pencil survey administered by their classroom teacher. In each school building, trained addiction counsellors coordinated the survey distribution and assisted teachers with administration when needed. Participants were informed about the confidential nature of the survey and that they could withdraw from participation at any time without consequence. School principals provided parents with an informed consent form to ensure parental

agreement for participation. Information regarding the survey was provided to all parents by letter and were available on each school district website for viewing. Parents could elect for their children to opt out of participating by informing the school principals. Ethical approval was granted by the ADAMHS ethics committee.

Measures

Demographic Characteristics. All participants indicated their gender, age and ethnicity (e.g., White, Hispanic, Black) at the beginning of the survey. In order to investigate differences based on age, this variable was recoded dichotomously based on younger (12 to 14 years) and older (15 to 18 years) adolescents.

Vaping Behaviors. Vaping behaviors were assessed by asking participants if they had ever engaged in vaping behaviors (yes or no). If participants responded yes, they were invited to answer three more questions about their vaping behaviors based upon past 30 day use: (1) on how many days (if any) have you vaped nicotine?; (2) on how many days (if any) have you vaped just flavoring, without any nicotine or marijuana in it?; and (3) on how many days (if any) have you vaped marijuana? Participants were provided with a choice of response on a 6-point Likert scale, including: *0 days*; *1-2 days*; *3-5 days*; *6-9 days*; *10-19 days*; and *20 or more days*. In addition to ascertaining the frequency of use for each product vaped, vaping behaviors were recoded into a dichotomous score for each product: *no past month vaping* and *past month vaping* (use of the product at least 1 day in the past month).

Cigarette and Cannabis Smoking. Smoking behaviors were assessed by frequency of use and the type of product consumed. Frequency of cigarette smoking over the past 30 days were assessed using a 6-point Likert scale; *not at all*; *less than one cigarette per day*; *1-5 cigarettes per day*; *6-10 cigarettes per day*; *about one-half pack per day*; and *about one pack or more per day*. With respect to cannabis use, participants indicated use over the past 30 days with responses on a 5-point Likert scale; *never*; *1-2 times*; *3-5 times*; *6-10 times*; and *11+ times*. In addition to ascertaining the frequency of use, smoking behaviors were recoded into a dichotomous score for each product: *no past month smoking* and *past month smoking* (use of the product at least once in the past month).

Mental Health Symptoms. Mental health symptoms were assessed using the Problem Severity Scale (PSS) of the Ohio Youth Scales (Ogles et al., 2001). The PSS was developed based on problem behaviors identified in the DSM-IV (APA, 1994), common presenting problems for youth with emotional disturbances, consultations with childcare service providers and items from other commonly used instruments to assess youth psychopathology (Ogles et al., 2001). The PSS consists of 20-items based on common mental health symptoms (e.g., feeling worthless or useless) and problem behaviors (e.g., yelling, swearing, or screaming at others) rated on a 6-point Likert scale (ranging from 0 [*not at all*] to 5 [*all of the time*], for a

total possible score ranging from 0 to 100). Qualitative descriptors have been assigned to the overall score, with scores ranging from 0 to 9 indicating *no problems,* 10 to 19 *low problems*, 20 to 36 *moderate problems*, 37 to 52 *severe problems*, and 53 to 100 *intense problems* (Ogles et al., 2001). Within the present sample, the internal consistency for the PSS was excellent (Cronbach α = 0.93). Through a confirmatory factor analyses, Bonadio and Tompsett (2017) identified a four-factor model for the PSS (Aggression, Anxiety, Depression and Delinquency). Each factor is associated with a unique number of items (ranging from three to eight), with higher scores indicating greater problem severity in each domain.

Statistical Analysis
        IBM SPSS version 25 was used for data processing and analysis. For the first research question, descriptive statistics were used to identify the prevalence of various vaping and smoking behaviors. Chi-square analyses with odds ratio calculations were conducted to identify gender or age-related differences in the prevalence rates of these behaviors. For these analyses, both gender and age were coded dichotomously. For the second research question, independent samples *t*-tests were conducted to identify whether youth endorsing more frequent vaping behaviors were more likely to have engaged in cigarette or cannabis smoking. For the third research question, additional independent samples *t*-tests were conducted to identify whether youth who reported vaping or smoking over the past month endorsed a greater severity of overall mental health symptoms. Finally, eight separate binary logistic regression analyses were conducted to predict classification of vapers (nicotine; flavor; cannabis), smokers (cigarette; cannabis), and users of multiple products (vaping and cigarettes; vaping and cannabis; vaping, cigarettes and cannabis) over the past month. Predictor variables included gender, age, aggressive problems, delinquent problems, depressive symptoms and anxious symptoms. Preliminary analyses were conducted to verify the assumptions for the binary logistic regression analysis.

Results
        Prevalence rates for vaping, cigarette and cannabis smoking, and the use of multiple products are depicted in Table 1. Overall, 27.5% (*n* = 1746) of adolescents reported that they had vaped. As for rates of vaping over the past 30 days, 17.4% (*n* = 1113) reported having vaped nicotine, flavoring or cannabis. Of these adolescents, 2.1% reported vaping flavoring only, 4.2% nicotine only; and 1.4% cannabis only. Among adolescents reporting vaping multiple products, 3.5% reported vaping both nicotine and cannabis, 3.4% both nicotine and flavoring, 2.4% all three products, and 0.4% cannabis and flavoring.
        No significant gender differences were noted among adolescents reporting having ever vaped (χ^2 [1, 6351] = 1.27, *p* = .26), vaped nicotine (χ^2 [1, 1746] = 0.04, *p* = .85) or vaped flavoring (χ^2 [1, 1746] = 0.05, *p* =

.83). However, males (30.5%) reported higher rates of cannabis vaping compared to females (25.7%) (χ^2 [1, 1746] = 4.84, p = .03, OR = 1.26, 95% CI [1.03, 1.56]). Males also reported higher rates of cigarette smoking (2.9%) when compared to females (1.6%) (χ^2 [1, 6392] = 10.71, p = .001, OR = 1.74, 95% CI [1.25, 2.49]), in addition to higher rates of dual-use (both vaping and cigarette use; 8.3% males and 5.4% females; χ^2 [1, 1746] = 5.54, p = .019, OR = 1.57, 95% CI [1.08, 2.29]). No gender differences were identified for cannabis smoking (χ^2 [1, 6378] = 1.87, p = .17).

Older adolescents, aged 15 to 18, were more likely to have ever vaped (39%) compared to younger adolescents aged 12 to 14 (13.7%) (χ^2 [1, 6351] = 505.46, p < .001, OR = 4.04, 95% CI [3.56, 4.58]). As for the use of specific vaping products among those reporting having vaped, no age differences were noted for nicotine vaping (χ^2 [1, 1746] = 2.27, p = .132). Older adolescents (29.6%) reported higher rates of cannabis vaping than younger adolescents (22.6%) (χ^2 [1, 1746] = 7.37, p = .007, OR = 1.44, 95% CI [1.10, 1.87]), and younger adolescents (40.2%) reported higher rates of flavor vaping compared to older adolescents (27.6%) (χ^2 [1, 1746] = 22.68, p < .001, OR = 1.76, 95% CI [1.39, 2.22]). Older individuals were found to have higher rates of cigarette smoking (3.5% vs. 0.8%; χ^2 [1, 6392] = 53.87, p < .001, OR = 4.74, 95% CI [3.00, 7.48]), cannabis smoking (13.9% vs. 2.0%; χ^2 [1, 6378] = 286.65, p < .001, OR = 7.88, 95% CI [5.97, 10.40]), and dual-use (7.5% vs. 4.6%; χ^2 [1, 1746] = 3.99, p = .046, OR = 1.68, 95% CI [1.01, 2.81]) compared to younger individuals.

Frequency of Vaping Behaviors and Engagement in Cigarette and Cannabis Smoking

Differences in vaping frequency between individuals reporting cigarette (n = 136) and cannabis (n = 498) smoking are reported in Table 2. Overall results suggest that adolescent cigarette smokers (past month) reported more frequent nicotine, flavor and cannabis vaping. These results are consistent with the findings reported when analyses were conducted separately for males and females and for younger and older adolescents, with the exception of there not being a difference in the frequency of flavor vaping for females and youth aged 15-18.

Table 2

Frequency of vaping behaviors reported by those reporting cigarette smoking and cannabis smoking over the past month.

| | Cigarette smoking | | | | | | | |
| | No | | Yes | | | | | |
Variable	M	SD	M	SD	df	t	p	Cohen's d
Overall								
Nicotine vaping	1.16	1.66	3.04	1.97	1744	12.54	< .001	1.03
Flavor vaping	0.59	1.17	0.96	1.59	1744	3.44	.001	0.27
Cannabis vaping	0.58	1.26	1.53	1.81	1744	8.09	< .001	0.97
Males only								
Nicotine vaping	1.16	1.67	3.07	2.11	858	9.79	< .001	1.00
Flavor vaping	0.60	1.18	1.05	1.73	858	3.17	.002	0.30
Cannabis vaping	0.65	1.36	1.70	1.91	858	6.48	< .001	0.63
Females only								
Nicotine vaping	1.16	1.65	3.00	1.74	884	9.79	< .001	1.09
Flavor vaping	0.59	1.15	0.82	1.34	884	1.36	.173	-
Cannabis vaping	0.52	1.16	1.24	1.61	884	4.17	.002	0.51
Age 12-14 only								
Nicotine vaping	0.45	0.50	0.80	0.41	391	3.13	.002	0.77
Flavor vaping	0.39	0.49	0.65	0.49	391	2.33	.020	0.53
Cannabis vaping	0.21	0.41	0.45	0.51	391	2.46	.014	0.52
Age 15-18 only								
Nicotine vaping	0.47	0.50	0.84	0.36	1351	7.79	< .001	0.85
Flavor vaping	0.27	0.45	0.32	0.47	1351	1.07	.284	-
Cannabis vaping	0.27	0.44	0.57	0.50	1351	6.83	< .001	0.63

| | Cannabis smoking | | | | | | | |
| | No | | Yes | | | | | |
	M	SD	M	SD	df	t	p	Cohen's d
Overall								
Nicotine vaping	0.86	1.43	2.41	1.99	1734	18.10	< .001	0.89
Flavor vaping	0.52	1.06	0.84	1.49	1734	5.10	< .001	0.25
Cannabis vaping	0.16	0.60	1.88	1.78	1734	30.13	< .001	1.29
Males only								
Nicotine vaping	0.86	1.45	2.51	2.01	854	13.54	< .001	0.94
Flavor vaping	0.50	0.64	2.08	1.84	854	5.26	< .001	0.36
Cannabis vaping	0.16	1.04	0.98	1.58	854	22.64	< .001	1.39
Females only								
Nicotine vaping	0.87	1.41	2.30	1.97	878	11.95	< .001	1.22
Flavor vaping	0.55	1.08	0.70	1.28	878	1.72	.085	-
Cannabis vaping	0.15	0.57	1.66	1.69	878	19.83	< .001	1.20

Age 12-14 only							
Nicotine vaping	0.43	0.50	0.65	0.48	385	3.02	.003	0.45
Flavor vaping	0.37	0.48	0.57	0.50	385	2.83	.005	0.41
Cannabis vaping	0.16	0.37	0.61	0.49	385	7.88	< .001	1.04
Age 15-18 only							
Nicotine vaping	0.39	0.49	0.75	0.43	1347	13.47	< .001	0.78
Flavor vaping	0.25	0.43	0.32	0.47	1347	2.67	.008	0.16
Cannabis vaping	0.08	0.27	0.74	0.44	1347	34.02	< .001	1.81

Results further indicated that youth who smoked cannabis (past month) engaged in more frequent nicotine, flavor and cannabis vaping. Analyses conducted separately for males and females indicated similar findings to what was found for cigarette smoking, whereby the only non-significant finding was that there was no difference in the frequency of flavor vaping between female cannabis smokers and non-smokers. Youth in both age categories reporting cannabis smoking engaged in nicotine, flavor and cannabis vaping more frequently than those who did not smoke cannabis.

Predictors of Vaping, Smoking and Multiple Product Use

Preliminary analyses were conducted to identify whether vapers, smokers, and youth using multiple substances differed in self-reported mental health symptoms. Table 3 depicts results from a series of independent samples *t*-tests indicating that adolescents engaging in all vaping and smoking behaviors endorsed greater overall mental health symptoms. Based on the qualitative descriptors of the PSS, youth who did not engage in these behaviors consistently had mean scores within the *low problems* range, whereas youth who engaged in these behaviors consistently had mean scores within the *moderate problems* range.

Table 3
Overall mental health symptoms reported by adolescents reporting vaping (nicotine, flavor, cannabis), cigarette smoking, cannabis smoking, and use of multiple products over the past month

	No		Yes					
Variable	*M*	*SD*	*M*	*SD*	*df*	*t*	*p*	Cohen's *d*
Nicotine vaping	12.92	14.73	26.15	20.38	5819	21.93	< 0.001	0.74
Flavor vaping	13.58	15.33	27.08	20.41	5819	17.82	< 0.001	0.75
Cannabis vaping	13.54	15.23	28.38	20.99	5819	19.13	< 0.001	0.81
Dual-user (cigarette, vaping)	14.36	15.93	32.37	22.13	5819	11.28	< 0.001	0.93

Dual-user (cannabis, vaping)	13.51	15.22	29.40	20.68	5812	20.03	< 0.001	0.88
Tri-user (cigarette, cannabis, vaping)	14.42	15.99	33.65	21.56	5812	10.09	< 0.001	1.01
Cigarette smoking	14.27	15.83	32.31	22.76	5855	12.33	< 0.001	0.93
Cannabis smoking	13.38	15.13	28.36	20.47	5844	20.32	< 0.001	0.92

Note. Mental health symptoms as measured by the total score on the PSS, for a total possible score ranging from 0 to 100.

To ascertain the predictors of various vaping and smoking behaviors, multiple binary logistic regression analyses were conducted. The absence of multicollinearity was verified through correlational analyses, with no Pearson correlation coefficients between the independent variables being higher than .90 (Hair, Black, Babin, & Anderson, 2007; see Table 4 for the correlation matrix).

Table 4.

Pearson correlation coefficients of the variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. Vape nicotine	-											
2. Vape flavor	.28**	-										
3. Vape cannabis	.34**	.09**	-									
4. Dual-use (CG-VP)	.24**	.06*	.20**	-								
5. Dual-use (CA-VP)	.36**	.10*	.67**	.27**	-							
6. Tri-use (CG-CA-VP)	.20**	.02	.26**	.82**	.38**	-						
7. Cigarette smoking	.20**	.04	.18**	.95**	.24**	.78**	-					
8. Cannabis smoking	.31**	.06*	.63**	.25**	.95**	.36**	.29**	-				
9. Aggressive problems	.14**	.14**	.14**	.10**	.13**	.08*	.14**	.21**	-			

Table 4.

Pearson correlation coefficients of the variables

10. Delinquent problems	.32**	.10**	.40**	.26**	.45**	.25**	.29**	.51**	.51**	-		
11. Depressive symptoms	.07*	.10**	.08**	.07*	.11**	.07*	.13**	.19**	.60**	.39**	-	
12. Anxious symptoms	.03	.11**	.04	.06*	.08*	.06*	.09**	.13**	.13**	.31**	.80**	-

*Note. * p < .05. ** p ≤ .001. CG = cigarette; VP = any vape; CA = cannabis. Tri-use = use of CG, CA and VP.*

Vaping Behaviors. For the three different vaping behaviors, all Omnibus tests indicated that the six-predictor models were significant in predicting engagement in vaping over the past 30 days (Table 5). The first model accounted for 30.7% of the total variance in nicotine vaping although the Hosmer and Lemeshow Goodness of Fit test indicated that the model provided a poor fit for the data, $\chi^2 (8) = 58.91$, $p < .001$. Older age (Exp[B] = 1.39, $p < .001$), greater levels of delinquency (Exp[B] = 1.61, $p < .001$) and greater levels of aggression (Exp[B] = 1.03, $p < .001$) were identified as being significant predictors of nicotine vaping. The second model accounted for 13.5% of the total variance in flavor vaping with the Hosmer and Lemeshow Goodness of Fit test indicating that the model provided a poor fit for the data, $\chi^2 (8) = 59.89$ $p < .001$. Older age (Exp[B] = 1.17, $p < .001$), greater levels of aggression (Exp[B] = 1.05, $p < .001$), and greater levels of delinquency (Exp[B] = 1.20, $p < .001$) were significant predictors for flavor vaping. The third model accounted for 31.9% of the variance in cannabis vaping although the Hosmer and Lemeshow Goodness of Fit test indicated that the model provided a poor fit for the data, $\chi^2 (8) = 45.25$, $p < .001$. Older age (Exp[B] = 1.34, $p < .001$), and greater levels of delinquency (Exp[B] = 1.66, $p < .001$) were significant predictors of cannabis vaping.

Table 5
Logistic regression analyses predicting vaping (nicotine, flavor, cannabis), cigarette smoking, cannabis smoking, and use of multiple products

Variables	Model Chi-square	R Square	B	SE	Exp(B)	95% CI	Wald statistic	p
Vape nicotine	1061.67	.307						< .001
Gender			.114	.093	1.12	[0.93, 1.35]	1.49	.222
Age			.326	.028	1.39	[1.31, 1.47]	131.21	< .001
Aggression			.032	.008	1.03	[1.02, 1.05]	14.91	< .001
Delinquency			.475	.026	1.61	[1.53, 1.69]	344.75	< .001
Depression			.006	.011	1.01	[0.99, 1.03]	0.26	.609
Anxiety			-.035	.019	0.97	[0.93. 1.00]	3.33	.068
Vape flavor	349.44	.135						< .001
Gender			.028	.106	1.03	[0.84, 1.27]	0.71	.790
Age			.160	.031	1.17	[1.11, 1.25]	27.09	< .001
Aggression			.046	.008	1.05	[1.03, 1.06]	29.88	< .001
Delinquency			.182	.022	1.20	[1.15, 1.25]	71.53	< .001
Depression			.008	.011	1.01	[0.99, 1.03]	0.48	.488
Anxiety			.015	.020	1.02	[0.98, 1.06]	0.55	.460
Vape cannabis	832.76	.319						< .001
Gender			-.039	.120	0.96	[0.76, 1.22]	0.11	.744
Age			.294	.037	1.34	[1.25, 1.44]	62.53	< .001
Aggression			-.005	.011	1.00	[0.98, 1.02]	0.28	.648
Delinquency			.508	.028	1.66	[1.57, 1.76]	330.42	< .001
Depression			.016	.013	1.02	[0.99, 1.04]	1.46	.227
Anxiety			-.036	.024	0.97	[0.92, 1.01]	2.17	.141
Cigarette smoking	257.10	.234						< .001
Gender			-.562	.210	0.57	[0.38, 0.86]	7.15	.007
Age			.478	.071	1.61	[1.40, 1.85]	45.64	< .001
Aggression			.018	.015	1.02	[0.99, 1.05]	1.44	.231
Delinquency			.273	.032	1.31	[1.23, 1.40]	70.44	< .001
Depression			.049	.020	1.05	[1.01, 1.09]	5.96	.015
Anxiety			-.048	.038	0.95	[0.89, 1.03]	1.63	.202
Cannabis smoking	1095.08	.389						< .001
Gender			.007	.119	1.01	[0.80, 1.27]	0.01	.952
Age			.471	.040	1.60	[1.48, 1.73]	139.72	< .001
Aggression			-.015	.011	0.99	[0.96, 1.01]	2.02	.155
Delinquency			.588	.030	1.80	[1.70, 1.91]	383.58	< .001
Depression			.014	.013	1.01	[0.99. 1.04]	1.09	.297
Anxiety			-.028	.024	0.97	[0.93, 1.02]	1.30	.254

	χ²	R²	B	SE	Exp[B]	95% CI	Wald	p
Dual-use (CG-VP)	237.12	.245						< .001
Gender			-.265	.225	0.77	[0.49, 1.19]	1.39	.239
Age			.494	.078	1.64	[1.41, 1.91]	39.79	< .001
Aggression			.006	.017	1.01	[0.97, 1.04]	0.12	.733
Delinquency			.327	.036	1.39	[1.29, 1.49]	84.34	< .001
Depression			.014	.022	1.01	[0.97, 1.06]	0.41	.520
Anxiety			-.006	.041	0.99	[0.92, 1.08]	0.02	.884
Dual-use (CA-VP)	992.84	.387						< .001
Gender			-.008	.128	0.99	[0.77, 1.27]	0.01	.948
Age			.471	.043	1.60	[1.47, 1.74]	119.63	< .001
Aggression			-.015	.011	0.99	[0.96, 1.01]	1.62	.204
Delinquency			.571	.030	1.77	[1.67, 1.88]	355.81	< .001
Depression			.006	.014	1.01	[0.98, 1.03]	0.182	.670
Anxiety			-.010	.026	0.99	[0.94, 1.04]	0.158	.691
Tri-use	202.41	.274						< .001
Gender			-.353	.272	0.70	[0.41, 1.20]	1.68	.195
Age			.510	.096	1.67	[1.38, 2.01]	27.95	< .001
Aggression			-.026	.021	0.97	[0.94, 1.02]	1.54	.215
Delinquency			.384	.042	1.47	[1.35, 1.60]	82.33	< .001
Depression			.020	.026	1.02	[0.97, 1.07]	0.61	.436
Anxiety			.005	.048	1.01	[0.92, 1.10]	0.12	.913

Note. Nagelkerke R Square is reported. *SE* = Standard error; CG = cigarette; VP = any vape; CA = cannabis. Tri-use = use of CG, CA and VP.

Smoking Behaviors. The Omnibus tests indicated that the six-predictor models were significant in predicting engagement in cigarette and cannabis smoking over the past 30 days (Table 5). The fourth model accounted for 23.4% of the variance in cigarette smoking, although the Hosmer and Lemeshow Test indicated a poor fit for the data, $\chi^2(8) = 19.03$, $p = .015$. Significant predictors for cigarette smoking included being male (Exp[B] = 0.57, $p = .007$), older (Exp[B] = 1.61, $p < .001$), endorsing greater levels of delinquency (Exp[B] = 1.31, $p < .001$) and greater depressive symptoms (Exp[B] = 1.05, $p = .015$). The fifth model accounted for 38.9% of the variance in cannabis smoking, although the goodness of fit test indicated the model was also a poor fit for the data, $\chi^2(8) = 38.00$, $p < .001$. Older age (Exp[B] = 1.60, $p < .001$) and endorsing greater levels of delinquency (Exp[B] = 1.80, $p < .001$) were significant predictors of cannabis smoking.

Multiple-Product Use. The three remaining models investigated the use of multiple products including dual-use of vaping and cigarettes, dual-use of vaping and cannabis and the use of all three products (i.e., tri-use). Results from the Omnibus tests indicated that all of the six-predictor models were significant in predicting engagement in these behaviors over the past 30 days (Table 5). Although the regression models for the dual-use

of vaping and cannabis indicated a poor fit of the data (χ^2 (8) = 36.92, *p* < .001), the regression model for the dual-use of vaping and cigarette and tri-use indicated a good fit for the data (χ^2 (8) = 9.33, *p* = .315; χ^2 (8) = 11.63, *p* = .168, respectively). Despite accounting for different amounts of the variance in these behaviors (24.5% for dual-use of vaping and cigarettes; 38.7% for dual-use of vaping and cannabis; and 27.4% for tri-use), in all three models, older age (Exp[B] = 1.60–1.67, all *p* < .001) and greater levels of delinquency (Exp[B] = 1.39–1.77, all *p* < .001) were significant predictors of these behaviors.

Discussion

The first objective of the current study was to identify recent prevalence rates of vaping, smoking, and multiple product use among high-school students. Overall, prevalence rates of vaping were quite high, with 27.5% of adolescents reporting having ever vaped and 17.4% reporting having vaped over the past month. Among those who reported past month vaping, nicotine was the most commonly vaped substance followed by flavoring and cannabis. These findings are consistent with recent research indicating that the prevalence rates of vaping have dramatically increased over the past few years (Cullen et al., 2019; Johnston et al., 2018). Moreover, results from previous Wood County ADAMHS surveys indicates a dramatic increase in vaping among 12th graders from 2018 to 2020, with rates of cannabis vaping increasing by 11.8% and nicotine vaping increasing by 12.6% (Ivoska, 2018). Similar increases have been noted among both 8th and 10th graders, although prevalence rates were not as high (Ivoska, 2018). Although the purchase of vaping products is illegal for minors and the fact that vaping behaviors have been associated with various physical and mental health risks (Leventhal et al., 2016; St. Helen & Eaton, 2018; Wang et al., 2016), these findings highlight that these products are still widely accessible and being used by youth.

In line with research investigating vaping and traditional cigarette use (Kristman-Valente et al., 2017; Morean et al., 2015; Trivers et al., 2018), current results suggest that adolescents who smoked cigarettes were more likely to have engaged in frequent nicotine and cannabis vaping in comparison to non-smokers. These findings are also consistent to what was found for cannabis smoking. When examining gender differences, the present findings are consistent with previous research suggesting no significant gender differences for youth reporting nicotine and flavored vaping (Kwon et al., 2018). However, males were 1.57 times more likely to be dual-users, 1.74 times more likely to be cigarette smokers, and 1.26 times more likely to be cannabis vapers. These findings are consistent with research reporting that males are more likely to be dual-users (Yu et al, 2018) and cannabis vapers (Morean et al., 2015). Rates of use also differed by age, being consistent with past findings suggesting that older adolescents are more likely engage in both nicotine and cannabis vaping (Kwon et al, 2018; Yu et al 2018). Although rates of smoking were significantly lower

than those of vaping, older adolescents were also found to report higher rates of cigarette smoking, cannabis smoking and dual-use compared to younger adolescents. Based on these findings, it is unclear whether the use of EVPs represents a substitute (vaping devices replacing smoking) or a supplement (vaping devices used in addition to smoking) to traditional nicotine and cannabis smoking for older adolescents.

A novel finding of the current study is that youth aged 12 to 14 were almost two times more likely to report flavor vaping compared to those aged 15 to 18. It's plausible that younger youth engage in flavor vaping at higher rates as this type of vaping may be perceived as safer than nicotine or cannabis vaping and may be preferred due to the range of tastes and flavors (Evans-Polce et al., 2017; Patrick et al. 2016). Moreover, it is possible that youth who report flavor vaping at an early age are at an increased risk of transitioning to vaping other products such as nicotine and cannabis as they become older. Further longitudinal research is necessary to verify this hypothesis, as a majority of past research has focused on the transition from e-cigarette to traditional cigarette use (Barrington-Trimis et al., 2018; Bold et al., 2018; Goldenson et al., 2017; Soneji et al., 2017) and not the transition from flavor vaping to nicotine or cannabis vaping.

Concerning mental health symptoms, results suggest that youth who reported engaging in any type of vaping or smoking endorsed greater mental health symptoms compared to youth who did not report these behaviors. Of note, those who reported the use of multiple products (i.e., vaping, cigarettes and/or cannabis) endorsed the greatest severity of mental health symptoms. Results from the regression analyses indicate that delinquent problems were the most consistent predictor of all vaping, smoking and multiple product use behaviors. Specific to nicotine and flavor vaping, aggressive problems also appeared to be associated with engagement in these behaviors and depressive symptoms were associated with engagement in cigarette smoking. Previous research has reported that adolescents engaging in e-cigarette use demonstrated greater internalizing and externalizing problems compared to non-users (Kwon et al., 2018; Leventhal et al., 2016; Staff et al., 2020). As such, current findings are consistent with what has been found for externalizing problems, but not internalizing problems.

The reported association between externalizing problems and various vaping and smoking behaviors is consistent with the problem behavior syndrome suggested by Jessor and Jessor (1977), who hypothesized that youth engaging in these behaviors may be at a greater risk of co-occurring delinquent, aggressive and substance use behaviors (Willoughby, Chalmers & Busseri, 2004). However, results suggest that these associations may differ based on the specific type of substance vaped, with delinquency being more closely associated with nicotine and cannabis vaping and aggression being more closely associated with nicotine and flavor vaping. As for internalizing problems, only cigarette smoking was found to be associated with greater depressive symptoms. Leventhal and colleagues (2016) noted that adolescents who only used e-cigarettes

presented a lower risk of internalizing disorders compared to those only using conventional cigarettes. Given the developmental period of adolescence, it is possible that youth who engage in vaping are doing so more for experimental reasons as opposed to utilizing vaping as a coping tool in order to self-medicate, or regulate negative affect associated with emotional dysfunctions (Gehricke et al., 2007). However, because these associations were investigated cross-sectionally, these proposed relationships and mechanisms are speculative and should be investigated utilizing longitudinal designs.

Implications

The present findings have several public health implications. As rates of vaping behaviors far exceed rates of traditional cigarette smoking, there is a need for prevention initiatives targeted toward youth and their parents. Moreover, as youth who reported frequent vaping behaviors were more likely to engage in cigarette and cannabis smoking, there is an added risk of multiple product use in the short and long-term. Indeed, there was an ordered pattern in the presence of overall mental health symptoms whereby users of multiple products reported the greatest severity. Although the directionality of these relationships cannot be established, it is plausible that preventing both the initiation of vaping behaviors and improving mental health and coping resources would be beneficial for youth. As longitudinal studies have identified that mental health symptoms tend to precede vaping behaviors (Kwon et al., 2018; Staff et al., 2020), mental health programs including the teaching and practice of emotion regulation skills could be promoted within schools. These programs have the potential to benefit all adolescents, including those at-risk for substance use and other mental health disorders (Greenberg & Abenavoli, 2017).

Limitations

This study has a number of limitations. First, the cross-sectional nature of the assessment precludes establishing causal effects. The use of longitudinal studies would elucidate the interrelation between vaping, smoking and the presence of various mental health symptoms. Second, although participants were informed about the anonymity of their responses, data was collected with the use of a self-report questionnaire and the results may be biased. Nevertheless, the removal of inconsistent responses and the high sample size helps ensure the reliability of the results. Third, although the regression models explained a significant portion of variance in the vaping and smoking behaviors, some of the models indicated a poor fit for the data. Although an important limitation, previous analyses have indicated that this is a common problem in applying the Hosmer-Lemeshow test, where power increases in accordance with the sample size (Yu, Xu, & Zhu, 2017). Fourth, although the study employed a large sample size, participants come from a single county within the state of Ohio in the United States. Thus, the findings may not be generalizable to other populations.

Notwithstanding, this study contributes to our understanding of vaping and smoking behaviors among high-school students and the association of these behaviors with various mental health symptoms and problem behaviors.

Conclusion

In sum, a significantly larger proportion of high-school students are reporting engagement in vaping, when compared to cannabis and cigarette smoking, with the use of these substances being associated with various mental health symptoms. Whereas gender differences were not noted for flavor and nicotine vaping, males were more likely to engage in cannabis vaping. Moreover, younger adolescents were more likely than older adolescents to engage in flavor vaping. Future studies utilizing longitudinal designs should investigate the potential progression from flavored vaping to nicotine or cannabis vaping, in addition to the interrelationship of these behaviors with various mental health symptoms.

Ethics statement

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000 (5). Informed consent was obtained from all patients for being included in the study.

Conflict of Interest
There is no conflict of interest.

Availability of data and materials
Data will be made available upon reasonable request.

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Authors' contributions
All authors significantly contributed to the preparation of this manuscript.

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