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Research paper

Factors associated with dual use of tobacco and electronic cigarettes: A case control study

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ABSTRACT

Background: Many electronic cigarette (EC) users reduce cigarette consumption without completely quitting. It is important to assess the characteristics and experiences of these users, commonly called "dual users", in comparison with EC users who have completely substituted smoking (non-smoking vapers).
Methods: A questionnaire was uploaded in an online survey tool. EC users were invited to participate irrespective of their current smoking status. Dual users were matched for age and gender with non-smoking vapers.
Results: From 19,441 participants, 3682 were dual users. After random 1:1 matching with non-smoking vapers (all of whom were former smokers), 3530 participants in each group were compared. Dual users had longer smoking history, lower daily cigarette consumption and similar cigarette dependence compared to non-smoking vapers. Their daily consumption was reduced after initiation of EC use from 20 to 4 cigarettes per day. Most of them were using ECs daily, however, more were occasional EC users compared to non-smoking vapers. Use of advanced (third generation) devices and daily liquid consumption was lower in dual users compared to non-smoking vapers. The most important reason for initiating EC use was to reduce smoking and exposure of family members to smoke for both groups, but higher scores were given to "avoid smoking ban in public places" by dual users compared to non-smoking vapers. The strongest predictors of being dual user from multivariate analysis were: higher risk perception for ECs (OR = 2.27, 95% CI = 1.40–3.68), use of first-generation EC devices (OR = 1.98, 95% CI = 1.47–2.66), use of prefilled cartomizers (OR = 1.94, 95% CI = 1.23–3.06) and occasional use of ECs (OR = 1.62, 95% CI = 1.21–2.17).
Conclusions: The results of this case-control study indicate that higher risk perceptions about, and less frequent use of, ECs was associated with dual use of ECs and tobacco cigarettes. Since this is a cross-sectional survey, which explores association but not causation, longitudinal studies are warranted to further explore the reasons for dual use.

Introduction

Electronic cigarettes (ECs) have been marketed in recent years as alternatives to smoking. They are electrically-driven devices, used to vaporise a liquid that may or may not contain nicotine. They consist of a battery part (usually lithium battery), and an atomizer where liquid is stored and is aerosolized by heating a resistance encircling a wick. The main ingredients of liquids are propylene glycol, glycerol and a variety of flavourings. A huge variety of devices and different liquids are available, with the main purpose to satisfy users' need and preference.

The powerful addictive properties of nicotine and of the ritualistic behaviour of smoking make smoking cessation a difficult task. Currently-approved products for smoking cessation have low long-term quit rates, with nicotine replacement therapy having less than 7% sustained abstinence rate (Moore et al., 2009), while oral medications have less than 20% quit rate at one year (Rigotti et al., 2010). Therefore, tobacco harm reduction strategies and products have been developed, with the goal to reduce smoking-related morbidity and mortality burden by providing nicotine in a less harmful form (Rodu & Godshall, 2006). ECs are tobacco harm reduction products that may deal with both chemical (through

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nicotine delivery) and behavioural (through motor simulation and sensory stimulation) addiction to smoking (Farsalinos, Romagna, Tsiapras, Kyrzopoulos, & Voudris, 2013). Awareness and use of ECs are growing exponentially, but there is controversy over their potential as smoking substitutes. Surveys have shown that they may be effective in promoting reduction of cigarette consumption or even complete abstinence (Dawkins, Turner, Roberts, & Soar, 2013; Etter & Bullen, 2011). Cross-sectional studies have raised doubts whether ECs promote smoking cessation (Popova & Ling, 2013; Vickerman, Carpenter, Altman, Nash, & Zbikowski, 2013) but recently-published randomized studies showed a significant potential of ECs to promote smoking reduction and cessation, even in smokers with no intention to quit (Adriaens, Van Gucht, Declerk, & Baeyens, 2014; Bullen et al., 2013; Caponnetto et al., 2013). Still, many EC users fail to completely substitute smoking, and thus become "dual users". It is important to understand the characteristics, patterns of use and perceived experience of dual users compared to EC users who have completely substituted smoking with EC use (non-smoking vapers). The purpose of this case-control study was to identify the different characteristics of these two groups in a worldwide sample of EC users, by providing a questionnaire in several languages and by promoting the study through the Internet.

Methods

The study methodology has been described in detail previously (Farsalinos, Romagna, et al., 2014). In brief, a questionnaire was developed and uploaded in an online survey tool (www.surveymonkey.com). The questionnaire was available in several languages, with at least two native speakers (one of whom was a qualified translator) checking the validity of each translation based on the original English questionnaire. The survey was approved by the ethics committee of our institution and online informed consent was provided by all participants.

Participants were aged >18 years, with current, former or never smokers eligible to participate. Duplicate records were deleted based on the IP address. The questionnaire evaluated the baseline characteristics of the participants, including age, gender and education, past and current smoking status and EC patterns of use and smoking dependence (before EC use initiation) by using the Fagerström Test for Cigarette Dependence (FTCD) (Fagerström, 2012). Participants' opinion about the risk profile of ECs was assessed by asking them to provide a score of: (1) absolutely harmless; (2) less harmful than tobacco cigarettes; (3) equally harmful to tobacco cigarettes, and; (4) more harmful than tobacco cigarettes. Finally, the reasons for initiating EC use were assessed by asking participants to provide a score from 1 (not important) to 5 (most important) for each of the answer options.

Statistical analysis

The sample size varied by variable because of missing data; therefore, for some questions, the sum of responses may be less than 100%. In some questions, responders were allowed to choose more than one option; in these cases, each answer is presented separately and the sum of responses may exceed 100%. Continuous variables are reported as median (interquartile range [IQR]), because medians are less sensitive to extreme values. Categorical variables are reported as number (percentage). Since this is a case-control study, pairwise analysis was performed, using non-parametric tests. Wilcoxon signed ranks test was used to compare continuous variables between dual users and non-smoking vapers, while McNemar test was used for categorical variables with 2 categories. For variables with more than 2 categories, marginal homogeneity test was used. Wilcoxon signed ranks test was used to compare cigarette consumption before and after initiation of EC use in dual users. Finally, a logistic regression analysis was performed to determine odds ratios (OR) of variables which would determine dual use. Initially, a univariate analysis was performed. Subsequently, a stepwise backward logistic regression model was applied, with dual use being the dependent variable and all variables with a P value of <0.1 on univariate analysis entered as covariates. A P value of <0.05 was considered statistically significant and all analyses were performed with commercially available software (SPSS v. 18, Chicago, IL, USA).

Table 1
Baseline characteristics of participants.

	Total	Non-smoking vapers	Dual users	Statistic	*P* value
Participants	7060	3530	3530		
Age (years)	38 (30–46)				
Gender (male)	2605 (73.8)				
Translation					
English	1291 (18.3)	490 (13.9)	801 (22.7)	MH = 15.6	<0.001
French	1117 (15.8)	516 (14.6)	601 (17.0)		
German	1707 (24.2)	932 (26.4)	775 (22.0)		
Greek	444 (6.3)	240 (6.8)	204 (5.8)		
Hungarian	306 (4.3)	229 (6.5)	75 (2.1)		
Italian	1278 (18.1)	665 (18.8)	613 (17.4)		
Polish	376 (5.3)	119 (3.4)	257 (7.3)		
Russian	455 (6.4)	334 (9.5)	121 (3.4)		
Spanish	88 (1.2)	5 (0.1)	83 (2.4)		
Where did you hear about this survey?					
EC users' forums	4795 (67.9)	2482 (70.3)	2313 (65.5)	MH = −4.0	<0.001
Internet search engines	718 (10.2)	335 (9.5)	383 (10.8)		
Family/friends	476 (6.7)	221 (6.3)	255 (7.2)		
Physical/internet EC shops	1019 (14.4)	466 (13.2)	553 (15.7)		
TV/radio/newspapers	36 (0.5)	19 (0.5)	17 (0.5)		
Education					
Less than high school	868 (12.3)	472 (13.4)	396 (11.2)	MH = −4.3	<0.001
High school	3039 (43.0)	1567 (44.4)	1472 (41.7)		
Higher education	3122 (44.2)	1479 (41.9)	1643 (46.5)		

Values are presented as number (percent) or median (interquartile range).
Abbreviations: EC, electronic cigarettes; MH, marginal homogeneity statistic.

Results

Participant characteristics

A total number of 19,441 participants filled the questionnaires. Of those, 3682 were dual users. A randomized 1:1 matching for age and gender with non-smoking vapers was performed, with the final sample consisting of 3530 participants in each group. The baseline characteristics of participants are displayed in Table 1. Most participants used the English, French and Italian translation of the questionnaire. Distribution of responders by region of residence was: 85.1% from Europe, 9.6% from America, 2.0% from Asia, 0.6% from Australia, and 0.1% from Africa. The median age of the participants was 38 years, with significantly higher proportion being males. Almost half of them received higher education, which was more common in dual users. Most participants were informed about this survey from EC users' Internet forums. Of note, all non-smoking vapers were former smokers.

Past and current smoking status-EC use patterns and beliefs

Past and current smoking status and EC use patterns are displayed in Table 2. Dual users were smoking for longer duration but had slightly lower daily cigarette consumption compared to non-smoking vapers. Almost one-third of dual users were smoking occasionally (less than daily) while the rest mentioned that their daily consumption was reduced from 20 to 4 cigarettes per day. The FTCD was similar in both groups, as was the number of past attempts to quit smoking. The duration of EC use was similar in both groups, but more dual users were using ECs occasionally instead of daily compared to non-smoking vapers. More non-smoking vapers were using newer-generation devices (also called "Mods") compared to dual users. In terms of liquid use, consumption was higher and "do-it-yourself" preparation (buying base ingredients and concentrated flavours which they subsequently mix) was more prevalent in non-smoking vapers relative to dual users. A reduction in nicotine levels used in EC liquid was observed as time of use progressed in both groups, from a median level of 17 and 18 mg/mL at initiation of use to 12 and 10 mg/mL at the time of participation to the survey for dual users and non-smoking vapers, respectively. Nicotine concentration of 18 mg/mL or more was the initial choice for 52% of the population, with non-smoking vapers being more likely to use such nicotine levels (54% vs. 49% for dual users, McNemar $\chi^2 = 15.4$, $P < 0.001$). Examining the reasons for initiating EC use (Table 3), reducing or quitting smoking because it is not a healthy habit had the highest score for both groups (median = 5, IQR: 4–5); however, more non-smoking vapers gave a higher score in this response compared to their matched dual users (Table 3). Reducing secondary smoking exposure to family members was scored as a very important reason (score = 4), with non-smoking vapers again giving higher score compared to dual users. Lower scores were given to economic reasons and avoiding smoking ban in public places, but dual users gave higher score in these responses compared to non-smoking vapers.

The majority of participants gave a low score in perceived risk of EC use, reporting that they considered ECs less harmful than tobacco. A very small proportion considered ECs equally or more harmful than tobacco, while 14.1% of non-smoking vapers and 8.5% of dual users considered them completely harmless.

Logistic regression analysis

The results of logistic regression analyses are displayed in Table 4 (univariate analysis) and Table 5 (multivariate analysis).

Table 2
Past and current smoking status and electronic cigarette use patterns.

	Non-smoking vapers	Dual users	Statistic	*P* value
Smoking history				
Years smoking	20 (12–28)	20 (12–30)	$Z = -4.2$	<0.001
Cigarettes per day	20 (18–30)	20 (16–30)	$Z = -2.1$	<0.039
FTCD	6 (4–8)	6 (5–8)	$Z = -0.7$	0.48
Total past quit attempts	2 (0–5)	2 (0–5)	$Z = -1.0$	0.322
Current smoking status				
Daily smokers		2411 (68.3)		
Occasional smokers		1090 (30.9)		
Cigarettes per day now		4 (2–7)	$Z = -41.1$[a]	<0.001
First hear about EC in users' forums	671 (19.0)	623 (17.6)	$\chi^2 = 2.1$	0.147
EC duration of use	9 (4–17)	8 (4–17)	$Z = -0.4$	0.671
EC use pattern				
Daily	3411 (96.6)	3323 (94.1)	MH = −4.6	<0.001
Occasionally	97 (2.7)	176 (5.0)		
Not anymore	19 (0.5)	28 (0.8)		
EC device most often used				
First generation (cigarette-like)	102 (2.9)	207 (5.9)	MH = 10.1	<0.001
Second generation (eGo-style)	1569 (44.4)	1837 (52.0)		
Third generation ("Mods")	1816 (51.4)	1477 (41.0)		
EC liquid use				
Prefilled cartomizers	45 (1.3)	97 (2.7)	MH = 6.9	<0.001
Ready-to-use liquids	2065 (58.5)	2260 (64.0)		
Do-it-yourself liquids	1399 (39.6)	1160 (32.9)		
EC daily consumption				
mL liquid per day	3 (2–5)	3 (2–4)	$Z = -4.8$	<0.001
nr of cartridges per day	1 (1–2)	1 (1–2)	$Z = -0.4$	0.655
Current nicotine levels in EC	10 (6–14)	12 (8–16)	$Z = -8.6$	<0.001
Nicotine levels at initiation of EC use	18 (12–18)	17 (11–18)	$Z = -3.4$	0.001

Values are presented as number (percent) or median (interquartile range).
Abbreviations: FTCD, Fagerström Test for Cigarette Dependence; EC, electronic cigarette; MH, marginal homogeneity statistic.
[a] Comparison with cigarette consumption before initiation of EC use (Wilcoxon signed rank test).

Table 3
Reasons for electronic cigarette use initiation and concepts about their risk profile.

	Non-smoking vapers	Dual users	Statistic	*P* value
Reasons for initiating EC use[a,b]				
Reduce/quit smoking because it is not a healthy habit	1157 (32.8)	991 (28.1)	$Z = -3.6$	<0.001
Reduce smoking exposure to family members	1505 (42.6)	1014 (28.7)	$Z = -9.8$	<0.001
Avoid smoking ban in public places	952 (27.0)	1334 (37.8)	$Z = -8.0$	<0.001
Economic reasons (ECs cheaper)	1251 (35.4)	1388 (39.3)	$Z = -2.6$	0.008
Enjoy the variability of flavours in ECs	1363 (38.6)	1262 (35.8)	$Z = -2.0$	0.051
Perceived risk of EC use (compared to smoking)				
Absolutely harmless (score = 1)	497 (14.1)	300 (8.5)	MH = −8.7	<0.001
Less harmful than smoking (score = 2)	3011 (85.3)	3162 (89.6)		
Equally harmful to smoking (score = 3)	11 (0.3)	46 (1.3)		
More harmful than smoking (score = 4)	2 (0.1)	12 (0.3)		

Values are presented as number (percent) or median (interquartile range).
Abbreviations: EC, electronic cigarette; MH, marginal homogeneity statistic.
[a] Participants were asked to provide a score from 1 (not important) to 5 (most important) for each answer option.
[b] Number of subjects with higher score relative to the matched pair is displayed. *Z*-statistic represents the result of Sign test.

Table 4
Factors associated with being dual user from univariate regression analysis.

	OR (95% CI)	*P*
University/college education	1.32 (1.14–1.54)	<0.001
First heard about EC in users' forums	0.91 (0.81–1.03)	0.140
Years smoking	1.00 (1.00–1.01)	0.136
Cigarettes per day	1.00 (0.99–1.00)	0.024
FTCD	1.01 (0.99–1.03)	0.593
Duration of EC use (months)	1.00 (1.00–1.01)	0.837
Occasional EC use	1.86 (1.45–2.40)	<0.001
Types of EC liquids used[a]		
Using ready-to-use liquids	0.51 (0.36–0.73)	<0.001
Using DIY liquids	0.39 (0.27–0.55)	<0.001
Liquid consumption per day (mL)	0.97 (0.95–0.98)	<0.001
Nicotine levels at the time of the survey (mg/mL)	1.04 (1.03–1.04)	<0.001
Nicotine levels at EC initiation (mg/mL)	0.99 (0.98–0.99)	<0.001
Nicotine levels at EC initiation (<18 mg/mL)	1.21 (1.10–1.33)	<0.001
EC devices used[b]		
First generation (cigarette-like)	2.55 (1.99–3.26)	<0.001
Second generation (eGo-style)	1.47 (1.33–1.62)	<0.001
Reasons to initiate EC use (score)		
Reduce/quit smoking because it is not a healthy habit	0.94 (0.90–0.98)	0.003
Reduce smoking exposure to family members	0.84 (0.81–0.87)	<0.001
Avoid smoking ban in public places	1.17 (1.13–1.22)	<0.001
Spare money	1.06 (1.02–1.10)	0.003
Enjoy flavors variability	0.96 (0.93–0.99)	0.021
Perception about risk of EC use (score)[c]	1.86 (1.61–2.14)	<0.001

[a] Compared to using prefilled cartomizers.
[b] Compared to third generation devices (also called "Mods").
[c] Defined as: 1 = absolutely harmless; 2 = less harmful than smoking; 3 = equally harmful to smoking; 4 = more harmful than smoking.

Table 5
Factors associated with being dual user from multivariate regression analysis.

	OR (95% CI)	*P*
University/college education	1.27 (1.07–1.50)	0.006
Occasional EC use	1.62 (1.21–2.17)	0.001
Types of EC liquids used[a]		
Use of prefilled cartomisers	1.94 (1.23–3.06)	0.004
Nicotine levels at the time of the survey (mg/mL)	1.04 (1.03–1.05)	<0.001
Nicotine levels at EC initiation (<18 mg/mL)	1.31 (1.17–1.46)	<0.001
EC devices used[b]		
First generation (cigarette-like)	1.98 (1.47–2.66)	<0.001
Second generation (eGo-style)	1.29 (1.16–1.45)	<0.001
Reasons to initiate EC use (score)		
Reduce smoking exposure to family members	0.84 (0.81–0.87)	<0.001
Avoid smoking ban in public places	1.18 (1.13–1.23)	<0.001
Perception about risk of EC use (score)[c]	2.27 (1.40–3.68)	<0.001

[a] Compared to using "do-it-yourself" liquids.
[b] Compared to third generation devices ("Mods").
[c] Defined as: 1 = absolutely harmless; 2 = less harmful than smoking; 3 = equally harmful to smoking; 4 = more harmful than smoking.

Education, smoking consumption, EC products choice and consumption, reasons for using ECs and risk perception about ECs were significantly associated with dual use. From multivariate analysis, perception about risk of EC use, types of EC device and liquid used and frequency of EC use were the most important determinants of being a dual user.

Discussion

To the best of our knowledge, this is the first case-control cross sectional survey which analysed the factors associated with dual use of ECs and tobacco cigarettes compared to complete smoking cessation with EC use. The analysis of a large sample of participants, matched for age and gender with vapers, identified education, use of less advanced devices and atomizers, nicotine levels at initiation of EC use, reasons for initiating EC use, and perceptions about risk of EC use as determinants of dual use.

The most important determinant of dual use was perception about the level of risk associated with EC use. Although the majority of the study participants thought that ECs are less harmful than tobacco cigarettes, a larger proportion of dual users compared to non-smoking vapers reported that they considered ECs equally or more harmful than smoking. Although literature reviews have concluded that ECs expose users to much lower levels of toxic chemicals compared to tobacco cigarettes (Farsalinos & Polosa, 2014a; Hajek, Etter, Benowitz, Eissenberg, & McRobbie, 2014), a recent study found that only 65% of smokers considered ECs less harmful than smoking in 2013 compared to 84.7% in 2010 (Tan & Bigman, 2014). Information provided by regulators and scientists about the risk of alternative to smoking products such as ECs is directly influencing the perceptions of the population (Popova & Ling, 2014), thus it is important to provide proper, reliable and accurate information that will not result in over- or under-estimation of any potential risk. The current situation of contrasting interpretation of research (Dutra & Glantz, 2014; Farsalinos & Polosa, 2014b; Niaura, Glynn, & Abrams, 2014) is probably contributing to the creation of confusing views about ECs, and our study indicates that this might result in dual use instead of EC use as a complete substitute for smoking.

Dual use was associated with specific patterns of EC use. Occasional use of ECs is not expected to be effective in smoking cessation, similarly to any other therapeutic or substitute product. Studies have shown that daily use and higher frequency of use within the day are strongly associated with quitting smoking (Biener & Hargraves, 2014; Siegel, Tanwar, & Wood, 2011). Herein, daily consumption was also associated with dual use in univariate analysis, however, occasional (compared to daily) use was a stronger and independent predictor in multivariate analysis. The occasional use of ECs is likely to be associated with the reasons for initiating EC use; although dual users gave a high score to the intention to quit smoking, higher score was given to avoidance of public places smoking bans as a reason for initiating EC use compared to non-smoking vapers. This is a confirmation that intentions are important determinants of the success of ECs in complete smoking substitution, and this factor should be examined in all relevant studies. A recent study showed that, when used with the intention to quit smoking, ECs were more successful compared to NRTs and unaided efforts to quit smoking (Brown, Beard, Kotz, Michie, & West, 2014).

Lower nicotine levels at EC use initiation and use of first and second generation devices were independent predictors of dual use. Selection of nicotine levels is important in the attempt to quit smoking, with some vapers even reporting the need to elevate the nicotine concentration initially chosen on order to quit smoking (Farsalinos et al., 2013). This is probably associated with the observations from several studies that ECs deliver nicotine at a lower rate compared to tobacco cigarettes (Bullen et al., 2010; Farsalinos, Spyrou, et al., 2014; Vansickel, Cobb, Weaver, & Eissenberg, 2010). Therefore, it seems important to advice smokers to use high nicotine-containing liquids during EC use initiation. The use of new-generation devices delivers nicotine more effectively than first-generation devices (Farsalinos, Spyrou, et al., 2014), therefore, the finding that use of less advanced devices was associated with dual use is not surprising. However, more randomized controlled studies are needed to assess the effect of different nicotine concentrations and devices on the efficacy to quit smoking. Until now, randomized controlled studies have mostly assessed the efficacy of first-generation devices, showing moderate results in terms of smoking cessation rates (Bullen et al., 2013; Caponnetto et al., 2013). However, recent studies have shown that newer-generation devices are substantially more effective as smoking substitutes (Adriaens et al., 2014; Polosa, Caponnetto, Maglia, Morjaria, & Russo, 2014).

Some limitations are applicable to this study. It should be emphasized that participants in internet surveys are mostly dedicated users. Herein, this is verified by the fact that almost 70% of the subjects were informed about this survey through EC users' forums. Therefore the results should be interpreted with caution and the characteristics of dual users participating in this survey may be different from those of the general population. The significant reduction in the smoking consumption of dual users further supports the above. Therefore, it is possible that the predictive value of the factors associated with dual use may be stronger in the general population which consists of less dedicated dual users. Obviously, this cross-sectional survey cannot provide definite proof whether the different factors are the cause or the result of dual use. Therefore, longitudinal studies following-up smokers from the time of EC use initiation onwards are warranted. Moreover, dual users should be followed-up continuously, to assess if they subsequently quit smoking (Etter & Bullen, 2014) or abandon EC use and become exclusive tobacco cigarette users.

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Author contributions

KF was responsible for the study concept. KF and GR were responsible for preparing the questionnaire. KF, GR and VV were responsible for data analysis and interpretation. KF was responsible for preparing the manuscript. All authors reviewed and approved the manuscript before being submitted for publication.

Conflict of interest statement

Some of the studies performed by KF and VV used unrestricted funds provided to the institution (Onassis Cardiac Surgery Center) by electronic cigarette companies.

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