

Waterpipes and Electronic Cigarettes: Increasing Prevalence and Expanding Science

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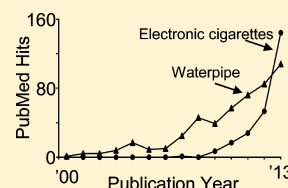
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ABSTRACT: The prevalence of noncigarette tobacco product use is on the rise across the globe, especially for waterpipes (also known as hookah, narghile, and shisha) and electronic cigarettes (e-cigarettes). The scientific literature reveals that waterpipe tobacco smoking is associated with exposure to a variety of toxicants that can cause short- and long-term adverse health events. In contrast, there is far less evidence of health harms related to e-cigarette use, although the variety of products in this category makes it difficult to generalize. We searched the PubMed database for all publications on waterpipes and e-cigarettes from January 2000 to March 2014. The number of publications on waterpipes rose in a slow, linear pattern during this time, while the number of publications on e-cigarettes showed exponential growth. The different trends suggest there may be more interest in studying a novel nicotine product (the e-cigarette) over a traditional tobacco product (the waterpipe). We posit that, although the specific research needs for these products are different, public health would be served best by a more equitable research approach. Scientists should continue to devote attention to understanding the unknown long-term health effects of e-cigarettes and their potential to serve as harm reduction or smoking cessation tools while simultaneously investigating how to reduce waterpipe smoking given that it exposes users to toxicants known to cause harm to health. Recent regulatory action in the United States, which proposes to include waterpipes and e-cigarettes under some of the same regulations as tobacco cigarettes, makes such research particularly timely.



INTRODUCTION

Tobacco use and subsequent exposure to carcinogens and other toxicants cause over 480 000 deaths annually in the United States.¹ These deaths are primarily due to daily tobacco cigarette smoking, which is maintained by nicotine dependence, and the concomitant inhalation of tobacco toxicants.¹ Rates of current cigarette smoking by U.S. adults have decreased from 40% in 1955 to 18% in 2012,^{2,3} but rates of use of noncigarette tobacco products are on the rise.^{1,4–6} Two examples of such products are waterpipes (also known as hookah, narghile, and shisha) and electronic cigarettes (e-cigarettes). Along with increased prevalence, the scientific literature on both of these products is expanding. The purpose of this Perspective on Statistical Trends is to familiarize readers with the literature on waterpipes and e-cigarettes, to comment on the relative growth rates of that literature, and to discuss the need for more research about these products.

WHAT ARE WATERPIPES AND E-CIGARETTES?

Although users of waterpipes and e-cigarettes report similar misperceptions about these products' lower levels of health risk relative to tobacco cigarettes, the two products are very

different in terms of their structure, operation, and health effects.

Waterpipes. A waterpipe (Figure 1) is topped by a ceramic "head" into which a moist, sweetened, and flavored tobacco mixture is placed.⁷ Beneath the head, which has holes in its base, a hollow central conduit enters a half-filled water bowl. The bottom of the conduit is submerged in the water. A hose/mouthpiece assembly exits the bowl above the waterline and terminates at the user's lips. Examples of waterpipes and related materials appear in Table 1. Because waterpipe tobacco is moistened with sweeteners and flavorants and will not burn on its own, it requires a heat source, usually charcoal placed atop a piece of perforated aluminum foil covering the tobacco-filled head. Inhalation on the mouthpiece creates negative pressure in the water bowl. This negative pressure draws air over the charcoal, and the heated air, mixed with charcoal smoke, travels through the tobacco-filled head, down the conduit, through the water in bubbles, out the top of the bowl into the hose, and into the user's mouth and lungs.^{7,8} Thus, waterpipe smoking involves the inhalation of both charcoal and tobacco smoke.⁹

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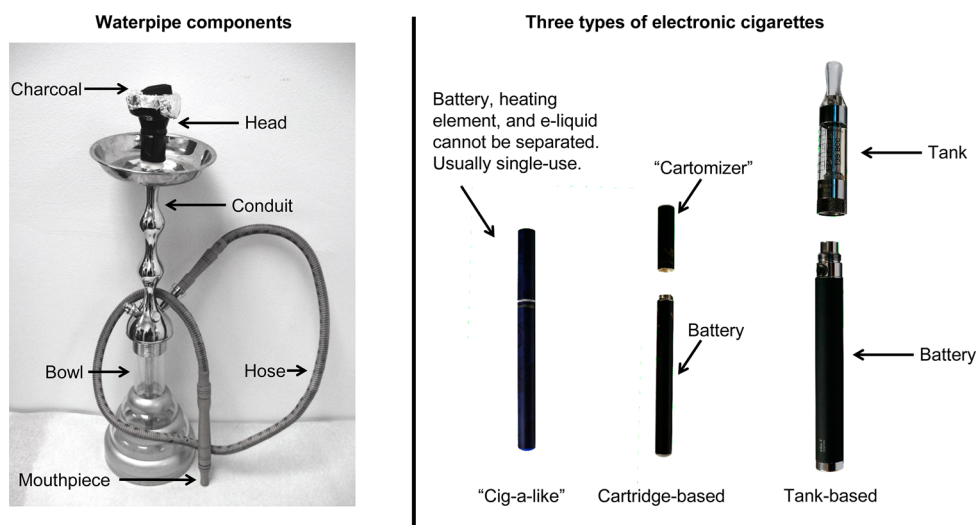


Figure 1. Waterpipe (left) and three types of e-cigarettes (right). During waterpipe use, burning charcoal is placed atop a tobacco-filled head that is covered with perforated aluminum foil. The user inhales on the mouthpiece, drawing air across the charcoal, through the tobacco in the head, and down the central conduit. The mixture of charcoal and tobacco smoke bubbles through a half-filled water bowl and cools, whereupon the smoke travels into the hose, through the mouthpiece, and into the user's lungs. E-cigarettes come in many varieties including one-piece, disposable "cig-a-likes"; cartridge-based models that can typically be recharged and refilled; and tank-based models that consist of a rechargeable battery, heating element, and liquid reservoir that can hold up to 8 mL of liquid.

Table 1. Components and Examples of Brands for Waterpipes and E-cigarettes

Product or Component	Description	Brand Example
E-cigarettes		
Disposable model ("cig-a-like")	A prefilled e-cigarette that is thrown away after the e-liquid is used.	NJoy
Cartridge-based model (nontank)	An e-cigarette battery attached to a standard size refillable cartridge that combines the e-liquid, usually in a wicking material, with the heating element.	Joytech eGo battery with Boge cartomizer
Refillable tank model	An e-cigarette battery attached to a refillable reservoir that holds the e-liquid. The reservoir is often transparent for monitoring the e-liquid level.	Joytech eGo battery with Kanger T2 Clearomizer
E-liquid	A liquid that refills e-cigarettes. The e-liquid typically contains nicotine, flavorants, and humectants.	Totally Wicked
Drip tip	A separate tip (usually cylindrical) that is attached to the heater and used in lieu of the cartridge. The user "drips" e-liquid through the drip tip directly onto the heater.	Thor
E-hookah	Identical to e-cigarettes but marketed as related to waterpipes (e.g., similar flavors).	NEwhere
Waterpipes		
Single hose	A waterpipe with a single hose/mouthpiece assembly meant for one user at a time.	Mya
Multiple hose	A waterpipe with two or more hose/mouthpiece assemblies meant for multiple users.	King Tut 4 Hose
Ma'assel Moassel or shisha or sheesha	Sweetened, flavored tobacco meant for use in a waterpipe.	Al Fakher
Nontobacco preparations	"Herbal" products that do not contain tobacco and are marketed for use in a waterpipe.	SoeX Herbal
Charcoal (quick-lighting)	Heat source for use in waterpipe tobacco smoking. Chemicals in the coal allow it to be ignited with a match or lighter.	Three Kings
Charcoal ("natural" or "traditional")	Heat source for use in waterpipe tobacco smoking. Requires another heat source to ignite (e.g., electric burner).	Nour
Mouth tips	Plastic disposable tips that attach to a waterpipe mouthpiece. Marketed to stop the spread of disease when sharing a waterpipe.	Kanara

In addition to tobacco, nontobacco products are available for waterpipes using the same preparation method.

E-Cigarettes. An e-cigarette consists of an electric power supply (usually a battery), a metal heating element, and a liquid. This liquid consists of humectants (typically propylene glycol and/or glycerin), flavorants, and nicotine, although non-nicotine versions are also available.¹⁰ When the e-cigarette power source is active, the element heats some of the liquid and forms a mist or aerosol. The user inhales this aerosol, which looks similar to the smoke from a tobacco cigarette. Because the nicotine in an e-cigarette is derived from tobacco and because e-cigarettes are not licensed as smoking cessation tools

or treatments for any medical disorder, they are legally defined as tobacco products in the United States.

Importantly, there are many different types of e-cigarettes (Figure 1), including so-called "cig-a-likes" that are designed to look like cigarettes. Some e-cigarettes are cartridge-based; they can be rechargeable or disposable and usually contain approximately 1 mL of nicotine liquid. Others are tank-based rechargeable systems that have reservoirs which store up to 8 mL of nicotine liquid above the heating element.^{10,11} In addition to these configurations, e-cigarettes can differ in the voltage of the power source, resistance of heating element, and dose of nicotine liquid (generally up to 36 mg/mL).¹¹ Although

marketed as a distinct product, an e-hookah is a type of e-cigarette. In the same product category, personal vaporizers are pocket-sized devices that operate the same way as e-cigarettes but may not be tube-shaped like many e-cigarettes. Examples of product components and brands appear in Table 1. The many types of e-cigarette configurations, coupled with the fact that relatively few of these devices and liquids have been subject to empirical investigation, limit the generalizability of e-cigarette research.

■ WHO USES WATERPIPES AND E-CIGARETTES?

While waterpipe tobacco smoking has been documented since at least the 1600s,¹² e-cigarettes were patented in 2004 and introduced into the U.S. consumer marketplace in 2007.^{13,14} Despite these very different timelines, rates of waterpipe and e-cigarette use are both increasing in the United States and elsewhere.

Waterpipes. Waterpipe use occurs in Africa,^{15–17} Asia,^{18–20} Europe,^{19,21,22} the Western Pacific,^{23,24} and the Americas,^{8,19,25,26} but it is particularly prevalent in the Eastern Mediterranean Region,^{27–31} especially among young adults. For example, past 30 day waterpipe tobacco smoking was reported by 30% of university students in Jordan³² and 28% of adolescents in Iran.³¹ Daily or weekly waterpipe smoking was reported by 38% of university students in Lebanon.³³ In the United States, waterpipe use is becoming more common, particularly among adolescents and young adults.³⁴ In a nationally representative survey of high school seniors, 21% reported past year waterpipe use in 2013,³⁵ up from 17% in 2009.³⁶ In a separate survey of 105 000 university students from across the country, waterpipe smoking was second only to cigarette smoking as the most common form of tobacco use.³⁷ Nearly one in three students (30%) reported using waterpipes at some time in their lives, and 8% reported current use.³⁷ The sweetness and variety of the flavors (fruit, candy, coffee, etc.) of waterpipe tobacco and the misperception that the smoke that users inhale is not dangerous likely contribute to the product's popularity. The social nature of waterpipe smoking may also add to its appeal. Users often gather in hookah bars or lounges to smoke together.³⁸

E-Cigarettes. Like waterpipe tobacco smoking, e-cigarette use is increasing globally.^{6,14,39–42} In the United States, nationally representative surveys revealed that, in 2012, 8% of adults had ever tried e-cigarettes and 1% were current users,⁶ whereas in 2009, less than 1% reported ever using it.¹⁴ Women, younger adults, and those with lower education are more likely to have used e-cigarettes than their counterparts.^{6,43} Most e-cigarette users are current or former smokers,^{6,14,39} and dual use of regular tobacco cigarettes and e-cigarettes is common.⁴ In 2013, 21% of current U.S. smokers reported that they also used e-cigarettes some days or every day.⁴⁴ Prevalence data from other countries demonstrate the same pattern of higher rates of use among smokers than nonsmokers. In a 2012 survey of more than 26 000 adults in the European Union, 20% of current cigarette smokers reported ever using e-cigarettes, compared to only 5% of former smokers and 1% of never smokers.⁴² Current smokers often report that e-cigarettes helped them to cut back on smoking, and former smokers often report that e-cigarettes helped them to quit,^{45,46} although evidence for these reports is mixed.^{43,47}

Use among youth in the U.S. is rising.⁴⁸ From 2011 to 2012, reported ever use of e-cigarettes increased from 3 to 7% among middle- and high-school students in the National Youth

Tobacco Survey, suggesting that 1.78 million American youth had tried e-cigarettes by 2012.⁴⁹ In a statewide survey of 50 000 students in grades 8–12 in Utah, more students (6%) reported past 30 day use of e-cigarettes than any other nicotine-containing product, including regular cigarettes (4%) and waterpipes (5%).⁵⁰ As with other flavored tobacco products,^{51,52} youth might be attracted to the wide variety of fruit and candy flavors.

■ WHAT ARE THE CHEMICAL CONTENTS AND HEALTH EFFECTS OF WATERPIPE SMOKE AND E-CIGARETTE AEROSOL?

The effects of any tobacco product can be described in terms of the toxicants found in product emissions (toxicant yield), the toxicants with which the users come into contact (exposure), and the health-related outcomes experienced by users. Here, the waterpipe literature is rich, whereas the e-cigarette literature is only now emerging. A brief summary is provided below, and more detailed reviews are available elsewhere.^{4,8,11,53–56}

Waterpipes. Waterpipe smoke contains many of the same toxicants as cigarette smoke, including polycyclic aromatic hydrocarbons (PAHs),^{57,58} volatile aldehydes,⁵⁹ carbon monoxide (CO),⁹ nicotine,⁵⁸ and heavy metals.⁶⁰ Each waterpipe use episode exposes users to greater amounts of toxicants than a single cigarette.⁶¹ During a 45 min waterpipe use episode, users can inhale 40–80 L of smoke,^{62–64} compared to 1 L or less for a single 5 min cigarette.^{63,65} Relative to the smoke from a single cigarette, the toxicant content of the smoke from a waterpipe use episode may contain up to 1.2 times the amount of nicotine, 8 times the CO, 3 times the nitric oxides, 4–15 times the acrolein, 6–31 times the formaldehyde, and 3–245 times the various PAHs.^{58,59} Users are demonstrably exposed to nicotine and CO^{63,66–68} in doses that are physiologically active and can lead to CO intoxication.^{62,69–72} In addition, there is growing evidence that nonusers can also be exposed to waterpipe smoke toxicants, as particulate matter and CO can be found in the air where waterpipes are smoked,^{73,74} and CO, nicotine, and other toxicants can be detected in nonusers who are present during waterpipe tobacco smoking.^{75,76} Although the nontobacco products available for use in waterpipes do not deliver nicotine,⁶² studies suggest that the smoke that they produce contains other toxicants associated with waterpipe tobacco smoking and can be damaging to human lung cells.^{77,78}

The toxicants found in waterpipe smoke have known links to health problems. Carbon monoxide contributes to heart disease.⁹ PAHs can cause cancer, and volatile aldehydes can lead to lung disease.^{57,59} Not surprisingly given its makeup, waterpipe tobacco smoke has been shown to have negative effects in animal models⁷⁹ and *in vitro* preparations.⁷⁷ In humans, long-term waterpipe tobacco smoking has been linked to cardiovascular disease, cancer, lung disease, and other health problems,^{53,80} although the strength of the evidence for these linkages varies by health problem and individual study quality. In sum, waterpipe tobacco smoking, like cigarette smoking, can lead to dependence, disability, and potentially fatal illnesses.

E-Cigarettes. Most chemical analyses and toxicology studies have examined the liquid found in e-cigarette cartridges or refill solutions rather than the aerosol emitted by the product.⁸¹ In the handful of studies focused on e-cigarette aerosol, results indicate that it contains nicotine⁸² and that it may also include some of the same toxicants as cigarette smoke, such as tobacco-specific nitrosamines and metals.^{83,84} However, the types and amounts of these substances vary considerably by

brand, product, flavor, and battery output voltage.^{55,85,86} One study characterized the amounts of certain toxicants in e-cigarette aerosol as between 9 and 450 times less than the amounts in cigarette smoke,⁸³ although the levels of one particular carcinogen (formaldehyde) can match those found in tobacco smoke if the liquid in the e-cigarette is heated using higher voltage batteries.⁸⁶ The nicotine in e-cigarette aerosol effectively reaches the bloodstream of users,^{87,88} in some cases in concentrations that are similar to those seen in tobacco cigarette smokers.⁸⁹ The toxicant levels in the secondhand aerosol inhaled by nonusers are unclear: one study detected only nicotine,⁸² whereas another detected a range of harmful pollutants in indoor air after the use of e-cigarettes.⁹⁰

Most physical effects of e-cigarette use, including airway impedance, cough, dry mouth, and headache, appear to be of low severity,^{56,91,92} although there have been case reports of more serious illnesses like lipid pneumonia.⁹³ Propylene glycol and vegetable glycerin (the humectants found in e-cigarette liquid) can irritate airways when inhaled for short periods.⁹⁴ The flavored liquids inside e-cigarette cartridges and refill solutions raise additional health concerns. Exposure to high concentrations of nicotine, such as that found in a 30 mL bottle of 36 mg/mL “cotton candy” flavored nicotine liquid used to refill an e-cigarette, can be toxic. Calls received by U.S. Poison Control Centers about e-cigarette exposure are increasing.⁹⁵ The long-term health effects of users’ and nonusers’ exposure to e-cigarette aerosol are unknown.⁵⁶

■ WHAT ARE THE TRENDS IN PUBLICATIONS OF RESEARCH ON WATERPIPES AND E-CIGARETTES?

In order to characterize the growth in scientific interest and output regarding waterpipes and e-cigarettes, we searched PubMed for all literature regarding these products each year from January 2000 to March 2014. For waterpipes, we used the search string “waterpipe” or “narghile” or “arghile” or “shisha” or “goza” or “narkeela” or “hookah” or “hubble bubble”, and for e-cigarettes, we used “electronic cigarette” or “electronic cigarettes” or “e-cigarette” or “e-cigarettes” or “electronic nicotine delivery”. Figure 2 shows the results of these searches after deleting obviously unrelated results. The growth rates of the literature for these two products appear different, with a slow and steady linear increase for the waterpipe literature and exponential growth for the e-cigarette literature. To test for a

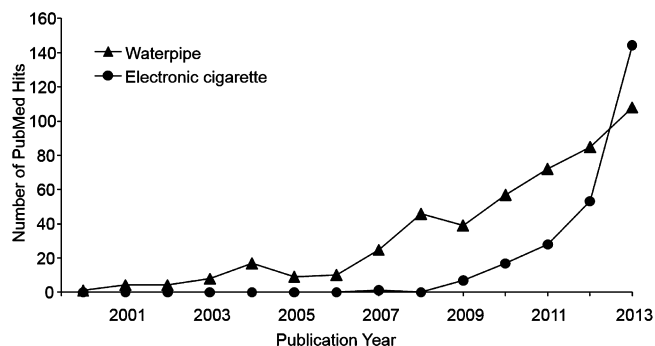


Figure 2. Number of PubMed hits by year (2000–2013) for published literature about waterpipes (used as early as the 1600s) and e-cigarettes (first patented in 2004). The cumulative data (not shown) were analyzed using a Poisson regression, revealing a significant difference in rate of publication of waterpipe versus e-cigarette literature ($p < 0.001$).

difference in growth rates, we analyzed the cumulative data using a Poisson regression. The results revealed a significant difference between the two types of publications ($p < 0.001$). Although the cumulative number of publications in 2013 was 485 for waterpipes and 250 for e-cigarettes, the model predicts that, between 2014 and 2015, the cumulative number of publications about e-cigarettes will surpass the number for waterpipes. Indeed, the absolute number of e-cigarette papers (144) in 2013 surpassed that of waterpipe (108) by over 30%. However, many of the articles about e-cigarettes published to date include commentary without original data. For example, in a systematic review that examined all of the e-cigarette literature published between January 1, 2006 and July 1, 2013, more than half of the English-language articles reviewed (96 of 182) were discarded due to a lack of new empirical data.⁴ As more researchers turn their attention to e-cigarettes, we anticipate that the proportion of publications on e-cigarettes that contain new empirical data will increase.

The current and predicted disparities in publications of empirical research on these two products are striking. The rapidly accelerating growth curve observed for published work about e-cigarettes reveals an enthusiasm for research on the topic that is not matched by that for waterpipes. There may be several reasons for this disparity, including the novelty of e-cigarettes and their controversial reception by the public health community.^{96,97} In addition, researchers in the U.S. may have devoted fewer resources to studying waterpipe tobacco smoking because, until recent evidence of its high prevalence in the U.S.,³⁷ it was most associated with countries in the Eastern Mediterranean region.

There are important reasons to study both products. Waterpipe tobacco smoking has been around for hundreds of years, and, relative to e-cigarettes, it is typically more prevalent among youth and adolescents, exposes users to more toxicants in higher concentrations, and has been associated with a greater burden of disease. At the same time, e-cigarettes may prove to be valuable tools for harm reduction or smoking cessation. The current evidence suggests that, although likely not harm-free, e-cigarette aerosol typically contains fewer toxicants and is less harmful to health than the smoke emitted by a tobacco cigarette. Because of this, e-cigarettes have the potential to serve as harm reduction tools should cigarette smokers successfully switch from regular to electronic cigarettes or quit using tobacco entirely after using e-cigarettes to step down their consumption.⁹⁶ Current evidence about e-cigarettes’ success as a cessation tool is mixed. One randomized controlled trial found that individuals using e-cigarettes were equally likely to quit smoking as individuals using the nicotine patch.⁴⁷ However, some observational studies have found that use of e-cigarettes does not lead to smoking cessation.⁴³ Thus, it is important not that there be less research on e-cigarettes but that there be equal energy and resources devoted to the study of waterpipes.

■ WHAT ARE THE SPECIFIC RESEARCH NEEDS CONCERNING WATERPIPES AND E-CIGARETTES?

While the literature on waterpipe tobacco smoking and e-cigarette use is growing, more research is needed on both products in order to inform appropriate science-based public health interventions and regulatory action. We must examine the toxicological effects of both products relative to the effects of cigarette smoking and nonsmoking control conditions. Such studies might include *in vitro* and *in vivo* laboratory research

examining the effects of smoke/aerosol exposure, as well as prospective and epidemiological research in humans examining short- and long-term health effects of product use.⁹⁸ Toxicology studies should investigate the effects of waterpipes and e-cigarettes on both users and nonusers (i.e., second-hand smoke/aerosol).

In addition to toxicology studies, there are a variety of other research needs that are relevant to both waterpipes and e-cigarettes. Future studies might focus on the following: the extent to which flavors and nicotine content contribute to initiation and regular use; the role, if any, that these products play in subsequent tobacco cigarette use among youth and adult nonsmokers; how to label these products in a manner consistent with their individual and public health risk; the effects of advertising on initiation and use; and the environmental impact of product manufacturing and disposal. There are also product-specific research needs, such as studying the possible role of e-cigarettes as a harm reduction or cessation tool among adult smokers. Research about the effects of waterpipes and e-cigarettes is particularly timely because it could guide regulatory efforts by the U.S. Food and Drug Administration, which has recently proposed to include these products under the authority provided by the Family Smoking Prevention and Tobacco Control Act.⁹⁹ These regulations would subject waterpipes and e-cigarettes to some of the same restrictions as regular tobacco cigarettes, including banning sales to minors and prohibiting sampling.

Research on waterpipes and e-cigarettes could also contribute to possible intervention efforts. The types of appropriate interventions for these two products are likely to be quite different. Given the toxic chemicals present in waterpipe smoke and its link to some health conditions, interventions should prevent uptake by nonusers and encourage users to quit. The social context of waterpipe smoking presents a challenge for prevention and control efforts, perhaps especially among youth. For example, college students who are too young to gain entry into bars where alcohol is served may gather at hookah lounges instead. Because alcohol is often not available at these venues, the age of legal entry is lower. If these students no longer smoke waterpipes, they would need to find alternative venues for gathering. The social nature of waterpipe smoking might also result in peer pressure among nonusers to try this tobacco product.

Because e-cigarettes have the potential to serve as harm reduction or smoking cessation tools and their long-term health effects are unknown, the intervention needs for e-cigarettes are less clear and consistent than those for waterpipes. Although research on cessation and health effects is ongoing, interventions targeted at specific groups are warranted. Specifically, public health proponents might design interventions that discourage e-cigarette use among youth and nonusers of tobacco (who could use the product as a gateway to tobacco use) or among smokers who use e-cigarettes as a bridge between cigarettes without quitting or reducing smoking.

This Perspective on Statistical Trends sheds light on the changing patterns in research on waterpipes and e-cigarettes but is limited because we assessed only the number of publications on waterpipes and e-cigarettes, not the quality of those publications. For example, many of the studies described in our review of these products' chemical contents and health effects were cross-sectional or included biased samples (e.g., the study sampled only dedicated users with positive attitudes about the products). Additionally, we searched only one

database, PubMed. However, in a previously conducted systematic review, we found that most citations from other databases were also included in PubMed.⁴

CONCLUSIONS

Waterpipe tobacco smoking and e-cigarette use are becoming more prevalent in the U.S. and worldwide. The exponential increase in publications about e-cigarettes compared to the slower, linear increase in publications about waterpipes suggests greater interest on the part of the scientific community for studying a novel nicotine product of unknown harm than for a traditional tobacco product with a larger body of evidence suggesting associated health harms. We believe that public health may be served best by a balanced research approach that focuses on understanding the possible long-term effects of e-cigarette use and e-cigarettes' potential to serve as harm reduction or smoking cessation tools while simultaneously designing and evaluating interventions to combat waterpipe smoking and its associated health problems.

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Notes

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ABBREVIATIONS

PAH, polycyclic aromatic hydrocarbon; CO, carbon monoxide

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