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A pilot study on nicotine residues in houses of electronic cigarette (e-cigarette) users, tobacco smokers, and non-users of nicotine-containing products

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Abstract

Background—Nicotine deposited on the surfaces has been shown to react with airborne chemicals leading to formation of carcinogens and contributing to thirdhand exposure. While prior studies revealed nicotine residues in tobacco smokers' homes, none have examined the nicotine residue in electronic cigarette (e-cigarette) users' homes.

Methods—We measured nicotine on the surfaces in households of 8 e-cigarette users, 6 cigarette smokers, and 8 non-users of nicotine-containing products in Western New York, USA. Three surface wipe samples were taken from the floor, wall and window. Nicotine was extracted from the wipes and analyzed using gas chromatography.

Results—Half of the e-cigarette users' homes had detectable levels of nicotine on surfaces whereas nicotine was found in all of the tobacco cigarette smokers' homes. Trace amounts of nicotine were also detected in half of the homes of non-users of nicotine-containing products. Nicotine levels in e-cigarette users homes was significantly lower than that found in cigarette smokers homes (average concentration 7.7±17.2 vs. 1,303±2,676 μg/m^2; $p<0.05$). There was no significant difference in the amount of nicotine in homes of e-cigarette users and non-users ($p>0.05$).

Conclusions—Nicotine is a common contaminant found on indoor surfaces. Using e-cigarettes indoors leads to significantly less thirdhand exposure to nicotine compared to smoking tobacco cigarettes.

Keywords

e-cigarettes; electronic cigarettes; nicotine; thirdhand exposure

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Introduction

Tobacco cigarettes and electronic cigarettes (e-cigarettes) vary in many ways. Tobacco cigarettes emit smoke which is created by the combustion of tobacco whereas electronic cigarettes emit a vapour that is produced when an atomizer heats up e-liquid which is a nicotine solution in propylene glycol and/or vegetable glycerin. Tobacco smoke contains numerous toxicants that are formed by combustion such as carbon monoxide and polyaromatic hydrocarbons (PAHs). Although some toxicants have been found in e-cigarette vapours, the levels are significantly lower than in tobacco smoke (Goniewicz et al. 2014). Studies have shown that e-cigarette users exhale some vapour which contain nicotine, but at the significantly lower levels than the amount of nicotine released from tobacco cigarette secondhand smoke (Czogala et al.,2014). Therefore the bystander would be exposed to low nicotine in the air, while exposure to many toxicants would be significantly reduced or eliminated when compared to tobacco smoke.

Thirdhand cigarette smoke (THS) is the residue of secondhand smoke that can persist in air, dust and on surfaces (Bahl, Jacob, Schick, & Talbot, 2014; Bell, 2014). This phenomenon has been documented for years in regards to tobacco cigarettes and recently has been gaining attention (Barnoya & Navas-Acien, 2013; Matt, Quintana, Destaillats, Gundel, & Sleiman, 2011). This is not because it is a new concept, but it is due to that fact that it was only recently named and depicted as an expected extension of secondhand smoke (Bell, 2014). It has been shown that THS is a result of burning tobacco cigarettes; however there is currently no data on whether using e-cigarettes in indoor spaces (so called ‘vaping’) can cause significant thirdhand exposure to nicotine.

Studies have shown that nicotine emitted with secondhand tobacco smoke can stick to various surfaces (Bahl et al., 2014; Matt et al., 2004; Sleiman et al. 2010). This residual nicotine can then react with other airborne oxidizing chemicals to create carcinogens and mutagens. These are usually in the form of tobacco-specific nitrosamines (TSNAs) (Sleiman et al. 2010). Non-smoking residents and smokers are exposed to these chemicals in amounts 3-8 times higher when tobacco cigarette smoking occurs indoors compared to outdoors (Matt et al., 2004). One study found that cumulative TSNA exposure from THS is 16 times higher in toddlers and 56 times higher in adults than what would be inhaled by a non-smoker (Bahl et al., 2014). It was also reported that cumulative nicotine exposure from THS residue can be 6.8 times higher in toddlers and 24 times higher in adults (Matt et al., 2004).

We have previously shown that in controlled laboratory conditions vapours released directly from e-cigarette can be deposited on various surfaces and contribute to thirdhand exposure (Goniewicz & Lee, 2014). However, the exposure patterns and nicotine deposition in real-life situations (outside laboratory) may be affected by various environmental factors. For example, if inhaled nicotine is effectively absorbed from vapours in e-cigarette users' lungs, the amount exhaled by users would be very low. The aim of this study was to verify whether nicotine from e-cigarettes can be deposited on surfaces in houses of e-cigarette users.

Methods

Settings

Subjects were recruited from a group of participants in a larger cross-sectional study aimed to measure biomarkers of exposure. Eligible participants had to live in the Buffalo city area and smoke or vape in their home regularly on a daily basis. It was also required that tobacco cigarettes had not been smoked in the homes of e-cigarette users for at least a year. Selected participants were asked for permission to collect wipe samples in their households. Total of 22 subjects agreed to provide access to their houses for samples collection. Samples were taken from three groups: 8 non-smoking households, 6 cigarette smoking households, and 8 electronic cigarette vaping households.

The people living in the homes that samples were taken were of a diverse population. Volunteers included Caucasian (N=19) and African Americans (N=3), men (N=5), women (N=9), in an age range of 30-70 years, living in low (N=6) and middleclass/higher (N=16) income households. Out of the 6 cigarette smoking households, 5 were low income and 1 was a higher income household, whereas out of the 8 electronic cigarette smoking households, 1 was a low income household and 7 were higher income households. Seven participants lived alone while others (N=15) lived with family members. E-cigarette users estimated that they puffed indoor on their own devices from 50 to 500 times a day. The nicotine concentration in their e-liquids ranged from 10 to 15 mg/mL. The size of the room in e-cigarette homes where the samples were taken varied from 24 to 70 m^2. Tobacco smokers smoked indoor from 5 to 40 cigarettes per day. The majority of households (N=4) had full flavour cigarettes smoked in them. The size of the room where the samples were taken in homes varied from 16 to 70 m^2. Control samples were also collected from 8 houses with no smoking or vaping inside (average room volume from 288 to 488 m^3)

Sampling Protocol

Surface wipe samples were collected as described previously by Quintana et al. (2013) from three different surfaces in each home: the window, wall and floor. All surfaces were located in the room that the smoker/user spent the most time smoking/vaping in. Samples were taken using half of a KimWipe wet with .1% ascorbic acid. The area of a 10 cm × 10cm template was wiped and then the wipe was inserted into an amber vial with a Teflon lined cap. Surface wipe sampling was conducted exactly the same for every wipe. The first pass was made top to bottom across the entire template, the second pass was made right to left and then this process was repeated. Samples were placed in a refrigerator within 2 hours of sampling until it was time for analysis (see below).

Sample Analysis

Each wipe was prepared by being spiked with 1µg of the quinoline (internal standard). Nicotine was then extracted from the wipe using 5 mL of KOH in methanol by vortexing the tubes for 15 minutes. The samples were then analysed using gas chromatography (GC-NPD). The chromatograph conditions were the same as specified in NIOSH standard method for nicotine determination in air (National Institute of Occupational Safety and Health, 2003). The calibration and controls were created by spiking KimWipes with known amounts of nicotine. The amount of nicotine ranged from .05 µg to 100 µg. The calibration curve was linear in the range of nicotine (r^2 = .9981). The lowest limit of quantitation was 5 µg/m^2.

Statistical Analysis

Based on the determined amount of nicotine in a wipe sample, we calculated the amount of nicotine per one sq. meter for each sample. A Kruskal-Wallis test was performed to determine if there was a significant difference in nicotine levels between the groups of homes. This non-parametric test was performed because the sample size of this study is not large enough to assume that the data is normally distributed. For all tests Statistica version 10.0 software was used.

Results

We found that half of the e-cigarette users' homes had measureable levels of nicotine on surfaces. Nicotine was found in all of the tobacco cigarette smokers' homes. We also found that nicotine levels in e-cigarette users homes was significantly lower than that found in cigarette smokers homes (average concentration 7.7±17.2 vs. 1,303±2,676 µg/m^2; $p<0.05$).

Traces of nicotine were also detected in half of the homes of non-users of nicotine-containing products. There was no significant difference in the amount of nicotine in e-cigarette users' and non-users' homes (7.7±17.2 vs. 7.2±13.8; $p>0.05$). Nicotine levels in non-smokers homes was significantly lower than that found in cigarette smokers homes (7.2±13.8 vs. 1,303±2,676 µg/m^2; $p<0.05$). There was no significant difference in the levels of nicotine found upon the different surfaces in the homes ($p>0.05$).

Discussion

We provided preliminary data on levels of nicotine deposited in houses of e-cigarette users. Nicotine was found in only half of the e-cigarette smoking homes. The levels of nicotine in e-cigarettes users' homes were almost 200 times lower than the levels detected in tobacco smokers homes. These results indicate that using e-cigarettes indoors results in much lower exposure to nicotine residues on surfaces compared to smoking tobacco cigarettes.

Interestingly, nicotine was also found in half of the non-users homes at a detectable amount. Although the traces of nicotine need to be confirmed with mass spectrometry analysis, this result suggests that thirdhand exposure to nicotine may affect also those subjects who are living in a currently smoke-free of vapour-free houses. It is not clear how nicotine found its way into the homes of non-users of nicotine-containing products. These trace amounts of nicotine may have been settled on the surfaces of non-users' home from previous occupants who had smoked some time ago. Nicotine may also have been introduced into their homes through open windows or ventilation tracts. Low levels of nicotine (average 1.6 µg/m^2) deposited on surfaces in houses of non-smokers have been previously reported by Matt et al. (2011). Our data suggest that nicotine is a common environmental contaminant found on indoor surfaces even in non-smokers homes.

Nicotine is a primary marker of tobacco residue. It also can be used as a primary marker of electronic cigarette vapour residue. However nicotine cannot be used to distinguish between exposure to tobacco smoke and e-cigarette vapours. Future studies should address this limitation. There is a need for developing specific markers which can differentiate the source of exposure. These markers may include minor tobacco alkaloids or nicotelline (Jacob, Goniewicz, Havel, Schick & Benowitz, 2013; Jacob, Yu, Shulgin, 1999).

Although the data on secondhand and thirdhand exposure to e-cigarette vapours are sparse, there have been regulations put in place to protect nonusers from potential exposure. There are controversies whether e-cigarettes should be allowed indoors or not. National and local authorities across the world, as well as managers and owners of premises, have been implementing new regulations or updating existing smoke-free laws so e-cigarettes are not allowed in public. In the United States, some cities have introduced restrictions on electronic cigarettes, so they can only be used in vape stores or lounges. Many public health advocates raised concerns on e-cigarette safety and effects on users and bystanders. Although there is consensus that electronic cigarettes are much safer than tobacco cigarettes, there is lack of data on their long-term effects on bystanders and on the health of the public.

Our data suggest that thirdhand exposure to nicotine from e-cigarette is low, however future risk estimation must take into account not only risk for healthy adult bystanders, but also vulnerable populations. Since infants, pregnant women, and people with cardiovascular diseases are more susceptible to harmful substances, further research should be done to see if the small amounts of nicotine released from e-cigarettes and deposited on surfaces are actually harmful to these populations.

Acknowledgments

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Highlights

- There are controversies whether e-cigarettes should be allowed in public spaces.
- This study showed that thirdhand exposure to nicotine from e-cigarette is low.
- Using e-cigarettes reduces thirdhand exposure to nicotine compared to smoking.
- Nicotine is a common environmental contaminant found on indoor surfaces

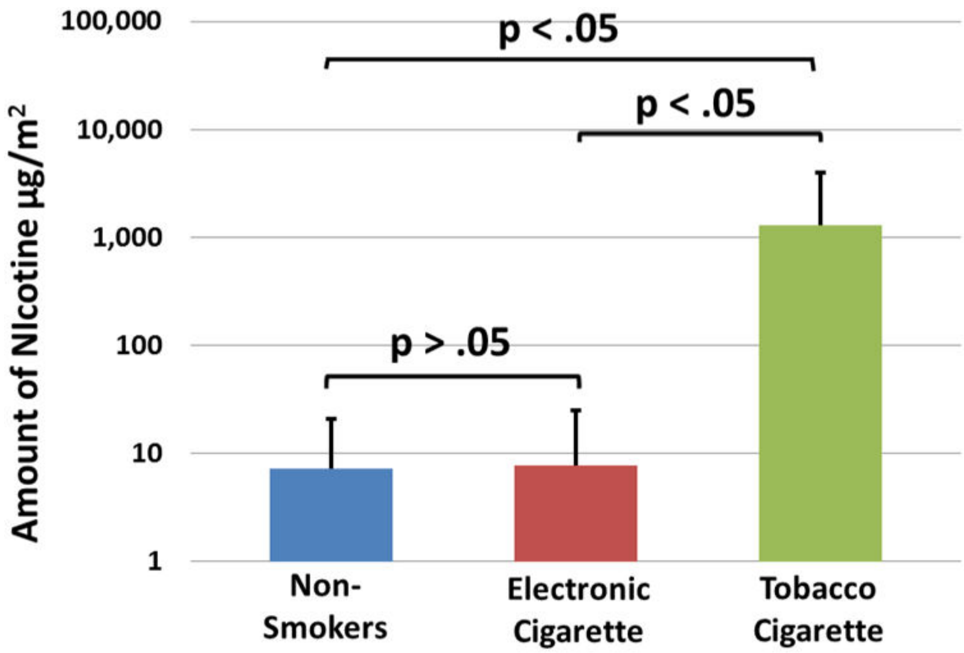

Figure 1.

Average amounts of nicotine deposited on indoor surfaces in houses non-users of nicotine-containing products (N=8), e-cigarette users (N=8), and tobacco cigarette smokers (N=6). Bars are standard deviations.