



Establishing the Association Between Traditional Tobacco, E-cigarette and Dual Use and Mental Health Problems Among High School Students: Results from a 2022 Behavioral Surveillance Survey

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Abstract

This study examined the association among past-year use of conventional cigarette (CC), e-cigarette (EC), dual use (using both CC and EC), with presence of substance use (i.e., alcohol use and marijuana use), having friends and family members who use cigarettes, and mental health problems (e.g., depression, anxiety, psychological distress (PD), problem gambling (PG) and adverse childhood experiences (ACEs)). A secondary analysis was conducted using data from 2022 Bangkok Behavioral Surveillance Survey (BBSS) (6,000 invited, 5,740 completed). Among the respondents, approximately, 14.1% used EC only, 11.0% used CC only, and 7.9% used both in the past year. The use of a substance (e.g., cannabis, alcohol), having mental health problems (e.g., having PD, PG, sleep disturbance, > 4 ACEs) and having friends or family members who use cigarettes were highly associated with use of CC, EC and dual use. Despite the lack of causal conclusions, this unique study presents associations that might have implications for future legislation on EC that impacts Asian youth. We also stress the need for research, particularly in view of the fact that EC is seen as less dangerous than smoking CC, and has essentially replaced smoking in Thailand.

Keywords Conventional cigarettes · E-cigarette · Dual use · Mental health problems · Alcohol · Cannabis

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The global tobacco market has witnessed a significant expansion over the past decade. New tobacco or nicotine containing products have been introduced as alternatives to cigarettes with an increasing popularity, especially among young individuals (Bast et al., 2022; Cruz et al., 2019; Harrell et al., 2017). Moreover, studies have shown an increasing trend in the concurrent use of various tobacco or multiple nicotine products, known as dual and multiple use (Johnson et al., 2018; Lee et al., 2015). In Thailand, these trends among the youth population have received substantial attention owing to rising public health concerns. However, it remains unclear whether the decline in smoking among individuals aged 13 to 16, as reported in a 2020 study (Ofuchi et al., 2020), is accompanied by a simultaneous increase in the utilization of other nicotine products.

In some high-income countries, the use of tobacco (or other nicotine-containing products) outweighs the use of conventional cigarettes (CC) among the youth population (Brown et al., 2014; Wang et al., 2022). For example, among high school students in United States in 2021, e-cigarettes (EC) emerged as the most commonly used product, with a prevalence rate of 11.3%, followed by CC, cigars, smokeless tobacco, hookahs, and nicotine packets. Overall, 13.4% of youth in the United States were current users (within past 30 days) of any tobacco product (Wang et al., 2022). In a sample of Norwegian youths (aged 13 to 17 years) 31.0% reported having tried at least one tobacco product, with the use of snuff is twice as prevalent as both CC and EC. In Denmark, 27.0% of youths used at least one type of tobacco or nicotine product, while 5.6% reported using more than one product (Bast et al., 2022).

While switching from cigarettes to other tobacco products may lead to a reduction in smoking, it is crucial to recognize that the use of any tobacco product poses a significant threat to both the individuals and the public health as a whole. Recent years have brought forth a clearer understanding of the dangers associated not only with tobacco but with nicotine. Both substances have been linked to an increased risk of cardiovascular and respiratory disease, and can have adverse effects on the reproductive system (Mishra et al., 2015). In addition, nicotine has been found to a negatively impact the development of the adolescent brain (Leslie, 2020; Yuan et al., 2015). The use of EC among youths in the United States has been associated with intention to smoke, but not with intention to quit smoking. This raises concerns regarding youths who may initially use EC for recreational purposes, as it may potentially lead to regular smoking, consequently posing long-term mental and physical health risks (Park et al., 2016). Moreover, experimental use of products like EC among young individuals can serve as a gateway to CC use (O'Brien et al., 2021; Owotomo et al., 2020), thereby contributing to an overall increase in CC consumption among youth worldwide (Pacek et al., 2019). The gateway theory works in two directions, as both EC and CC share common risk factors and both mechanisms can be at play (Martinelli et al., 2023). In addition to the use of cigarettes, youths who engage in substance use typically begin with substances that are legally accessible, such as alcohol and CC, and subsequently, a proportion of them may experiment with marijuana and other drugs (Kandel & Kandel, 2015). However, there is limited data regarding these smoking practices among youth in Thailand, including the concurrent use of CC and EC.

The fact that smoking is harmful for physical health, and is considered the main cause of death worldwide. However, understanding the role of smoking in mental health remains important. It is crucial to understand the pathways whereby cutting down on smoking reduces the burden of physical health problems, as well as that of mental health. Ibrahim's study provides evidence that nicotine dependence is associated with an increased risk of post-traumatic stress disorder (PTSD) (Ibrahim et al., 2022). The study indicates that smoking is not only associated with poorer mental health, but may also serve as a contributing factor. While it has long been evident that smoking (and nicotine addiction) is more prevalent among individuals with mental health problems, the direction of causality remains controversial (Ibrahim

et al., 2022). The relationship between cigarette smoke exposure and mental health problems remains unclear, as chronic smoking can lead to neurological disorders that can contribute to the onset of mental health problems, or individuals with mental health problems may smoke to relieve symptoms or a combination of both factors may be at play. While smoking typically appears during adolescence, coinciding with the onset of psychiatric symptoms, most health problems appear later, in early adulthood (Munafò, 2022). A meta-analysis of prospective studies concluded that cigarette smoking might represent a previously overlooked modifiable risk factor for psychosis. However, the potential for confounding and reverse causality are should be considered (Gurillo et al., 2015). Notably, it has been observed that there is a significant association between first-episode psychosis and tobacco use when compared with healthy controls. (Myles et al., 2012). Previous studies found EC, CC and dual use were associated with depression, (Smaoui et al., 2015; Weinberger et al., 2017; Wootton et al., 2020), anxiety (Fluharty et al., 2016; Morissette et al., 2007; Yan et al., 2019), and other mental health problems (Carter et al., 2014; Lawrence & Williams, 2016; Leung et al., 2011, 2012; Sung et al., 2011). Advani et al. (2020) found that the concurrent use of EC with CC was associated with increased sleep duration and higher likelihood of marijuana use. Individuals who use EC are more likely to have a history of attention deficit hyperactivity disorder (ADHD), post-traumatic stress disorder (PTSD), gambling addiction, anxiety disorders, low self-esteem, and impulsivity (Grant et al., 2019). Despite some considering EC to be harmless, concerns regarding adverse health effects and addiction have heightened due to increased use of EC among youths (Conway et al., 2018; King et al., 2018; Lanza & Teeter, 2018; Saddleon et al., 2015; Tavolacci et al., 2016). Poor quality of life was associated with regular EC use. If smokers used EC products with nicotine, the likelihood of reporting poor quality of life was lower than individuals who did not use such products. Higher concentration of nicotine in EC cartridges was associated with higher risks of poor physical and poor overall health, and with lower chance of excellent mental health (Chang et al., 2019). Additionally, one study identified an association between alcohol use and EC use (Hefner et al., 2019).

In Thailand, the Ministry of Public Health has implemented measures to prohibit the import of EC into the country (Department of Disease Control, 2017). These measures are enforced through three laws. Firstly, the Tobacco Products Control Act of 1992, Article 10, prohibits advertising any other product with a characteristic which can be understood as an imitation of a cigarette or tobacco product or cigars, with violations punishable by a fine of not more than 20,000 baht. Secondly, Article 12 of the 1967 Drug Act, which prohibits producing, selling, or importing of illegal substance into the country, where violations punishable by imprisonment for a term not exceeding 5 years and a fine not exceeding 10,000 baht. Lastly, Article 72 of the 1920 Customs Act prohibits importing a product that has not passed through Customs into the country, with violations subject to a fine of four times the value of the goods, which includes the import duty, or imprisonment for not more than 10 years or both fine and imprisonment. At present, all types of EC products and accessories lack legal certification and, thus, EC are prohibited to be imported. Nonetheless, an underground market for EC exists, and users justifying its uses as a way to quit CC (Kasemsap, 2018). However, the ever-evolving technology of EC continues to impede timely toxicology studies and that hinders our understanding of the long-term health effects of EC in Thai context. (Thepthien et al., 2021).

The existing body of evidence examining the association between CC, EC, and dual use with mental problems and/or adverse childhood experiences (ACEs) among adolescents and young adults (aged 14–18 years) primarily originates from the Western countries. However, there is a dearth of research investigating effective prevention efforts in Southeast Asian countries. Therefore, this study aimed to address this research gap by two main objectives. The first objective was to explore the prevalence of use of CC only, use of EC

only, and the concurrent use of both CC and EC among adolescents in educational institutions. Secondly, we aimed to determine whether the use of CC, or the use of EC, or the concurrent use of CC and EC is associated with mental health problems (e.g., depression, anxiety, sleep disturbance, sadness, stress, problem gambling, ACEs) or having friends and/or family members who use EC, cannabis, and/or alcohol. Based on the literature review, we formulated the following hypotheses: (1) The sample would indicate a trend towards the use of EC compared to the use of CC, (2) The use of CC, EC, or both CC and EC would be associated with an increased use of cannabis and alcohol, and (3) Dual use of EC with CC was associated with use of other addictive substances (e.g., cannabis, alcohol), as well as mental health problems, problem gambling, and inadequate sleep.

Methods

Study Design and Data Source

A total of 5,740 students, with 48.8% being female, were included in this cross-sectional study. The participants reported ages ranged from 12 to 19 years, with a mean age of 15.9 years ($SD=1.6$). Data for the study was obtained from the 2022 Bangkok Behavioral Surveillance Survey (BBSS), an anonymous, self-administered online survey. The BBSS compiles data on a broad range of health topics, including health risk behaviors, physical and mental health, prevention behavior, substance use, and other topics. The BBSS is conducted every two years. For this 2022 survey, the sample consisted of students studying in high school Grades 2 and 5, as well as Grade 2 vocational students in 48 public educational institutions in Bangkok. The sampling design employed a multistage cluster probability approach to obtain a representative sample of students in high school from the Bangkok. Within each school, five classrooms were randomly selected. Students aged 18 years or less and living or residing in the Bangkok metropolitan area for at least 6 months were included. The final sample consisted of 5,740 (95.6%) of approximately equal numbers of males and females (2,939 males, 2,801 females), out of 6,000 students who were invited to participate in the study by sharing the prepared online form with the messaging application. The informed consent form and questionnaire link were sent to the students through the school administrators and teachers. Participants completed the online survey via Lime-Survey, with a token given to each student such that a participant could access the survey only once. After the participants had completed the online questionnaire, their responses were sent automatically to researchers. The submit button was not activated unless all data were provided, thus ensuring no missing data. If any student was unable to complete the questionnaire, the process could be terminated without the researcher getting access the data. Data collection was conducted during the second semester of the 2021 academic year, from November 2021 to March 2022. The protocol for this study was approved by the Human Research Council, Faculty of Social Sciences and Humanities Mahidol University (Certificate Approval No: 2021/120.2610, MUSSIRB 2021/151(B2)).

Measures

Dependent Variable A categorical variable was created to indicate the frequency of CC and EC use in the year prior to the survey. Past-year CC/EC use was assessed with the following question: “*During the past year, how many times (if any) have you used CC /EC?*” The

response options ranged from (0) none to (5) 40 times or more. Participants who answered “>1 time use in the last year” were classified as ever-used CC or EC users. Participants who answered “yes” to using CC and “yes” to using EC were classified as ever-used Dual Users.

Independent Variables The use of Marijuana and binge drinking were asked whether they had ever used during the past year each of the two substances. The response scale ranged from (0) none to (5) 40 or more times. Respondents were grouped into 3 categories [(0) never, (1) 1–2 times (2) > 2 times]. We also measured peer and family cigarette smoking and EC use. Mental health problems were measured with a Thai translation of the Hopkins Symptom Checklist (HSCL-25). The HSCL-25 consists of 25 items, 10 designed to screen for anxiety and 15 designed to screen for depression (Skogen et al., 2017). The mean HSCL score was also divided into three categories (“ ≤ 1.75 ,” “ > 1.75 & < 2.00 ,” and “ > 2.00 ”) for investigating associations with EC,CC and dual use (Tjora et al., 2022). A measure of ACEs was constructed using responses to 14 items designed to tap exposure to ACEs. Responses to each of these times were coded so that yes=1 and no=0. In order to examine the cumulative effect of ACEs, respondents were grouped by the number of ACEs they experienced (0, 1, 2, 3, 4 and 5 or more).The ACEs inventory was created using items similar to ACEs measures utilized in previous research (Hicks et al., 2021; Boccio et al., 2022). The ACEs has been shown to have good reliability, indicating that retrospective responses to childhood abuse and serious household dysfunction are generally stable over time (Pinto et al., 2014). Mental health-related measures included self-reported stressful life in the past 30 days, sadness for two weeks or more in 12 months. The question on sleep duration asked how many hours, on average, the respondent slept per night. The questionnaire items used for analysis in this study are summarized in Appendix Table 3.

Data and Statistical Analysis

We first analyze the data by examining descriptive statistics for the frequency of substance use in the past year [(0) Never (1) 1–2 times (2) 3–9 times (3) 10–19 times (4) 20–39 times (5) 40 times or more]. Next, respondents were grouped into those who ever/never used either EC or CC into 2 groups [(0) never used, (1) used at least once time a year]. Then, the respondents were grouped into those who never smoked either type of cigarette in the past year, those who used EC only, those who used CC only, and those who smoked both types (Table 1). We began by comparing various past-year subgroups (non-use, EC use only, CC only, and dual use) in terms of the available independent variables, to generate a profile of each type of user. Data were analyzed by Chi-square for associations between four categorical variables. A p-value of < 0.05 was considered statistically significant. Analysis included tests for association between four sub-groups, and variables including use of other addictive substance (e.g., marijuana, alcohol), having friends and/or family members who use CC/EC, and mental health problems (depression, anxiety, sleep, sadness, stress, problem gambling, duration of sleep, ACEs). Logistical regression was used to examine the association between primary variables of interest with dichotomous outcomes (Table 2). The first model examined the relationship between CC use in the past year [(0) never used, (1) CC used only] exclude EC and dual use, substance use (e.g., cannabis, alcohol), having friends/family members who currently use cigarettes, and mental health problems (depression, anxiety, sleep inadequacy, sadness, stress, problem gambling, ACEs). The second regression model

Table 1 The association of non-use of any cigarette, use of conventional cigarettes only (CC), use of e-cigarettes only (EC), use of both CC and EC (Dual), and mental health disorders

Variable	Overall (<i>n</i> = 5,740)		None (<i>n</i> = 4,756)		CC (<i>n</i> = 200)		EC (<i>n</i> = 330)		Dual (<i>n</i> = 454)		Difference	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	χ^2	<i>p</i> -value
Gender												
Male	2,939	51.2	2,302	78.3	127	4.3	190	6.5	320	10.9	99.96	<0.001
Female	2,801	48.8	2,454	87.6	73	2.6	140	5.0	134	4.8		
Grade level												
HS Grade 2	1,874	32.6	1,645	87.8	39	2.1	86	4.6	104	5.5	96.51	<0.001
HS Grade 5	1,904	33.2	1,601	84.1	51	2.7	115	6.0	137	7.2		
Vocational 2	1,962	34.2	1,510	77.0	110	5.6	129	6.6	213	10.9		
Cannabis use												
Never	5,495	95.7	4,722	85.9	177	3.2	312	5.7	284	5.2	1426.58	<0.001
1–2 times	161	2.8	34	21.1	14	8.7	12	7.5	101	62.7		
>2 times	84	1.5	0	0	9	10.7	6	7.1	69	82.1		
Alcohol use												
Never	4,465	77.8	4,088	91.6	108	2.4	138	3.1	131	2.9	1355.32	<0.001
1–2 times	899	15.7	546	60.7	60	6.7	130	14.5	163	18.1		
>2 times	376	6.6	122	32.4	32	8.5	62	16.5	160	42.6		
Peer CC use												
None	3,935	68.6	3,678	93.3	57	2.9	126	1.8	74	2.0	1207.77	<0.001
1–2 persons	775	13.5	559	70.9	37	4.3	76	10.5	103	14.3		
>2 persons	1,030	17.9	519	49.3	106	5.0	128	18.3	277	27.4		
Family CC use												
No	3,171	55.2	2,747	86.6	82	2.6	179	5.6	163	5.1	97.39	<0.001
Yes	2,569	44.8	2,009	78.2	118	4.6	151	5.9	291	11.3		
Peer EC use												
None	3,897	67.9	3,634	93.3	114	2.9	70	1.8	79	2.0	1204.33	<0.001
1–2 persons	989	17.2	701	70.9	43	4.3	104	10.5	141	14.3		
>2 persons	854	14.9	421	49.3	43	5.0	156	18.3	234	27.4		
Family EC use												
No	4,760	82.9	4,067	85.4	170	3.6	206	4.3	317	6.7	176.11	<0.001
Yes	980	17.1	689	70.3	30	3.1	124	12.7	137	14.0		
Depression												
≤ 1.75	2,917	50.8	2,500	85.7	68	2.3	129	4.4	220	7.5	49.59	<0.001
1.75 & ≤ 2.00	725	12.6	581	80.1	30	4.1	57	7.9	57	7.9		
> 2.00	2,098	36.6	1,675	79.8	102	4.9	144	6.9	177	8.4		
Anxiety												
≤ 1.75	3,299	57.5	2,780	84.3	102	3.1	182	5.5	235	7.1	17.65	0.007
1.75 & ≤ 2.00	837	14.6	681	81.4	25	3.0	48	5.7	83	9.9		
> 2.00	1,604	27.9	1,295	80.7	73	4.6	100	6.2	136	8.5		
Psychological distress												
Never	1,989	34.7	1,763	88.6	47	2.4	67	3.4	112	5.6	85.34	<0.001
Sometimes	2,918	50.8	2,355	80.7	116	4.0	204	7.0	243	8.3		
Often	833	14.5	638	76.6	37	4.4	59	7.1	99	11.9		

Table 1 (continued)

Variable	Overall (<i>n</i> = 5,740)		None (<i>n</i> = 4,756)		CC (<i>n</i> = 200)		EC (<i>n</i> = 330)		Dual (<i>n</i> = 454)		Difference	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	χ^2	<i>p</i> -value
Stressful life												
Not at all	490	8.5	437	89.2	5	1.0	29	5.9	19	3.9	31.07	<0.001
Sometimes	3,200	55.7	2,657	83.0	102	3.2	175	5.5	266	8.3		
Often	2,050	35.7	1,662	81.1	93	4.5	126	6.1	169	8.2		
Stressful in Covid – 19 situation												
Low	2,979	51.9	2,482	83.3	101	3.4	157	5.3	239	8.0	23.12	0.001
Medium	1,459	25.4	1,243	85.2	42	2.9	86	5.9	88	6.0		
High	1,302	22.7	1,031	79.2	57	4.4	87	6.7	127	9.8		
Problem gambling (lifetime)												
Never	4,286	74.7	3,799	88.6	113	2.6	167	3.9	207	4.8	456.26	<0.001
1–3 times	436	7.6	317	72.7	14	3.2	57	13.1	48	11.0		
> 3 times	1,018	17.7	640	62.9	73	7.2	106	10.4	199	19.5		
Sleep duration												
> 6 h	2,758	48.0	2,419	87.7	60	2.2	132	4.8	147	5.3	104.80	<0.001
5–6 h	2,325	40.5	1,848	79.5	108	4.6	144	6.2	225	9.7		
≤ 4 h	657	11.4	489	74.4	32	4.9	54	8.2	82	12.5		
Adverse Childhood Experience (ACEs)												
None	1,256	21.9	1,131	90.0	25	2.0	42	3.3	58	4.6	202.15	<0.001
1	1,127	19.6	988	87.7	22	2.0	40	3.5	77	6.8		
2	882	15.4	722	81.9	36	4.1	53	6.0	71	8.0		
3	659	11.5	561	85.1	11	1.7	54	8.2	33	5.0		
4	533	9.3	424	79.5	26	4.9	42	7.9	41	7.7		
5 or more	1,283	22.4	930	72.5	80	6.2	99	7.7	174	13.6		

examined the relationship between EC use in the past year [(0) never used, (1) EC used only] exclude CC and dual use, with mental health and/or substance use problems, The third regression model examined the relationship between EC use and CC use in the past year [(0) never used, (1) used both EC and CC, exclude CC use only and EC use only]. These were compared against the independent variables, while covariates were entered in the first step of each model and included sex education level. Adjusted odds ratios (AOR) with the 95% confidence interval (CI) from the multinomial logistic regression are reported. Statistical analysis was performed using SPSS version 25.

Results

In this study, there were similar proportions of males and females for three grade levels. The frequency of substance use in the past year was measured, with findings of self-reported consumption equivalent to one or more small can/bottle of beer (22.2%), cannabis use (4.3%), CC use (11.0%), EC use (14.1%), and 7.9% dual use.

Table 2 Adjusted logistic regression of substance use and mental health problems with use of conventional cigarette only (CC), use of e-cigarette only (EC), and use of both CC and EC (Dual) ($n=5,740$)

Variable	CC vs. non-use		EC vs. non-use		Dual vs. non-use	
	AOR	95%CI	AOR	95%CI	AOR	95%CI
Cannabis use						
Non-use	reference		reference		reference	
Use	16.3*	[9.3, 28.6]	7.7*	[4.3, 13.9]	73.1*	[49.3, 108.3]
Alcohol use						
Non-use	reference		reference		reference	
1–2 times	4.3*	[3.1, 6.1]	7.9*	[6.1, 10.3]	11.2*	[8.6, 14.6]
> 2 times	11.1*	[7.0, 17.5]	18.4*	[12.8, 26.6]	56.1*	[40.5, 77.7]
Peer CC use						
None	reference					
1–2 persons	3.8*	[2.5, 5.9]				
> 2 times	11.3*	[7.9, 16.1]				
Family CC use						
No	reference					
Yes	1.9*	[1.4, 2.6]				
Peer EC use						
None			reference			
1–2 persons			5.7*	[4.5, 7.2]		
> 2 persons			12.7*	[10.0, 16.1]		
Family EC use						
No			reference			
Yes			3.5*	[2.8, 4.4]		
Anxiety						
≤ 2.0	reference		reference		reference	
> 2.00	1.8*	[1.3, 2.4]	1.3*	[1.0, 1.6]	1.4*	[1.1, 1.7]
Depression						
≤ 2.0	reference		reference		reference	
> 2.00	2.2*	[1.6, 3.0]	1.6*	[1.3, 2.0]	1.5*	[1.3, 1.9]
Psychological distress						
Never	reference		reference		reference	
Sometimes	2.1*	[1.5, 2.9]	2.5*	[1.9, 3.3]	1.9*	[1.5, 2.4]
Often	2.6*	[1.6, 4.0]	2.7*	[1.9, 3.9]	3.1*	[2.4, 4.2]
Stressful life						
Not at all	reference		reference		reference	
Sometime	3.6*	[1.5, 8.9]	1.1	[0.7, 1.6]	2.6*	[1.6, 4.2]
Often	5.9*	[2.4, 14.7]	1.3	[0.9, 2.0]	3.1*	[1.9, 5.1]
Problem gambling (lifetime)						
Never	reference		reference		reference	
1–3 times	1.7*	[1.2, 2.3]	4.0*	[2.9, 5.5]	2.6*	[1.8, 3.6]
> 3 times	4.1*	[3.4, 4.9]	3.5*	[2.7, 4.6]	4.9*	[4.0, 6.1]
Sleep duration						
> 6 h	reference		reference		reference	
5–6 h	2.1*	[1.5, 2.9]	1.5*	[1.3, 1.8]	1.9*	[1.5, 2.4]

Table 2 (continued)

Variable	CC vs. non-use		EC vs. non-use		Dual vs. non-use	
	AOR	95%CI	AOR	95%CI	AOR	95%CI
≤ 4 h	2.4*	[1.5, 3.6]	2.3*	[1.8, 2.9]	2.6*	[1.9, 3.5]
Adverse Childhood Experiences (ACEs)						
None	reference		reference		reference	
1	1.0	[0.6, 1.9]	1.1	[0.7, 1.8]	1.6*	[1.1, 2.3]
2	2.4*	[1.5, 4.0]	2.1*	[1.4, 3.2]	2.2*	[1.5, 3.2]
3	0.9	[0.5, 2.0]	2.8*	[1.8, 4.2]	1.3	[0.8, 2.1]
4	3.0*	[1.7, 5.3]	2.9*	[1.9, 4.7]	2.3*	[1.5, 3.5]
5 or more	4.7*	[2.9, 7.5]	3.3*	[2.3, 4.8]	5.0*	[3.6, 6.9]

AOR were adjusted for sex and grade level. Asterisk (*) indicates a statistically significant odds ratio ($p < 0.05$)

Table 1 shows the results of the Chi-square test of variables. The analysis examines the association of various past-year sub-groups (non-use, EC use only, CC use only, and dual use) by gender, education level, substance use, and having friends and/or family users of CC or EC. The analysis also looked at prevalence of mental health problems as an independent variable. The results of the analysis show that male students had a higher prevalence of self-reported use of CC, EC, and dual use compared to their female counterparts. Vocational school students had greater prevalence of smoking compared to 2nd and 5th year high school students. The proportion of students who used EC in combination with CC had higher reported use of marijuana and alcohol than that of students who smoked either CC or EC only. Similarly, the dual use of CC and EC was associated with depression, anxiety, feeling sad or hopeless, feeling undue stress, problem gambling, short duration of sleep, and a history of > 4 ACEs all of which were more than the symptoms reported by their counterparts who smoked either CC or EC only. 31.4% of respondents had friends who used CC, 44.8% had a family member who smoked CC, 32.1% had friends who used EC, and 17.1% had a family member who used EC.

Regarding self-reported experience of mental health problems, this study revealed that over one-third (36.6%) students had symptoms of clinical depression at a level twice the average or higher, while 27.9% had symptoms of anxiety at a level twice the average or more. Approximately 14.5% of students had periods of depression or hopelessness lasting for two weeks or more (either regularly or frequently in the past year). Moreover, 35.7% of respondents reported experiencing undue stress in the past 30 days (either regularly or often). 22.7% of respondents expressed feeling of poor mental health (stress, anxiety, depression) during the Covid-19 epidemic. Furthermore, 17.7% of respondents reported engaging in gambling activities that resulted significant gains and/or losses of money/property at least three times in the past. In terms of sleep pattern, 11.4% of the respondents reported obtaining four or fewer hours of sleep on a normal school night. Additionally, 22.4% reported experiencing five or more ACEs throughout their life time.

After adjusting for the relevant covariates, the multiple logistic regression analyses presented in Table 2 revealed significant associations between substance use (marijuana and alcohol) and mental health problems, with frequency of past-year CC, EC, and dual use. Specifically, among individuals who exclusively used CC in the past year compared to non-users, those who reported cannabis use exhibited 16.3 times higher odds of CC use than those who did not use cannabis. Furthermore, students who consumed alcohol one to two times

in the past year had 4.3 times and 11.1 times (past $r > 2$ times) the odds of CC compared to non-drinking students. The presence of peer influence was also found to be a significant factor. Students who had friends who smoked CC had higher odds of cigarette use if they were influenced by one to two friends, and 11.3 times higher odds if influenced by more than two friends. Moreover, students residing with family members who smoked cigarettes had 1.9 times higher odds of smoking compared to those who did not have family members who smoked. Additionally, students who smoked cigarettes also reported symptoms of mental health problems, including an anxiety score over 2.0 (AOR=1.8), depression (AOR=2.2), feeling sad or hopeless over periods of two consecutive weeks in the past year, whether occasionally (2.1 times), or frequently (2.6 times). Cigarette users were also found to have significant associations with experience of stress in the past month (occasionally 3.6 times, or frequently 5.9 times), having problem gambling with significant gains/losses (AOR_(1-3 times) = 1.7 and, AOR_(>3 times) = 4.1), lack of adequate sleep (AOR_(5-6 h.) = 2.1 and, AOR_(≤ 4 h.) = 2.4) compared to those who sleep > 6 h, and history of ACEs (AOR_(2 ACEs.) = 2.4, AOR_(4 ACEs.) = 3.0 and, AOR_(> 4 ACEs.) = 4.7) compared to those with no ACEs.

Similarly, regression analysis revealed statistically significant increased odds of mental health problems among individuals who exclusively used EC in comparison to non-users. Students who engaged in past-year EC use had significantly greater adjusted odds of cannabis (AOR=7.7) and alcohol use (AOR_(1-2 times) = 7.9 and, AOR_(> 2 times) = 18.4) compared to nonusers. Students who had friends who smoked EC were more likely to use EC than those without peer influence (AOR_(1-2 persons) = 5.7 and, AOR_(> 2 persons) = 12.7). Similarly, students who lived with family members who smoked EC had an increased chance of being EC users themselves (AOR=3.5). Respondents who used EC had increased odds of having an anxiety score over 2.0 (AOR=1.3), depression (AOR=1.6), feeling sad or hopeless over periods of two consecutive weeks in the past year (AOR_(sometime) = 2.5, and AOR_(often) = 2.7), engaging in problem gambling (AOR_(1-3 times) = 4.0 and, AOR_(> 3 times) = 3.5), lacking adequate sleep (AOR_(5-6 h.) = 1.5 and, AOR_(≤ 4 h.) = 2.3) compared to those who sleep > 6 h, and having a history of ACEs (AOR_(2 ACEs.) = 2.1, AOR_(3 ACEs.) = 2.8, AOR_(4 ACEs.) = 2.9 and, AOR_(> 4 ACEs.) = 3.3) compared to those with no ACEs.

Dual users of CC and EC, as compared to non-users, had significantly increased odds of experiencing mental health problems and having history of ACEs. The participants using both CC and EC had increased odds of cannabis use (AOR=73.1), alcohol use (AOR_(1-2 times) = 11.2 and, AOR_(> 2 times) = 56.1) compared to non-users, having an anxiety score over 2.0 (AOR=1.4), depression (AOR=1.5), feeling sad or hopeless over periods of two consecutive weeks in the past year (AOR_(sometime) = 1.9 and, AOR_(often) = 3.1), experience of stress in the past month (occasionally 2.6 times, or frequently 3.1 times), having problem gambling (AOR_(1-3 times) = 2.6 and, AOR_(> 3 times) = 4.9), lack of adequate sleep (AOR_(5-6 h.) = 1.9 and, AOR_(≤ 4 h.) = 2.6) compared to those who sleep > 6 h and history of ACEs (AOR_(1 ACEs.) = 1.6, AOR_(2 ACEs.) = 2.2, AOR_(4 ACEs.) = 2.3 and, AOR_(> 4 ACEs.) = 5.0) compared to those with no ACEs.

Discussion

This study examined the use of CC and EC, both individually and in combination (dual use), among a representative sample of the student population in Bangkok, Thailand. The use of EC along with CC has been linked to mental health problems (e.g., depression, anxiety, lack of sleep, sadness, stress, problem gambling, and history of ACEs). These findings

are in line with the literature (White et al., 2015; Jeon et al., 2016). Additionally, the results provide support to previous study that found a cross-sectional association between e-cigarette use and the use of marijuana and alcohol among young people (Chadi et al., 2019; Rothrock et al., 2020). The current study found e-cigarette use to be associated with marijuana use and support the gateway from e-cigarette use to marijuana reinitiation (Wong et al., 2020). According to the Gateway Theory of Kandel and Kandel (2015), e-cigarettes can potentially act as a gateway to subsequent use of other psychoactive substances.

This study revealed that the prevalence of dual use among young individuals was 8%. These findings are align with that of McCabe et al. (2017), who reported a prevalence of 7.3% for EC use with CC (within the past month) among adolescents in the United States while Azagba, 2018 reported 3.8% among high school students in the United States. As in previous studies, numerous cross-sectional and prospective studies show a strong positive association between EC use and smoking cigarettes (Morean et al., 2015; Raber et al., 2015; Temple et al., 2017). However, the limitations of this approach remain such as measurement error and confounding (Shahab et al., 2022).

A study of EC use among university students in Vietnam found a prevalence of 13.2% (Le et al., 2022). In this study, the overall prevalence of EC use was 14.1%, with 10.6% among junior high school students, 13.4% among high school students, and 18.0% among second year vocational students. These results are consistent with recent studies involving youth in the United States, where prevalence of EC use among high school students was 14.1% and 3.3% among middle school students (Cooper et al., 2022). In this study, overall prevalence of CC use was 11.0%, with 7.3% among junior high school students, 9.7% among high school students, and 15.9% among second year vocational students. The difference in estimates reflects the evolution of trends in EC use, underscoring the need for continued surveillance (Hu et al., 2016). This is especially relevant to monitor after the impact of the COVID-19 pandemic on the mental health and substance use patterns of individuals worldwide. Cabral (2022) also pointed out that the dual use of EC and CC accounts for a significant proportion of the adolescent population. The disparities in EC use across countries may be attributed to differences in product availability, marketing strategies, individual perceptions of EC risks, and influences from peer and family.

Studies have indicated the association between mental health problems, including depression and anxiety, and cigarette use among young individuals (Bierhoff et al., 2019; Boehm et al., 2016; Masaki et al., 2022; Sumbe et al., 2022; Tidey & Miller, 2015; Tjora et al., 2014). These studies have consistently indicated a significant association between symptoms of depression, anxiety, and impulsivity, and the use of CC and EC (Mathew et al., 2017). Specifically, individuals with high levels of depression and anxiety were more likely to smoke due to self-medication of nicotine, as they perceive smoking to alleviate anxiety and depression (Tidey & Miller, 2015). Although some studies found the positive association between anxiety, depression, and the dual use of EC and CC (Bandiera et al., 2017; Wiernik et al., 2019), while one study found a negative association (Bierhoff et al., 2019). EC liquids have the potential to contain a variety of solvents (e.g., propylene glycol, nicotine, tetrahydrocannabinol or hash oil, hundreds of flavoring compounds, and trace heavy metals). Some EC products contain nicotine salts, enabling the consumption of very high doses of nicotine that have been associated with high rates of continued use (Willett et al., 2019). Adolescence represents a vulnerable developmental period for the onset of nicotine use and mental illness (Becker et al., 2021). This study found that adolescents who use EC only, CC only and dual use had more anxiety and depression than those who did not. This may occur due to the following: (1) Attempts to self-medicate symptoms, such as cognitive deficits and low mood; (2) Effort to counteract sedating side effects of psychotropic medications; (3)

Common underlying genetic or environmental risk factors for smoking and mental illness; or (4) Neurotoxic impacts of nicotine on mental health. A combination of individual-specific factors likely contributes to continued use (Becker et al., 2021). Evidence from animal models suggests that prolonged nicotine exposure may also induce epigenetic changes and increase vulnerability to stress sensitivity (Yuan et al., 2015).

Previous studies have found that cumulative history of ACEs increases the likelihood of smoking or cannabis use, or both (Boccio et al., 2022; Duke, 2018; Fagan & Novak, 2018). The findings of this study suggest that history of more than four ACEs increases the likelihood of using CC or EC only, and presents twice the risk of dual use. These findings are in line with other studies which found that exposure to more than one ACE is strongly associated with CC use, other cigarette products, and more than one addictive substance (Boccio et al., 2022; Ofuchi et al., 2020; Parks et al., 2020). These results suggest that exposure to ACEs is not only a risk factor for substance use (e.g., tobacco, cannabis, alcohol), but leads to an increased risk of using more than one substance. The consequences associated with the use of more than one substance are of particular concern, as previous research has linked EC use, coupled with CC use, with a greater likelihood of negative consequences, such as later use of illicit drugs (Azagba, 2018; Boccio et al., 2022; Kristjansson et al., 2015).

The evidence regarding the association between cigarette use and sleep patterns remains inconclusive. However, findings from this study show that the use of CC or EC alone, and dual use were associated with inadequate sleep. This is consistent with previous studies that highlighted the association EC or CC use alone had on adverse effect on sleep (Berlin et al., 2019; Boddu et al., 2019; Boehm et al., 2016; Riehm et al., 2019; Kianersi et al., 2021). In particular, dual users were of concern because sleep deficiencies or sleep disturbances were associated with worse outcomes in various disease states (Medic et al., 2017). Advani et al. (2020) found that the use of EC alongside CC was associated with an increased sleep latency although the association was not significant. However, our study found a significant association between decreased sleep time and overall tobacco use. Our study can serve as confirmation that the use of EC, CC, and dual use were not a harmless health behavior, in that, inadequate sleep duration is associated with higher all-cause mortality (Liao et al., 2019). While the association between sleep and smoking is not fully understood, a nicotine pathway has been postulated as one potential mechanism. It is theorized that the nicotine in tobacco products activates the sympathoadrenal system thereby increasing heart rate, blood pressure, and glucose levels (Dugas et al., 2017). The activation has a potential to delay or interfere with sleep. Bilsky et al. (2016) also found that the use of CC or the dual use increased sleep duration. Those smokers with dual use had higher levels of nicotine compared to the use of CC or EC use alone suggesting that increased sleep time may be a direct result of nicotine stimulation in the central nervous system (CNS).

This study show evidence suggests that smoking behavior is highly associate with problem gambling. Both smoking and gambling are major public health concerns worldwide. In particular, problem gambling is of great concern regarding younger generation, with up to 86% of adolescents reporting some form of gambling, and 4–8% of adolescents reporting serious gambling problems (Jacobs, 2000; Kristiansen & Jensen, 2014; Splevins et al., 2010; Weinberger et al., 2015). Adolescent gamblers have been found to have higher rates of smoking compared to non-gamblers (Jackson et al., 2008; Jacobs, 2000; Kong et al., 2013; Splevins et al., 2010; Yip et al., 2011). Morevoer, it was found that those who gamble are twice as likely to have serious problems with cigarette use compared to non-gamblers. (Jacobs, 2000). This is in line with previous studies which have found that students with problem gambling had two to four times the risk of being smokers of CC or EC or both (Jackson et al., 2008; Jacobs, 2000; Splevins et al., 2010). However, the association

between gambling and smoking may arise for various reasons, including biological vulnerabilities, e.g., being naturally risk-taking or impulsive (Baker et al., 2004; Willoughby et al., 2013): Impulsivity is associated with both smoking and gambling in adolescents (Bloom et al., 2013; Chambers & Potenza, 2003; Vitaro & Wanner, 2011). Tobacco use and gambling have been linked to depression, and factors related to dysregulation may be linked to smoking and gambling (Desai & Potenza, 2008; Potenza et al., 2005). These findings suggest that stronger measures are needed to help adolescents quit smoking.

This study has several strengths that build on previous literature on EC use and mental health. Firstly, this study is unique in its approach in that unlike studies that use data from Western countries, this one draws upon a large sample size which should be generally representative of the student population in Bangkok. The survey was conducted online under the supervision of trained professionals and the respondents were asked to self-report EC and CC use in the past year which should not be difficult to recall. In addition, another strength of this study was in its use of widely used and validated mental health questionnaires (HSCL-25, ACEs), as well as reports of anxiety and depression, including self-reported history of ACEs. That said, this study also includes limitations often encountered in survey research such as the potential for response bias due to the illegal or sensitive nature of some of the variables assessed (e.g., gambling, under-age smoking, alcohol consumption, cannabis use). Thus, participants may under- or over-report risk behaviors. The use of cross-sectional data limits the possibility of individual and group tracking, and response cannot be controlled for past smoking or use of smokeless tobacco or other tobacco products. Another general limitation of survey data is the cross-sectional design, which does not allow conclusions to be drawn on causality. In addition, the sample for this study was only students at public institutions (i.e., under the Ministry of Education or the Bangkok Metropolitan Administration) who may vary in their substance use patterns when compared to their peers in private institutions.

Future Research

There is a dearth of studies on the relationship between CC and EC use, the dual use, mental health problems, and ACEs. Therefore, it is important to replicate this study using the same model but with different populations across Thailand to understand the extent of the issue nationwide. It is evident that the use of EC among adolescents in Thailand is increasing. Despite the fact that there is no legal recognition and sale of electronic tobacco products, and EC cannot be imported, these products are still making their way into the underground market, and are being advertised and sold via the Internet. Since EC devices have multipurpose mechanisms for holding substances other than nicotine, the concern of e-cigarette use potentially becoming a pathway to use of other substances has been raised. The previous study support the gateway hypothesis that e-cigarette use to marijuana reinitiation (Wong et al., 2020). The mechanisms and behavioral characteristics that may concern to the progression from e-cigarette use to initiation of other substance use should be further investigated to inform effective behavioral, educational, and policy interventions. Also current gateway discussions what is essentially a transition from less (e-cigarette) to more harmful (cigarette) modalities of nicotine use, there is considerable debate whether e-cigarettes act as a causal gateway to subsequent smoking in adolescents (Shahab et al., 2022). In addition, as the frequency of cigarette use was not included in this study, further study is needed to investigate the frequency of tobacco use and its association with mental health problems.

Appendix 1

Table 3 Questionnaire items used for the analysis

Variable	Item question/statement	Response
Conventional cigarette (CC) use	In the past year, how many times have you used cigarettes?	The response scale ranged from (0) Never (1) 1–2 times (2) 3–9 times (3) 10–19 times (4) 20–39 times (5) 40 times or more.
E-cigarette (EC) use	In the past year, how many times have you used e-cigarettes?	Use of cigarette and e-cigarettes were combined and dichotomized (0= “No”, 1= “Yes”) to estimate the prevalence of overall users of cigarette and e-cigarettes across usage levels. Participants who answered “yes” to using CC and “yes” to using EC were classified as ever-used Dual Users. We were dichotomized into 4 subgroups (nonuse, e-cigarette use only, cigarette smoking only, and dual use)
Alcohol use	In the past year, how many times have you drank an alcoholic beverage a full serve of alcohol e.g., a glass of wine, a whole nip of spirits, a glass of beer?	We were dichotomized past-year alcohol use into three categories (“none use”, “1–2 times”, and “>2 times”)
Cannabis use	In the past year, how many times did you use marijuana (excluding CBD extracts used only in medicine or as prescribed by a doctor)?	A dichotomous variable, “use,” was operationalized as past-year cannabis use compared with not use.
Peer use	How many current close friends do you have who smoke conventional/e-cigarettes?	The response scale ranged from (0) no (1) 1 person (2) 2 persons (3) 3 persons (4) 4 persons (5) 5 persons or more. We were dichotomized into three categories (“no”, “1–2 persons”, and “>2 persons”)
Family use	Do you live with a family member who currently smokes conventional/e-cigarettes?	The response options for both included (1) yes (2) no
Psychological distress	In the past 12 months, how often did you feel sad or hopeless in doing normal activities for two weeks or more?	The response scale ranged from (0) Never (1) Rarely (2) Occasionally (3) Most of the time (4) Always. We were dichotomized into three categories (“0 = not at all”, “1–2 = sometime”, and “3–4 = often”)
Stressful life	In the past 30 days, how often have you felt undue stress?	The response scale ranged from (0) Not at all stressful (1) Rarely (2) Sometimes (3) Often (4) Regularly. We were dichotomized into three categories (“0 = not at all”, “1–2 = sometime”, and “3–4 = often”)

Table 3 (continued)

Variable	Item question/statement	Response
Stressful in Covid – 19 situation	During the Covid-19 situation, how much did you experience poor mental health (stress, anxiety, depression)?	The response scale ranged from (0) Not at all (1) Very little (2) Quite a bit (3) Moderately (4) Quite a lot (5) Most. We were dichotomized into three categories (“0–2 = low”, “3 = medium”, and “4–5 = high”)
Problem gambling (lifetime)	How many times have you ever gambled that resulted in huge gains or losses of money/property?	The response scale ranged from (0) Never (1) 1 time (2) 2–3 times (3) 4–5 times (4) 6–7 times (5) 8–9 times (6) 10–11 times (7) 12 times or more. We were dichotomized into three categories (“never”, “1–3 times”, and “> 3 times”)
Sleep duration	On the night before regular classes, how many hours of sleep do you get?	The response scale ranged from (0) 4 h. or less (1) 5 h. (2) 6 h. (3) 7 h. (4) 8 h. (5) 9 h. (6) 10 h. or more. We were dichotomized into three categories (“≤ 4 hr.”, “5–6 hr.”, and “> 6 hr.”)
Anxiety and Depression	The HSCL-25 consists of 25 items, 10 designed to screen for anxiety and 15 designed to screen for depression.	All 25 questions used an ordered categorical scale with responses from 1 to 4: (“Not at all,” “A little,” “Quite a bit,” and “Extremely”). The mean HSCL-25 score was also divided into three categories (“≤ 1.75,” “> 1.75 & < 2.00,” and “> 2.00”)
Adverse Childhood Experiences (ACEs)	ACEs were constructed using responses to 14 items designed to tap exposure to ACEs, variety index measuring experiences of emotional abuse, physical abuse, sexual abuse, physical neglect, emotional neglect, family violence, household substance use, household mental illness, parental separation/divorce, family incarceration, witnessed community violent, economic adversity and exposure to the gang violence.	Responses to each of these times were coded so that yes = 1 and no = 0. In order to examine the cumulative effect of ACEs respondents were grouped by the number of ACEs they experienced (0, 1, 2, 3, 4, and 5 or more ACEs).

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Data Availability The data set gathered and/or analyzed for the current study will be made accessible upon request of the corresponding author.

Declarations

Ethical Approval The protocol for the Bangkok behavioral surveillance survey was approved by the Research in Human Subjects Ethics Committee of the Faculty of Social Sciences and Humanities of Mahidol University (Certificate Approach no: 2021/120.2610, MUSSIRB 2021/151(B2)). The sample respondents were informed of the purpose of the study and had the choice to participate or not, without any academic consequences for doing so. Personal information of respondents was concealed; thus, there was no risk of violating the confidentiality of the participants.

Conflict of Interest The author(s) declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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This paper is an original work and is not under submission to any other journals. It was not published elsewhere, was not posted on the internet, was not overlapped or duplicated and will not be submitted to another journal before a final editorial decision from your journal. All authors contributed to conceptualize ideas, interpret findings, and review the draft of the manuscript and approved it. None of the authors had any conflict of interest to declare. We will take public responsibility for the content and provide any relevant data upon request.

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