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How does health communication on social media influence e-cigarette perception and use? A trend analysis from 2017 to 2020

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ABSTRACT

Objective: E-cigarettes have achieved a high prevalence rapidly. While social media is among the most influential platforms for health communication, its impact on attitudes and behaviors of e-cigarettes and its changes over time remain underexplored. This study aims to address the gap.
Methods: Four years of data (2017–2020) were derived from the U.S. Health Information National Trends Survey (HINTS) (aged 18–64 years, $n = 9{,}914$). Initially, key variables were compared across years. Furthermore, guided by the health belief model, we employed a moderated mediation model to examine the influence of social media health communication on the public's perceptions and behaviors related to e-cigarettes, distinguishing between smokers and non-smokers throughout the four-year period.
Results: The evidence shows a process of dynamic interaction between communication, perception, and behavior. (1) We observed an increasing trend of *social media health communication* (SMH) and *perceived relative harm of e-cigarettes* (PHE). (2) Higher SMH was associated with more *e-cigarette use* directly in 2019. (3) Higher SMH was associated with less *e-cigarette use* indirectly through PHE in 2020. (4) Smokers consistently displayed heightened sensitivity in responding to harm perception compared to non-smokers.
Conclusions: The findings support two mechanisms underlying the association between SMH and e-cigarette use: direct and indirect. The changes in the pathways during the timespan may have been influenced by increased e-cigarette information on social media and public health events like COVID-19. Stricter regulations for unverified e-cigarette advertisements and anti-e-cigarette education on social media are called for to curtail e-cigarette use.

1. Introduction

The electronic cigarette (e-cigarette) represents an evolution of tobacco products, which has become an epidemic rapidly in the global market over the last decades (Health, U. D. o., Services, H., 2016). In the United States, the number of adults who use e-cigarettes frequently has increased by 2.2 million from 2017 to 2020 (Cornelius et al., 2022). The prevalence of adult e-cigarette users in the UK escalated from 1.7 % in 2012 to 6.3 % in 2020, peaking at 7.2 % in 2019 (McNeill et al., 2022). 3 % Canadians aged 25 years and older reported past-30-day e-cigarette use in 2020 (StatisticsCanada, 2022). However, the health outcomes of e-cigarettes are still uncertain, leading to ongoing debates in public health. Since 2019, two major epidemics, the e-cigarette, or vaping, product use-associated lung injury (EVALI) and the coronavirus disease 2019 (COVID-19), have occurred in the United States. These two public health emergencies have sparked wide-ranging discussion about the harm of e-cigarettes through media and health providers (Wackowski et al., 2022). COVID-19 further complicates tobacco product perceptions and behaviors. In the U.S., evidence indicates that some individuals were more cautious due to the heightened COVID-19 risk among smokers (Bandi et al., 2022; Kalkhoran et al., 2022; Patanavanich et al., 2023), whereas findings from the UK suggest that some people amplified tobacco use for psychological relief during the early stages of the pandemic (Chen, 2020; Gravely et al., 2021). Therefore, public attitudes and behaviors towards e-cigarettes may vary over time in response to changes in the social environment, making it essential to conduct a trend investigation.

In the digital era, social media has emerged as a new platform for facilitating health communication (Morris, 2011). From a communication perspective, social media health communication entails individuals' engagement in accessing, sharing, discussing, and generating health-related contents on social media to achieve health purposes (Chen &

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Wang, 2021; Moorhead et al., 2013). Past research has examined this form of communication within three user categories: health institutions, health professionals, and the general public (Chen & Wang, 2021). This study specifically investigates the impact of social media health communication on public perceptions and behaviors concerning e-cigarettes. As such, our primary focus is on exploring how the public uses social media for health-related communication across diverse platforms, including content communities like YouTube, social networking sites such as Facebook, and interactive forums (Moorhead et al., 2013). Empirical studies have highlighted the promising effects of anti-e-cigarette campaigns and cessation communities on social media (Graham et al., 2020; Struik & Yang, 2021). On the other hand, the quality and credibility of health information about e-cigarettes on social media have raised concerns. For instance, a scoping review conducted from 2017 to 2021 has revealed that e-cigarette manufacturers promote e-cigarettes on social media by using unsubstantiated health claims, which may mislead individuals' perceptions and behaviors (Lee et al., 2023).

Social media effectively mirrors changes in the social environment (Gunther, 2009; Zhong et al., 2023). Social media users expand yearly, surpassing 4 billion by October 2020 (DataReportal, 2020). Notably, during the pandemic, social media experienced accelerated growth, emerging as a vital platform for the public to access and exchange health-related information (Cuello-Garcia et al., 2020). For example, Facebook experienced a 37 % surge, and Chinese social media platforms observed a 58 % increase since the outbreak of COVID-19 (Kantar, 2020). Given the substantial user base and the important role of social media, it is anticipated that health communication on social media can have a profound and dynamic impact on the public's perceptions and behaviors regarding e-cigarettes. However, limited research has investigated the association between health communication on social media, perceived harm, and e-cigarette use in trend analyses. This study aims to address the research gap and to explore possible differences between smokers and non-smokers.

1.1. Graphing social media health communication, perceived harm and e-cigarette use by health belief model

The Health Belief Model (HBM) has been extensively utilized across various domains to predict and elucidate prevention actions of risky behaviors such as smoking (Mantler, 2013; Mohammadi et al., 2017). The HBM emphasizes the desire to avoid risks (Janz & Becker, 1984; Raamkumar et al., 2020). One pathway in the HBM leads from perceived threat and perceived benefits to health-related action. Perceived threat is a combination of perceived susceptibility and severity (Champion & Skinner, 2008). Individuals who perceive themselves to be at risk and realize how serious of such risks tend to take actions to avert those risks. Perceived benefits can influence whether such behavior changes happen by expecting the potential benefits of reducing the threats. Another concept in the HBM is the cue to action. Cues to action serve as a strategy to encourage behaviors. The influence of media is often considered a cue to action (Champion & Skinner, 2008; Janz & Becker, 1984; Mohammadi et al., 2017).

Applying the HBM to this study, we investigate: (1) how social media influences individuals' perceptions of harm related to e-cigarettes (perceived threat), and therefore indirectly associates with e-cigarette use (health-related action), (2) how communication on social media (cue to action) directly affects e-cigarette use, and (3) the moderating effect of smoking status, considering e-cigarettes as a harm reduction strategy (perceived benefits) for smokers.

Given the frequent comparisons between e-cigarettes and regular cigarettes in health-related advertisements and user-generated content on social media (Lazard et al., 2016; Sears et al., 2017), this study employs relative harm perception. Furthermore, it is important to note that relative harm perception can be particularly relevant when examining moderating effects based on smoking status, as smokers may prioritize relative harm when evaluating e-cigarettes (Jun et al., 2019).

1.2. Formulating hypotheses

Existing studies have produced mixed results on the association between social media health communication and perceived harm of e-cigarettes (Dai & Hao, 2017; Kwon & Park, 2020). Using social media for health communication potentially heightens e-cigarette exposure, with evidence indicating positive correlations between social media use and e-cigarette exposure (Cho et al., 2019; Massey et al., 2021; Zheng et al., 2021). It is possibly due to the prevalence of e-cigarette information on social media. For example, the number of e-cigarette videos on YouTube expanded by more than 2,500 new videos per month from 2013 to 2014 (Huang et al., 2016). Moreover, a study reported a fourfold increase in e-cigarette posts on Twitter within a month in 2019 (Wu et al., 2022). Another factor is the diverse targeting strategies employed by e-cigarette manufacturers to broaden advertising reach (Lee et al., 2023), including e-cigarette content that uses terms like "smoking cessation" or hashtags to engage individuals who are quitting smoking (Huang et al., 2016; Lee et al., 2023). Some manufactories even promote e-cigarettes as coping mechanisms for mental health issues, directing their messages at psychologically vulnerable groups seeking health support on social media (Rahmandar & Gribben, 2022).

Exposure to e-cigarettes on social media can possibly result in encountering dual information: pro-vaping and anti-vaping contents (Dai & Hao, 2017), which might lead to opposing perceptions of e-cigarette harm. Empirical studies have demonstrated that pro-e-cigarette content leads to less harm perception (Hung et al., 2022; Stanton et al., 2022). Conversely, a smaller but increasing number of studies have addressed the effects of anti-e-cigarette information on social media. An experiment investigating Twitter has demonstrated that health warnings showing that e-cigarette contains nicotine lead to more harm perception of e-cigarettes (Guillory et al., 2020).

Notably, social media serves as a reflective indicator of health discussion on e-cigarettes (Cole-Lewis et al., 2015), and the ratio of pro-e-cigarette and anti-e-cigarette messages may vary with time (Dai & Hao, 2017; Paek et al., 2014). The U.S. Food and Drug Administration (FDA) initiated e-cigarette regulations in 2016, including health warning mandates in 2018 (Keller-Hamilton et al., 2022). While there were no explicit restrictions on e-cigarette marketing on social media, all advertisements must include a health warning (FDA, 2018). In 2018, the FDA also increased anti-e-cigarette campaigns on social media (Sharpless, 2019). This was followed by heightened health discussions on social media triggered by EVALI and COVID-19, starting in 2019 (Chen et al., 2022; Kasson et al., 2021). Research indicates that while pro-e-cigarette content still surpasses anti-e-cigarette content, sentiment has shifted negatively since 2019 (Chen et al., 2022; Kasson et al., 2021). Analyzing 2020 data, scholars noted predominantly negative sentiment and anti-e-cigarette discussions on Twitter during COVID-19 (Lyu et al., 2021). In addition, an increasing trend of perceived relative harm of e-cigarettes from 2018 to 2020 was observed (Bandi et al., 2022). Therefore, the perceived relative harm of e-cigarettes is a dynamic cognitive process (Huang et al., 2019). We formulate the following hypotheses:

H1a. Social media health communication was negatively associated with the perceived relative harm of e-cigarettes from 2017 to 2019.

H1b. Social media health communication was positively associated with the perceived relative harm of e-cigarettes in 2020.

The impact of perceived e-cigarette harm on e-cigarette use has been well-documented by HBM and plentiful empirical research (Amrock et al., 2015; Champion & Skinner, 2008; Huang et al., 2019). As the HBM suggests, individuals are less likely to use e-cigarettes when they perceive more harm in e-cigarettes. Additionally, the mediator role of risk perception is identified by research across disciplines (Iorfa et al., 2020; Lee et al., 2008). A longitudinal study has demonstrated the mediating effect of harm perception on the association between social media use and subsequent e-cigarette use (Zheng et al., 2021). Hence, we formulate the next two hypotheses:

H2. Perceived relative harm of e-cigarettes is negatively associated with e-cigarette use.

H3. Perceived relative harm of e-cigarettes can mediate the association between social media health communication and e-cigarette use.

In the HBM framework, media influence is commonly regarded as a cue to prompt preventive actions (Champion & Skinner, 2008). Health communication on social media can directly influence e-cigarette use. Similar to the dual-content impact on public perceptions, individuals' actions are influenced by informational features. Positive claims about e-cigarettes on social media, such as user sharing, have been shown to be associated with increased e-cigarette use (Pokhrel et al., 2018; Sawdey et al., 2017). In contrast, longitudinal research indicates that anti-e-cigarette content on social media leads to reduced e-cigarette use (Pokhrel et al., 2021). Accordingly, we formulate the fourth hypothesis:

H4a. Social media health communication was positively associated with e-cigarette use from 2017 to 2019.

H4b. Social media health communication was negatively associated with e-cigarette use in 2020.

Harm reduction is conceptually formulated and empirically investigated as perceived benefits in prevention studies (Bonar & Rosenberg, 2011; Eshrati et al., 2008; Winer et al., 2022). Considerable evidence has demonstrated that smokers, in higher proportions, perceive e-cigarettes as less harmful than non-smokers. Consequently, smokers tend to shift from regular cigarettes and report greater e-cigarette use than their non-smoking counterparts (Amrock et al., 2015; Huang et al., 2019; Pearson et al., 2012). It is plausible that smokers perceive a heightened health threat so that the transition to products with lower nicotine becomes particularly compelling for them (Polosa et al., 2013).

A key precondition of harm reduction is the perceived harm. Since smokers can benefit more from reducing harm, it can be expected that they may respond more sensitively to harm perception than non-smokers. Understanding the disparities in e-cigarette awareness, reactions, and behaviors between smokers and non-smokers is pivotal for policymakers in tailoring effective prevention strategies. Hence, we propose the following hypothesis:

H5. Smoking status (smokers vs. non-smoker) negatively moderates the association between perceived relative harm of e-cigarettes and e-cigarette use.

2. Methods

2.1. Data source and sample

The data were obtained from the Health Information National Trends Survey collected from 2017 to 2020 (HINTS 5 Cycle 1–4, http://hints.cancer.gov/) by the National Cancer Institute. HINTS is a nationally representative mail-based survey that monitors health-related communication and behaviors in U.S. adults (Nelson et al., 2004). Two-stage random sampling is used by HINTS, and the response rates for 2017–2020 range from 30.2 % to 36.7 % (Cho et al., 2023). As per the National Center for Health Statistics, e-cigarette users are predominantly under 65 years old. Adult e-cigarette use among individuals aged 65 and over ranged from 0.6 % to 0.8 % between 2018 and 2020 (CDC, 2021). To effectively focus on the e-cigarette target demographics, individuals aged 65 and over are excluded in this study. As a result, the sample included 2,085 respondents in 2017, 2,177 in 2018, 3,323 in 2019, and 2,329 in 2020. Non-valid responses were deleted listwise for regression analyses.

2.2. Measures

The dependent variable *e-cigarette use* was a derived variable from two questions: (1) Have you ever used an e-cigarette? (yes/no) and those who answered "yes" were asked the following question: (2) Do you now use an e-cigarette every day, some days, or not at all? (every day/some days/not at all). Built upon emerging patterns defining the prevalence of e-cigarette use (Amato et al., 2016; Snider et al., 2017; Warner, 2016), the variable e-cigarette use was recoded from the two questions to measure the usage frequency, ranging from 0 to 3, where 0 indicated never use, 1 indicated past use, 2 indicated occasional use and 3 indicated daily use (Amato et al., 2016).

The independent variable *social media health communication* was the sum of three items that asked the respondents in the last 12 months whether they have used social media for the following reasons: (1) to share health information on social networking sites, such as Facebook or Twitter; (2) to participate in an online forum or support group for people with a similar health or medical issue; (3) to watch a health-related video on YouTube. Each item was scored 0 for *no* and 1 for *yes*. While Cronbach's alpha coefficient for SMH was 0.512, it should be noted that this may represent a lower-bound estimate of reliability due to the binary nature of the items (Sijtsma, 2009; Sun et al., 2007). Nevertheless, this construction method has been employed in previous studies (Huo et al., 2019; Qin et al., 2021; Ye et al., 2023). The constructed variable ranged from 0 to 3, where 0 indicated not conducting any kind of health communication, and 3 indicated performing all kinds of communication.

The mediator *perceived relative harm of e-cigarettes* was the response from a question asking the perceived harm of e-cigarettes versus regular cigarettes. Responses were categorized into five groups ranging from 1 to 5: much less harmful, less harmful, just as harmful, more harmful, and much more harmful. Responses such as "I have never heard of e-cigarettes/I don't know" were excluded from the analysis (Bjurlin et al., 2022).

The moderator *smoking status* measures whether the respondents are current smokers, coded 0 for *no* and 1 for *yes* for analysis.

To control for possible sociodemographic effects, the following variables were included as covariates in the regression analyses: *age, gender, education, income, race,* and *marital status*. Descriptive statistics for the variables across four years are presented in Table 1.

2.3. Data analysis

Data analysis was performed by SPSS (v26). First, descriptive analyses were conducted to summarize the characteristics of each variable across the four years. Second, a one-way ANOVA analysis was conducted to explore the trends of key variables across years. Furthermore, SPSS macro PROCESS (Hayes, 2017) Model 4 was used to identify the mediation effect of perceived relative harm of e-cigarettes on the association between social media health communication and e-cigarette use after controlling for demographics in each year. Mediation effects were statistically assessed using bootstrapping (5,000 samples) and 95 % confidence intervals (CI). Additionally, we employed PROCESS Model 14 to investigate how smoking status moderates the association between perceived relative harm and e-cigarette use. Then, we pooled all the samples together with a new variable indicating the year. The variable year was tested as a moderator to further investigate potential changes in each path in the mediation model across years (Li et al., 2022).

Additionally, this study adopted *percentage coefficient* (b_p) to supplement the familiar indicator β and comprehensively estimate the effect size (Zhao et al., 2022). b_p is a b coefficient when the dependent variable and independent variable is each linearly transformed to a percentage scale (0–1).

3. Results

3.1. Preliminary analyses

The demographic features of the respondents across four years were presented in Table 1. The average age of respondents ranged from 46 to 48 years. There were more female respondents. The average household income was consistent across years, falling within the range of $35,000 to $74,999. More than 45 % of respondents reported having completed

Table 1
Descriptive statistics of the independent, dependent, mediating, moderating and controlling variables (2017–2020).

	Year 2017	Year 2018	Year 2019	Year 2020
Dependent variable				
E-cigarette use (Four levels 0 ~ 3, Mean ± SD)	0.21 ± 0.52	0.23 ± 0.55	0.26 ± 0.61	0.26 ± 0.62
Independent variable				
SMH (Four levels 0 ~ 3, Mean ± SD)	0.59 ± 0.82	0.67 ± 0.85	0.68 ± 0.83	0.74 ± 0.85
Mediating variables				
PHE (Five levels 1 ~ 5, Mean ± SD)	2.79 ± 0.82	2.85 ± 0.82	3.01 ± 0.93	3.41 ± 1.02
Moderating variables- Smoking status (n. %)				
Current smoker	309 (14.8)	339 (15.6)	451 (13.6)	298 (12.8)
Current non-smoker	1,638 (78.6)	1,690 (77.6)	2,646 (79.6)	1,826 (78.4)
Sociodemographic controls				
Age (years, Mean ± SD)	47.67 ± 11.98	47.28 ± 12.17	46.89 ± 12.38	46.85 ± 12.56
Gender (n. %)				
Female	1,250 (60.0)	1,332 (61.2)	1,931 (58.1)	1,384 (59.4)
Male	818 (39.2)	825 (37.9)	1,332 (40.1)	940 (40.4)
Education ((n. %)				
Below high school	106 (5.1)	134 (6.2)	168 (5.1)	134 (5.8)
High school	338 (16.2)	353 (16.2)	503 (15.1)	380 (16.3)
Some college	617 (29.6)	621 (28.5)	952 (28.6)	636 (27.3)
College graduate and above	1,014 (48.6)	1,058 (48.6)	1,651 (49.7)	1,133 (48.6)
Household income (Nine levels, Mean ± SD)	5.72 ± 2.27	5.79 ± 2.29	5.84 ± 2.29	5.89 ± 2.27
Ethnicity (n. %)				
White	1,493 (71.6)	1,531 (70.3)	2,310 (69.5)	1,641 (70.5)
Others	494 (23.7)	520 (23.9)	774 (23.3)	538 (23.1)
Marriage status (n. %)				
Married and living with a romantic partner	1,206 (57.8)	1,166 (53.6)	1,904 (57.3)	1,307 (56.1)
Divorced, widowed, separated and single	861 (41.3)	998 (45.8)	1,365 (41.1)	977 (41.9)
N	2,085	2,177	3,323	2,329

Notes: a SD stands for standard deviation; SMH stands for social media health communication; PHE stands for perceived relative harm of e-cigarettes.

college or higher education. Around 70 % of respondents were non-Hispanic white, and more than half were living with a partner in each year.

3.2. Trends of key variables

Table 2 shows the trends of key variables across the four-year period. As shown, social media health communication increased from 0.197 in 2017 to 0.246 in 2020 (0.049, 95 % CI [0.027, 0.071], p <.001). Moreover, there was a significant upward trend in the perceived relative harm of e-cigarettes, rising from 0.448 in 2017 to 0.603 in 2020 (0.155, 95 % CI [0.135, 0.175], p <.001). Between 2017 and 2020, the perceived less harm of e-cigarettes compared to traditional cigarettes decreased from 26.8 % to 10.4 %. In contrast, the rate of perceived greater harm initially decreased from 8.9 % in 2017 to 7.4 % in 2018, but subsequently increased to 27.6 % by 2020.

As for e-cigarette use, we observed an increasing trend from 2017 to 2019 (0.018, 95 % CI [0.004, 0.032], p <.01) but a decrease in 2020. The change in smoking status across the years was inconsistent with fluctuation. See Fig. 1 for the visualization of the trends.

Table 2
Multiple comparisons of the e-cigarette use, SMH, PHE, and health smoking status.

	Year 2020 vs 2019	Year 2020 vs 2018	Year 2020 vs 2017
E-cigarette use	-0.001	0.009	0.018*
SMH	0.020*	0.024*	0.049***
PHE	0.101***	0.140***	0.155***
Smoking status	-0.005	-0.027	-0.018

Notes: The main cell is the difference in mean; One way ANOVA analysis with post hoc analysis (Games-Howell method) was used. SMH stands for social media health communication; PHE stands for perceived relative harm of e-cigarettes.
*p <.05; **p <.01; ***p <.001.

3.3. Testing mediation

H1a and H1b postulated divergent associations between social media health communication and perceived relative harm of e-cigarettes across the years. As presented in Table 3 and Fig. 2, the first three years failed to pass the statistical threshold, so H1a was not supported. A positive association was found in 2020 (b_p = 0.062, β = 0.069, p <.01), supporting H1b.

H2 predicted a positive relation from perceived relative harm to e-cigarette use. A statistically acknowledged positive effect was found across all four years (b_p = -0.243/-0.307/-0.292/-0.229, β = -0.258/-0.303/-0.297/-0.270, p <.001; Samples 2017, 2018, 2019, and 2020), supporting H2.

H3 predicted the indirect path from social media health communication to e-cigarette use mediated by perceived relative harm of e-cigarettes. As shown, a negative mediating effect was identified solely in 2020 (b_p = -0.014, β = -0.019, bootstrap 95 % CI ranges [-0.026, -0.003], Sobel test p <.01), partially supporting H3.

H4a and H4b postulated different associations of the direct path in different years. As shown in Table 3, there was a statistically acknowledged positive association only in 2019 (b_p = 0.048, β = 0.061, p <.01). Therefore, H4a was partially supported and H4b was not supported.

The total effects of social media health communication on e-cigarette use in each year were examined. Table 3 and Fig. 2 showed a positive effect merely in 2019 (b_p = 0.052, β = 0.065, p <.01).

3.4. Testing moderation

H5 predicted a negative moderating effect of smoking status on the association between perceived relative harm and e-cigarette use. Table 3 showed negative and statistically acknowledged moderation effects in 2017, 2018 and 2020 (b_p = -0.149/-0.244/-0.134, β = -0.141/-0.208/-0.136, p <.05), partially supporting H5.

Figure 3 illustrates the moderating effect in the three years, where the patterns were consistent. The lines showing that harm perception to e-cigarette use were more negative among current smokers. This suggests that smokers react more sensitively to harm perception as we hypothesized. Current smokers (solid line) exhibit more increased e-cigarette use compared to non-smokers (dotted line) when perceiving less harm of e-cigarettes (PHE = 0.25). Conversely, smokers decrease e-cigarette use more than non-smokers when perceiving more harm of e-cigarettes (PHE = 0.75). Notably, smokers still reported higher e-cigarette use even when they reduced their usage.

As mentioned, we also tested the variable *year* as a moderator. The results identified significant differences between the year 2020 and the first three years on the association between social media health communication and perceived relative harm of e-cigarettes. Although no impact was observed between social media health communication and perceived relative harm of e-cigarettes during the initial three years, the correlation turned notably positive in 2020. This moderating effect also reflects the evolving impacts of social media health communication on public perceptions of e-cigarettes and a negative shift in attitudes after 2019. See supplemental material for the visualization.

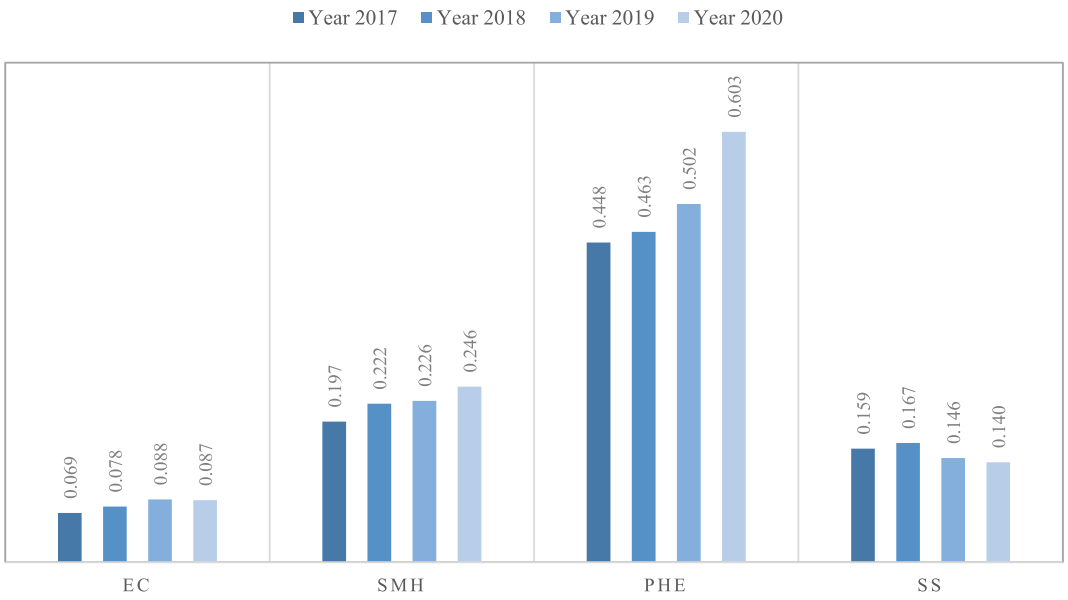

Fig. 1. Comparison of key variables across years *Notes:* EC: e-cigarette use; SMH: social media health communication; PHE: perceived relative harm of e-cigarettes; SS: smoking status. All variables are in percentage scale.

Table 3
Summary of mediation and moderation effects in each year.

Mediation pathways	Year 2017		Year 2018		Year 2019		Year 2020	
	β (b_p)	95 % CI	β (b_p)	95 % CI	β (b_p)	95 % CI	β (b_p)	95 % CI
SMH → PHE	0.006 (0.004)	[-0.033, 0.042]	-0.019 (-0.014)	[-0.057, 0.029]	-0.013 (-0.011)	[-0.048, 0.027]	0.069 (0.062) **	[0.016, 0.107]
PHE → EC	-0.258 (-0.243)***	[-0.290, -0.197]	-0.303 (-0.307)***	[-0.363, -0.252]	-0.297 (-0.292)***	[-0.335, -0.249]	-0.270 (-0.229)***	[-0.272, -0.187]
indirect path: SMH → PHE → EC	-0.002 (-0.001)	[-0.011, 0.009]	0.006 (0.004)	[-0.010, 0.019]	0.004 (0.003)	[-0.009, 0.014]	-0.019 (-0.014)**	[-0.026, -0.003]
direct path: SMH → EC	0.013 (0.009)	[-0.025, 0.043]	0.029 (0.022)	[-0.019, 0.063]	0.061 (0.048) **	[0.014, 0.083]	0.037 (0.028)	[-0.010, 0.065]
total effect	0.012 (0.008)	[-0.027, 0.043]	0.035 (0.026)	[-0.017, 0.069]	0.065 (0.052) **	[0.015, 0.088]	0.018 (0.014)	[-0.025, 0.053]
Moderation pathway								
PHE × SS→ (PHE → EC)	-0.141 (-0.149)**	[-0.256, -0.042]	-0.208 (-0.244)***	[-0.371, -0.117]	-0.058 (-0.071)	[-0.181, 0.039]	-0.136 (−134)*	[-0.254, -0.014]

Notes: Standardized beta are shown in each cell, with percentage coefficients in parenthesis; All model controlling for age, gender, education, income, ethnicity, marital status; CI stands for confidence interval.
SMH: social media health communication; PHE: perceived relative harm of e-cigarettes; EC: e-cigarette use; SS: smoking status.
*p <.05; **p <.01; ***p <.001.

4. Discussion

Under the guidance of HBM, this study investigates the trends of how social media influence the public's e-cigarette perceptions and behaviors over a four-year period. Our findings expand the literature, offering evidence that health communication on social media mirrors social-environmental changes, yielding dynamic impacts on the public. We identify a rising trend in health communication using social media during the four years and a negative shift in public attitudes towards e-cigarettes post-2019. This underscores the need for policymakers to closely monitor social media's role in e-cigarette prevention and adapt policies to changing environments.

4.1. Trends analysis of social media health communication and perceived relative harm

Our study revealed an increasing trend of social media health communication and the perceived relative harm of e-cigarettes from 2017 to 2020. Coincided with previous findings (Auxier & Anderson, 2021; Morris, 2011), the increasing trend of health communication on social media reflects the rapid developments of digital technology application in public health. Compared with offline health communication, social media provides a more convenient and private way for individuals to gain health support and connectedness, especially during quarantines in 2020 (Cuello-Garcia et al., 2020). Nevertheless, the increasing trend might also reflect the increased presence of health-related e-cigarette advertisements on social media, where the public has a greater chance of encountering such promotions (Cho et al., 2019; Massey et al., 2021; Richardson et al., 2015; Zhao & Zhang, 2017; Zheng et al., 2021).

The increasing trend of perceived relative harm of e-cigarettes corresponds with individuals' heightened sensitivity and awareness of harm perception especially during the pandemic (Lyu et al., 2021), as well as increased media and press evidence of e-cigarette harm (Kalkhoran et al., 2022; Patanavanich et al., 2023; Wackowski et al., 2022). The altered negative perception of e-cigarettes has influenced the public use, evident in the decreased e-cigarette use in 2020. This aligns with the decline in e-cigarette sales in the U.S. during the same year (Ali et al.,

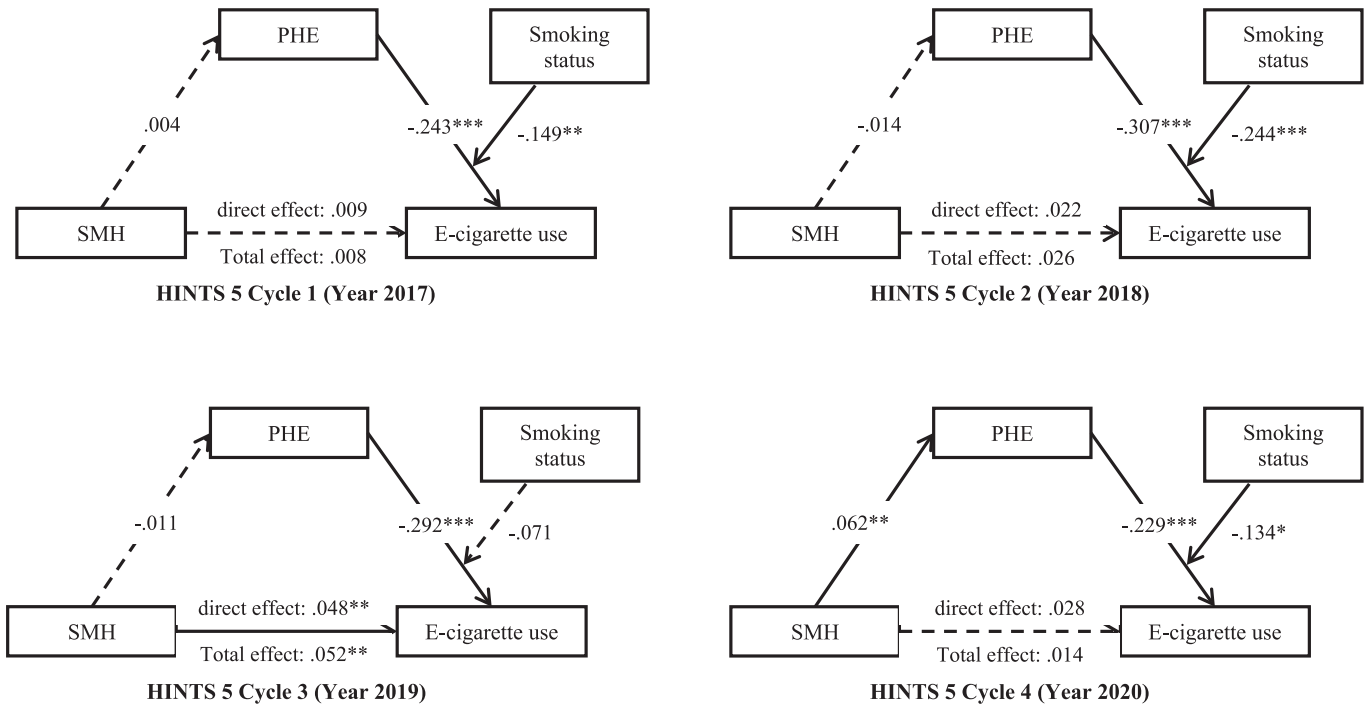

Fig. 2. Effect of SMH on e-cigarette use mediated by PHE and moderated by smoking status (2017–2020). *Notes: SMH stands for social media health communication; PHE stands for perceived relative harm of e-cigarettes. Path indicators are b_p, where b_p means percentage coefficients. *p <.05; **p <.01; ***p <.00*

2020).

The trends also coincide with changes in mediation effects over the four-year period, which will be explicated in the subsequent analyses.

4.2. Mediation and moderation effects across years

The results address the changing association between social media health communication and the perceived relative harm of e-cigarettes post-2019. Partially echoing prior findings (Dai & Hao, 2017; Guillory et al., 2020), we reported a positive association in 2020. Accordingly, a negative indirect path from social media health communication to e-cigarette use mediated by perceived relative harm was found. However, non-significant associations were observed in the previous three years. It is plausible that both the communication on social media and perceptions about e-cigarettes are dynamic processes. In the earlier period, health-related discussions about e-cigarettes on social media were limited but expanded yearly (Cole-Lewis et al., 2015). Meanwhile, the public's uncertainty in harm perception of e-cigarettes decreased each year as more health evidence appeared (Bandi et al., 2022). Additionally, two public events EVALI and COVID-19 added complexity and fear to the public's perceptions of e-cigarettes (Bandi et al., 2022). Therefore, the year 2020 witnessed a statistically acknowledged association between social media health communication and the perceived relative harm of e-cigarettes.

The direct association between health communication on social media and e-cigarette use also exhibited dynamic changes across years. The positive association passed the statistical threshold only in 2019. It is possibly because of incremental e-cigarette advertisements and peer generated contents on social media in 2019, coinciding with peak e-cigarette sales (Ali et al., 2020). The e-cigarette manufacturers implement sophisticated marketing strategies on all social media platforms, which might misguide individuals to try more e-cigarettes. For example, manufacturers sponsor health-related contents on social media, with promotion information and purchase link (Kong et al., 2022; Luo et al., 2014). However, there was no such positive association in 2020, possibly reflecting the changing health environment. People might be reluctant to use e-cigarettes due to fear and purchasing challenges during the pandemic (Bandi et al., 2022; Samet, 2020).

This study unveiled the moderating effects of smoking status. Aligning with prior research (Amrock et al., 2015; Pearson et al., 2012), we identified e-cigarette usage difference between smokers and non-smokers. Our contribution lies in demonstrating varied behavioral responses related to e-cigarette harm perception. Current smokers exhibited heightened sensitivity to e-cigarette harm perception, leading to a more substantial reduction in usage than non-smokers when perceiving e-cigarettes as more dangerous. This implies that targeted harm education for smokers may be particularly efficacious.

4.3. Theoretical and practical implications

Our findings contribute to the literature theoretically in two regards. First, this study reveals two mechanisms underlying the association between social media health communication and e-cigarette use, directly and indirectly. As social media comprises both legitimate health information and unverified health assertions, it may lead to different behavioral responses. Specifically, accurate health information increases the likelihood of individuals comprehending the harm of e-cigarettes, and as a result, reducing their use. Conversely, when controlling for the effects of harm perception, frequent social media use may reinforce e-cigarette use (Zheng et al., 2021).

The second contribution lies in advancing public health communication in digital and public health contexts. Examining four years longitudinally, our study sheds light on how health communication interacts with social settings. The COVID-19 pandemic has notably impacted health communication on social media, affecting the public perceptions of e-cigarette harm (Bandi et al., 2022). In the new media era, while prior research predominantly explored health communication through health institutions, professionals, and the public, it's worth noting that industries also employ social media for health-related advertisements (Lee et al., 2023; Luo et al., 2014). E-cigarette manufacturers often employ unverified health claims, potentially misleading users (Lee et al., 2023; Luo et al., 2014), especially in peer networks. Future studies might test the effects more formally by adding such measures as e-cigarette advertisement exposure on social media.

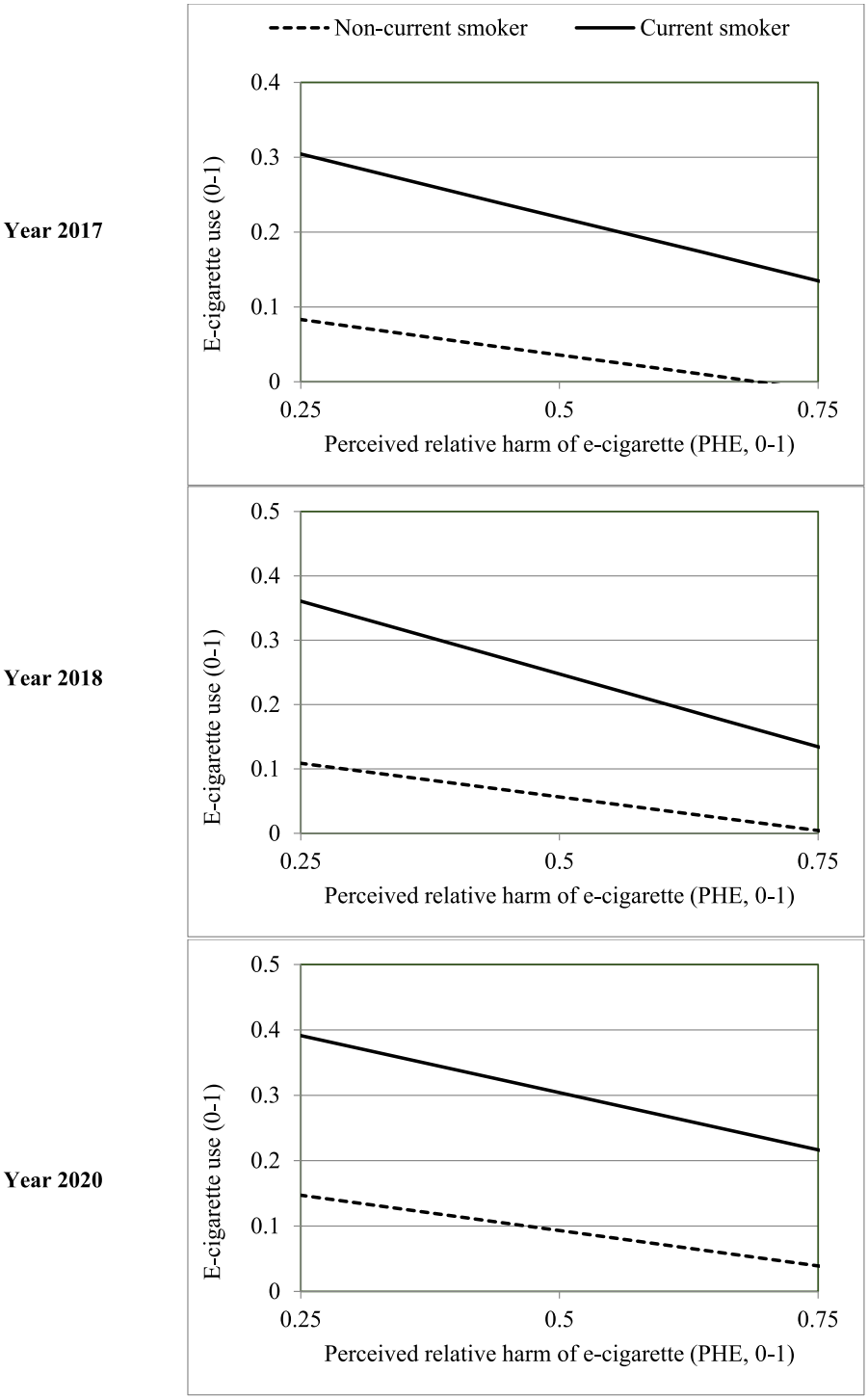

Fig. 3. The moderation effect of smoking status in 2017, 2018 and 2020.

This study also has practical implications. First, tailored anti-tobacco campaigns and interventions should be promoted on social media to guide people to perceive the harm of e-cigarettes more accurately (Zheng et al., 2021). Those digital campaigns can optimize outcomes by targeting smokers and frequent users of social media. Second, regulation of e-cigarette advertisements on social media needs to be emphasized, as digital channels are largely unregulated and mainly used to promote e-cigarettes by tobacco industries (Lempert et al., 2016; Tackett et al., 2020). Furthermore, due to the polarized health contents about e-cigarettes on social media, individuals may experience confusion when making decisions. Clinical professionals are recommended to implement e-health education for facilitating individuals in discerning accurate information on social media (Bevilacqua et al., 2021). Finally, the trends presented in this study demonstrate that individuals' health perceptions and behaviors are dynamic processes influenced by social environment. Health policymakers should be cautious about the impacts of major health events.

4.4. Limitations

Several limitations should be acknowledged in our study. First, as the study used a cross-sectional survey, the causal inferences can't be

determined. Future studies using experimental designs are encouraged to confirm the causality. Second, due to the constraint of using secondary data, the variable SMH refers to general social media use for health. A potential disparity exists between general health communication and communication concerning e-cigarettes, necessitating further investigation in future research. Third, HINTS provides only relative e-cigarette harm perception, distinct from absolute harm perception. Future studies should consider this distinction and investigate the role of absolute harm perception of e-cigarettes.

5. Conclusion

In summary, this study examines changes in the direct and indirect linkages between social media health communication and e-cigarette use from 2017 to 2020. It also highlights disparities between smokers and non-smokers regarding e-cigarettes, expanding the application of the HBM in the digital and pandemic context. The findings suggest a negative shift in public attitudes towards e-cigarettes after 2019. Understanding the effects of social media and the impact of the dynamic environment is crucial for public health policymakers. Implementing stricter regulations for unverified e-cigarette advertisements and anti-e-cigarette education on social media is recommended to curb e-cigarette use.

Data availability statement

Data are available in a public, open access repository. data are available via http://hints.cancer.gov/.

Ethics statements

Patient consent for publication.

Not applicable.

Ethics approval

The HINTS data meet established ethical standards and have obtained ethics approval.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

I have shared the link to my data in attached files.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.addbeh.2023.107875.

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