Peer Influence and Use of Electronic Cigarettes among Adolescents and Young Adults: A Meta-Analysis of Prospective Studies

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Abstract

Objective: To examine the association between peer use and individual use of EC among adolescents and young adults. **Methods:** We performed the search strategy on PubMed, EMBASE, and Cochrane. We selected prospective studies reporting adjusted odds ratio (aOR)/relative risk (aRR) with a 95% confidence interval (CI) and conducted a random-effects meta-analysis. **Result:** Eleven prospective studies were included, involving 32,014 participants in the quantitative analysis. Meta-analysis results showed a significant association between EC use by friends and increased odds of individual EC use (aOR = 1.79, 95% CI 1.43 to 2.25; I2 = 88.2% for ever use; aOR = 2.14, 95% CI 1.52 to 3.01; I2 = 88.5% for current use). In the subgroup meta-analysis of outcomes, having friends who used EC significantly increased the odds of ever- and current EC use. Similar findings were found in the subgroup meta-analyses by age group, region, sample size, study methodological quality, and follow-up time. **Conclusion:** This study revealed a positive association between individual EC use and friends' use, especially among those under 18 years, suggesting targeting peer networks to curb the EC epidemic.

Keywords: peer use- electronic cigarette- adolescents- young adults

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Introduction

Electronic cigarettes (ECs) or electronic nicotine-delivery systems (ENDS) vaporize solutions of nicotine with or without flavors. EC was first introduced in 2004 in China [1] and is now accessible worldwide. Noteworthy, ECs have become exponentially popular among adolescents and young adults in recent years, surpassing the rate of tobacco smoking in these populations [2]. In 2024, ECs emerged as the most frequently used tobacco product among middle and high school students in the United States, with 1.63 million students (5.9%) currently using e-cigarettes [3].

ECs were claimed as a safer form of cigarette with levels of toxicants at 9-450 times lower compared to traditional cigarettes [4, 5]. While the contents of EC and long-term health consequences of EC use remain equivocal, existing evidence shows their adverse effects are not restricted to the respiratory system [6] but may affect all other organs in the human body [7, 8]. Nicotine contained in EC products may cause addiction, increase the risk of myocardial infarction [9] and negatively impact brain development and cognitive function [10].

Although many randomized clinical trials have provided evidence supporting EC use for smoking cessation, [11] the grading of evidence remains consistently low [12]. Electronic cigarette use, in contrast, is possibly a route to cigarette smoking [13]. Facing the EC epidemic, several regulatory attempts have been made at federal and local levels, aiming to regulate EC trade and reduce the rate of EC use while allowing purposed use for smoking cessation, such as restrictions on nicotine content and minimum age of sale [1, 8, 14]. Along with the necessity to balance between potential harms and benefits of EC use, [8] preventing the initiation of EC use among young people is undoubtedly an urgent task for public health. Consequently, identifying the factors associated with EC use in this group is essential. One of the key factors influencing the behavior of young individuals is social influence. The use of alternative tobacco products, alcohol, and marijuana by parents, siblings, and friends is linked to higher usage rates among college students, with friends' use being the most significant correlate during this stage of life [15].

Therefore, assessing the impact of peer EC use on individual EC use is necessary. A systematic review

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conducted in 2019 examined social factors, including peer influence, on EC use, focusing on studies published prior to March 2018 [16]. However, this review included only one longitudinal study that identified the relationship between peer EC use and individual EC use, which found no statistically significant difference in the rates of EC usage between individuals whose peers use EC and those whose peers do not [17]. Since then, several additional studies have emerged on this topic, and these studies reported different results regarding the magnitude of the association between having friends who use EC and one's own EC use [18-26]. Thus, we carried out a meta-analysis of observational studies as well as subgroup analyses to synthesize existing findings and examine the magnitude of the influence of peer EC use on individual EC use.

Materials and Methods

Literature search

In November 2022, we searched for relevant studies on PubMed, EMBASE, and Cochrane. Our search focused on identifying studies using common keywords associated with the use of ECs by peers and individual ECs ever use or current use. Ever use of ECs is defined as the yes response to the item, "Have you ever used or tried using an ECs?". Current EC use is defined as use in the past 30 days. The search strategy comprised distinct groups of keywords, which are as follows: (1) "electronic cigarettes", "e-cigs", "vapor", "vaping", "tobacco nebulizers", "tobacco vaporizers"; and (2) "peer influence", "friends", "social environment", "social influence", "social context".

Selection criteria

We included observational studies using longitudinal data to examine the association between EC use by peers and one's EC use. Cross-sectional studies were excluded. We selected articles that presented outcome measures in the form of adjusted odds ratios (aORs) or adjusted relative risks (aRRs) and 95% confidence intervals (CIs). When multiple publications reported the same data, we prioritized including the most comprehensive study. Additionally, we limited the selection to articles published in the English language. We only considered studies focused on adolescents (10-19 years old) and young adults (19-39 years old), thus excluding any articles that involved populations outside of this age range or did not specify the appropriate age group.

Selection of studies

Titles and abstracts of the retrieved articles were screened independently by two researchers. The eligibility assessment was conducted based on a pre-established set of criteria. Any discrepancies between the two authors were discussed for agreement. Data extracted from each study included title, year of publication, first author's name, study design, study settings (reported by region/ country), study period (indicated in years), age and gender of participants, definitions for peer use of EC, aOR with 95% CI, and adjustment of variables.

Quality assessment

Studies in the meta-analysis were assessed regarding methodological quality by the Newcastle-Ottawa Scale (NOS). [27]. This scale utilizes a scoring system ranging from 0 to 9, categorizing studies based on three criteria: selection of studies, comparability, and outcome. Given the absence of established standards for the classification of quality, we categorized a study as high quality if it received scores above the mean score in each study type.

Main and subgroup analyses

The association between peers' EC use and one's EC use (ever use/current use) was identified by aORs with 95% CIs for the main analysis. In addition, we performed subgroup analyses by outcomes (ever use/current use), participant age (under 18 years/18 years and above), locations, study sample size (<3000 participants and \geq 3000 participants), the methodological quality of the study (low and high), and follow-up period (\leq 12 months and >12 months).

Statistical analyses

We computed a pooled aOR with 95% CI by synthesizing the aOR with 95% CI reported in each included study. To demonstrate the heterogeneity of the studies' results, we used Higgins I², which quantifies the percentage of total variation across studies. Calculation of I² followed this formula:

$$I^2 = 100\% \times (Q - df)/Q$$
,

in which Q is Cochran's heterogeneity statistic, and df is the degrees of freedom. Negative values of I^2 are adjusted to 0; I^2 ranges from 0% (no observed heterogeneity) to 100% (maximal heterogeneity). An I^2 of over 50% indicates substantial heterogeneity. The pooled estimate was computed utilizing a random-effects model, and the results were presented employing the DerSimonian and Laird methods. [28].

To explore potential publication bias, we utilized Begg's funnel plot and Egger's test. An asymmetrical Begg's funnel plot or a p-value less than 0.05 in Egger's test suggests publication bias. All statistical analyses were carried out using Stata SE version 15 software (StataCorp, College Station, Texas, USA).

Results

Search results and study selection

The study selection process is presented in Figure 1. We found 2,346 publications on PubMed, EMBASE, Cochrane, and bibliographies. After excluding 372 duplicated items, 1,887 more articles were excluded due to not meeting the selection criteria. The final analysis included eleven prospective cohort studies from ten articles [17-26].

General characteristics of selected studies

This study included eleven prospective studies with a total of 32,014 participants, of whom five studies reported the number of ever current smokers (4,018 individuals),

while four studies reported the number of current smokers (1,853 individuals). Most studies were performed in the United States. The age of participants ranged from 12 to 34 and were enrolled between 2013 and 2018, with 9 to 36 months of follow-up. All studies reported an increased likelihood of EC use associated with the specified exposures (Table 1).

Peer influence and use of EC

Figure 2 illustrates the effect of peer influence on the ever use of ECs as analyzed in our meta-analysis of prospective studies. Using a random-effects model, the analysis found a significant association between peer use of ECs and ever use of ECs across seven studies (aOR = 1.79, 95% CI 1.43 to 2.25; I² = 88.2%). This figure also shows the impact of peer influence on the current use of ECs, based on six studies, with the analysis indicating a stronger association (aOR = 2.14, 95% CI 1.52 to 3.01; I² = 88.5%).

Methodological quality of studies

Based on results from the NOS, the methodological quality scores of the studies included in the final analysis ranged from 6 to 8, with an average score of 7.3. Six studies that scored above 7.3 were classified as high quality (Table A.1)

Subgroup meta-analyses

Table 2 presents the results from the subgroup meta-analyses based on some factors. The subgroup meta-analysis by participant age, geographic region (including the United States and Canada), study sample size, the studies' methodological quality, and follow-up period consistently shows a positive association between exposure to peer use of ECs, and both ever use and current use of ECs (summary OR or RR > 1). Since the influence of peer ECs use was not examined separately for smokers and non-smokers, a subgroup analysis by smoking status was not performed.

Assessment of publication bias

Begg's funnel plot and Egger's test (P for bias = 0.851) showed no indication of publication bias with studies reporting associations between peer use of ECs and current use of ECs (Figure A.1). Begg's funnel plot and Egger's test (P for bias = 0.293) showed no indication of publication bias with studies reporting associations between peer use of ECs and ever use of ECs (Figure A.2).

Discussion

Our meta-analysis of eleven prospective studies provided robust evidence for the significant association of peer ECs use with increased risk or odds of ECs use among young people. The association remains significant in the stratification analyses by type of outcome (ever or current use of ECs), age group of participants, region, study sample size, and the study's methodological quality. There is growing evidence that ECs use is becoming an accepted part of youth culture [22]. Peer use of ECs has been suggested as a potential pathway to re-normalize ECs use among the young [18, 29]. According to social learning theory, [30] adolescents may adopt ECs use by observing others' behavior and perceiving social benefits. Having close friends who use ECs can spark curiosity about ECs use and provide opportunities for trying novel



Figure 1. Flow Diagram of Identification of Relevant Studies

2022 Ahmad [25]	2021 North [24]	2021 Obinwa [23]	2020 Vallone [22]	2019 Loukas (young adults) [21]	2019 Loukas (youth) [21]	2018 East [20]		2018 Urman [19]	2018 Agarwal [18]	2016 Bold [17]	Study (reference)	Table 1. Ge
Canada	SN	US (TATAMS)	SN	S	SN	US		SN	SN	SN	Country	neral Char
2018	2018	2014	2018	2014	2014	2016		2014	2014	2013	Year enrolled	acteristic
1 year	1 year	3 years	1 year	2.5 years	2.5 years	6 months		1.5 years	1 year	6 months	Follow-up time	cs of the St
668 participants (16-25 years, 251 females and 417 males)	3543 participants (21- 34 years, 66% were females)	3733 participants (11-15 years)	6165 never e-cig users (15-34 years)	2423 never e-cig users and 611 cases (18-29 years, 67% were females)	2288 never e-cig users and 359 cases (12-17 years, about 50% were females)	1020 never e-cig users (11-18 years, 552 females and 468 males)		1164 never e-cig users (median age=17.3 years)	2110 never e-cig users (18-29 years, 1401 females and 709 males)	340 ever e-cig users (12- 17 years, 161 females and 179 males)	Population (gender, age)	tudies Included in the
396	238	NA	NA	611	359	NA		326	329	170	Number of cases	Final A
current use of pod-type e-cig in the last 6 months	current use of pod-vape	current use of e-cig	ever use of JUUL e-cig current use of e-cig	ever use of JUUL e-cig	ever use of e-cig	ever use of e-cig		ever use of e-cig	ever use of e-cig	current use of e-cig	Outcome (ever use/ current use)	nalysis
Proportion of friends using e-cig (many vs. none/some)	number of close friends using e-cig (scored on a scale from 0 [none] to 4 [all])	number of close friends using e-cig (a few – all vs. none)	number of 4 closest friends using e-cig (scored on a scale from 0 [none] to 4 [all]) number of 4 closest friends using e-cig (scored on a scale from 0 [none] to 4 [all])	A close peer using e-cig (scored on a scale from 1 [none] to 5 [all])	A close peer using e-cig (scored on a scale from 1 [none] to 5 [all])	Some friend using e-cig (Yes vs No)	(3 or 4 vs 0)	number of friends using e-cig (1 or 2 vs 0)	number of close friends using e-cig (scored on a scale from 0 [none] to 4 [all])	friends use e-cig (Yes vs No)	Definition of exposure	
2.15 (1.37-3.34)	1.32 (1.11-1.58)	4.29 (2.89-6.38)	1.84 (1.59-2.12) 2.53 (2.05-3.11)	1.37 (1.21-1.56)	1.51 (1.14-1.99)	3.03 (1.63-5.64)	4.08 (1.96-8.49)	1.95 (1.26-3.02)	1.32 (1.11-1.57)	1.36 (0.78-2.38)	OR/RR (95% CI)	
age group, sex, province/territory, sensation seeking, vaping-related characteristics, polysubstance use, exposure to advertisements, and sensation seeking	sex, age group, race/ethnicity, current e-cig use, current cigarette smoking, social norms, and risk perceptions	age, sex, and race/ ethnicity), socioeconomic class, academic performance, positive affect, sensation seeking, family member use of e-cig, social acceptability, social norm, recall of advertising for e-clg at stores, recall of social media tobacco promotion, and other substance use	age group, sex, race/ethnicity, perceived financial situation, region, sexual orientation age group, sex, race/ethnicity, perceived financial situation, region, sexual orientation	sex, race, ethnicity, age, college type, current other tobacco use, sensation seeking, recall of exposure to e-cig marketing	sex, race, ethnicity, current other tobacco use, sensation seeking, recall of exposure to e-cig marketing	Age, gender, school performance, problem behavior, monthly alcohol use, smoking susceptibility, e-cig susceptibility, some friends smoke, some friends use e-cigarettes, at least one parent smokes, at least one parent uses e-cigarettes, sibling(s) smoke, sibling(s) use e-cigarettes, public approve of smoking, and public approve of e-cigarettes	gender, ethnicity, parental education, community of residence, ever use of cigarettes, hookah or cigars	gender, ethnicity, parental education, community of residence, ever use of cigarettes, hookah or cigars	age, gender, race/ethnicity, school enrollment, number of other tobacco products used	school type, sex, race, traditional eigarette smoking status, other tobacco use	Adjusted variables	

Table 1. Cont	inued								
Study ((reference)	ountry	Year en- rolled	Follow-up time	Population (gender, age)	Number of cases	Outcome (ever use/ current use)	Definition of exposure	OR/RR (95% CI)	Adjusted variables
2022 Wang [[26]	SI	2016	1 year	8560 never e-cig users (12-17 years)	2393	ever use of e-cig	number of best friends using e-cig (a few vs none)	2.69 (2.27-3.18)	sex, age, race and ethnicity, highest parental education, severity of internalizing and externalizing mental health problems, perception
							number of best friends using e-cig (some vs none)	3.69 (2.91-4.68)	of harm from e-cigarette use, current cigarette smoking status, and current use of other tobacco products
							number of best friends using e-cig (most vs none)	4.56 (3.14-6.63)	
							number of best friends using e-cig (all vs none)	4.08 (1.44- 11.59)	
					1049	current use of e-cig	number of best friends using e-cig (a few vs none)	2.69 (2.27-3.18)	
							number of best friends using e-cig (some vs none)	3.69 (2.91-4.68)	
							number of best friends using e-cig (most vs none)	4.56 (3.14-6.63)	
							number of best friends using e-cig (all vs none)	4.08 (1.44- 11.59)	

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experiences [23, 26]. This is particularly relevant and prevalent among young adults striving for independence from their parents, as the college environment might facilitate interactions with peers and provide opportunities to emulate peer behaviors [18]. Additionally, the theory of reasoned action underscores the significant influence of others in forming individuals' behaviors [31]. A study suggested that perceiving positive reactions to ECs use by one's best friend might independently predict subsequent ECs use initiation [19].

In addition, a dose-responsive association has been shown in several studies that considered the number of close friends using ECs, which revealed that a more intricate peer network of ENDS users was linked to higher odds of ENDS initiation [18, 22, 24, 26]. The bidirectional influence between having friends using ECs and ECs use was also reported [19]. An individual who uses ECs may create a supportive social environment for ECs use, which, in turn, motivates others in the network to initiate ECs use [19]. One of eleven studies included in this meta-analysis found no significant association between peer ECs use and individuals' ECs use, in which friend use was one of the most common reasons for trying ECs and would predict continued ECs use in univariate models but not in multivariate models [17]. This discrepancy might be due to the overlapped effect with cigarette smoking, which was adjusted for confounding (i.e., using traditional cigarettes in the past month at wave one and using other tobacco in the past month at wave 1) [17].

When examining the impact of peer networks on ECs use by age group, the influence appears to be more pronounced among adolescents than young adults. This finding might be attributable to the lower perception of ECs' harmfulness and addictiveness among adolescents compared to their older counterparts [32]. In addition, ECs, especially non-nicotine products, are diverse in packaging and flavors and commonly marketed with health benefits such as weight loss and increased energy and focus [33]. Therefore, adolescents may be prone to perceive that consuming ECs is not only beneficial but also a way to appear trendy and tech-savvy with their peers [34]. A study using survey data also found that although curiosity was the most common reason for ECs experimentation across age groups, college students were influenced by peer use, high school students were attracted by appealing flavors and middle school students perceived ECs as a healthier alternative to cigarettes [35]. Etim N et al. [36] uncovered that the association between peer ECs use, and current ECs use among males and females also varied by age. While the association remained consistent for males and females between 16 and 20 years old, the strongest association was observed among females before the age of 16 and for males in their 20s among alternative school students in the US [36]. Hence, future studies exploring the impact of peers on ECs use should take age and gender considerations into account.

By region, the association between peer use and ECs use remained statistically significant and comparable across regions. Most studies were conducted in the US (9 out of 10 studies). The current study targeted only cohort studies to provide more reliable results; however, this

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Table 2. Association between	Peer Influence and	l Use of Electronic	Cigarettes in	Subgroup I	Meta-Analyses by	Various
Factors*			-			

Factors	No. of study	Summary OR or RR (95% CI)	Heterogeneity, I ² (%)
Ever use of electronic cigarettes			
All	7	1.86 (1.52 - 2.29)	88.1
Age of participants			
<18	4	2.16 (1.53 - 3.06)	77.6
≥18	3	1.50 (1.22 - 1.84)	83
Region			
United States	7	1.86 (1.52 - 2.29)	88.1
Sample size			
<3000 participants	5	1.51 (1.27 - 1.79)	55.2
≥3000 participants	2	2.22 (1.53 - 3.22)	91.1
Methodological quality of study			
Low	1	3.03 (1.63 - 5.64)	100
High	6	1.72 (1.35 - 2.18)	90
Follow-up period			
≤ 12 months	4	2.01 (1.42 - 2.86)	91.6
>12 months	3	1.45 (1.25 - 1.69)	20.4
Current use of electronic cigarettes			
All	6	1.86 (1.52 - 2.29)	88.1
Age of participants			
<18	3	2.43 (1.41 - 4.19)	83.9
≥18	3	1.91 (1.18 - 3.09)	91.2
Region			
United States	5	2.14 (1.45 - 3.16)	90.8
Canada	1	2.15 (1.37 - 3.34)	100
Sample size			
<3000 participants	2	1.77 (1.13 - 2.75)	36.7
≥3000 participants	4	2.23 (1.51 - 3.60)	92.8
Methodological quality of study			
Low	4	2.01 (1.13 - 3.60)	90.1
High	2	2.41 (2.06 - 2.81)	0
Follow-up period			
≤ 12 months	5	1.89 (1.37 - 2.59)	85.4
>12 months	1	4.29 (2.89 - 6.38)	100

constraint may limit the inclusion of observational studies of other types conducted in other parts of the world. A review and meta-analysis on the global prevalence of ECs use reported that the current prevalence of ECs vaping varied widely between countries and continents among youth and young adults, possibly due to differences in the availability of ECs products and regulations [37]. For instance, the current prevalence of ECs use in America, Europe, Asia, and Oceania were 10%, 14%, 11%, and 6%, respectively [37]. Nevertheless, they share an upward trend, raising an urgent need for further investigation in other populations. Similar estimates of the association between peer ECs use and ECs usage were observed in the strata of sample size and study methodological quality.

To the best of our knowledge, this is the first meta-analysis to investigate prospective studies for

her investigation in s of the association ge were observed in hodological quality. e, this is the first pective studies for difference on ECs use separately for smokers and non-smokers, which has important implications, given that ECs use has been shown to be goal-directed. [16, 38].

compelling evidence to support targeted interventions to

prevent ECs use. However, a limitation is that all articles

included in the meta-analysis relied on self-reported

data, which could introduce bias. Nevertheless, based

on validated questionnaires, it was stated that self-

reporting of current or ever ECs use remained credible

[23]. Furthermore, large heterogeneities between the

studies exist in exposure classifications (binary, ordinal

or continuous) and in the study population, where some

studies were conducted among non-EC users [18, 22, 29]



Figure 2. Association between Peer Use of e-cigarettes and Use of e-cigarettes in a Random-Effect Model Meta-Analysis of Prospective Studies (n = 11). aOR, adjusted odds ratio; CI, confidence interval.

Future research should consider the use of conventional cigarettes as a stratification factor to reveal this point. Lastly, we could not provide the stratification by EC types due to limited studies investigating specific types of ECs products (general ECs products or JUUL). [22]

There is a need for large prospective studies using representative data and comprehensive controlling for potential confounders. Given diverse cultures and different social norms across countries and continents, more research should be invested in other countries rather than the US, especially in the Asian population, where ECs prevalence is increasingly high [37]. The impacts of peer use on the consumption of different types of devices should also be elaborated in future studies [18]. In addition, since some risk factors of ECs use have been suggested to be dynamic across adolescence to early adulthood, [36] future investigation of ECs use over time may provide a nuanced view of longitudinal using patterns among regular/irregular ECs users under peer influence [24].

We underscored the importance of peer networks in predicting ECs use. Studies suggested that campusbased tobacco control efforts should target school-based communities [25] or leverage the support of college students' peers to de-normalize ENDS use [18]. These interventions should be expanded to include students outside of the campus environment and maximize the impacts. In addition, it is crucial to implement initiatives targeting incorrect social perspectives related to electronic cigarette (ECs) products and effectively communicate the risks associated with e-cigarette use during adolescence. These efforts should be integral components of a comprehensive strategy to counteract the growing trend of youth vaping [26]. It is also noteworthy that successful tobacco control strategies might also be effective for ECs control. For instance, ECs control campaigns may consider involving young adults in distributing antivaping campaign materials, which have been shown to be effective in tobacco control programs based on college campuses [39].

Author Contribution Statement

NML and TTB contributed to the design, data extraction and data analysis of the research. NML, TTB and HTP contributed to the writing of the manuscript. JKO provided critical comments on the manuscript and supervised the research.

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Data Availability

The data that support the findings of this study are available from the corresponding author, JKO, upon reasonable request.

Conflict of Interest

The authors report there are no competing interests to declare.

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