



Short Communication

A longitudinal study of electronic cigarette users

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HIGHLIGHTS

- Little is known about change in the behaviour of users of electronic cigarettes over time.
- We followed 477 users of electronic cigarettes during one month and 367 users over one year.
- We found that electronic cigarette use had no deleterious effects on smoking behaviour.

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ABSTRACT

Objective: To assess behavior change over 12 months in users of e-cigarettes (“vapers”).

Methods: Longitudinal Internet survey, 2011 to 2013. Participants were enrolled on websites dedicated to e-cigarettes and smoking cessation. We assessed use of e-cigarettes and tobacco among the same cohort at baseline, after one month ($n = 477$) and one year ($n = 367$).

Results: Most participants (72%) were former smokers, and 76% were using e-cigarettes daily. At baseline, current users had been using e-cigarettes for 3 months, took 150 puffs/day on their e-cigarette and used refill liquids containing 16 mg/ml of nicotine, on average. Almost all the daily vapers at baseline were still vaping daily after one month (98%) and one year (89%). Of those who had been vaping daily for less than one month at baseline, 93% were still vaping daily after one month, and 81% after one year. In daily vapers, the number of puffs/day on e-cigarettes remained unchanged between baseline and one year. Among former smokers who were vaping daily at baseline, 6% had relapsed to smoking after one month and also 6% after one year. Among dual users (smokers who were vaping daily at baseline), 22% had stopped smoking after one month and 46% after one year. In dual users who were still smoking at follow-up, cigarette consumption decreased by 5.3 cig/day after one month (from 11.3 to 6.0 cig./day, $p = 0.006$), but remained unchanged between baseline and 1-year follow-up.

Conclusions: E-cigarettes may contribute to relapse prevention in former smokers and smoking cessation in current smokers.

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1. Introduction

Electronic cigarettes (e-cigarettes) are increasingly popular and the prevalence of e-cigarette use increases sharply every year (ASH, 2013). Sales of e-cigarettes have tripled every year since 2007 in the U.S. (Koch, 2012) and part of the recent decrease in cigarette sales in the U.S. is attributable to smokers switching to e-cigarettes (Kell, 2013). Some analysts even predict that within a decade, sales of electronic cigarettes will surpass sales of tobacco cigarettes (Wells, 2013). The spectacular success of e-cigarettes is a game-changing event in

the field of tobacco control. Yet, relatively little research has been published on e-cigarettes and on “vapers” (e-cigarette users). Several observational studies (Caponnetto, Polosa, Russo, Leotta, & Campagna, 2011; Farsalinos & Romagna, 2013; Schneiderhan, 2012) and two randomized trials suggest that e-cigarettes help smokers quit or reduce smoking (Bullen et al., 2013; Caponnetto, Campagna, et al., 2013). Outside these clinical studies, only a few longitudinal studies of vapers have been published (Adkison et al., 2013; Vickerman, Carpenter, Altman, Nash, & Zbikowski, 2013), and it is still unclear how the behavior of vapers evolves over time. This is important information to obtain because the effects of e-cigarettes on health and on smoking behavior will be more evident if vaping is an ongoing, rather than temporary behavior. The safety and toxicity of e-cigarettes will also largely depend on how long vapers use these products. Vapers' behavior may also change over time, in particular because this technology evolves

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rapidly, and because with time, they acquire more experience or may otherwise modify their behavior. Thus, the objective of this study was to assess change over time in the behavior of e-cigarette users.

2. Material and methods

Because e-cigarettes are purchased largely on the Internet, online registration is an appropriate method to recruit vapers. We posted a questionnaire in English and French on the smoking cessation website Stop-Tabac.ch, and asked websites informing about e-cigarettes or selling them and specialized discussion forums to publish links to the questionnaire. Starting in 2010, the baseline questionnaire included a detailed assessment of vaping and smoking behaviors, which has been previously reported. From August 2011 until January 2013, we collected e-mail addresses for those who agreed to participate in a follow-up study. Only data collected in this period were used in the current study. One month and one year after baseline data collection, we e-mailed all participants who had provided their e-mail address an invitation to answer the follow-up questionnaires. These covered e-cigarette use, current smoking, use of tobacco in the previous 7 days, cigarettes per day (in smokers), puffs/day on e-cigarettes (1-year only) and quit date (in former smokers). Participants were >18 years and the study was approved by the ethics committee of the Geneva University Hospitals.

We used χ^2 tests to compare proportions, t tests to compare means and Wilcoxon signed rank tests to compare medians. A P value of 0.05 was used as the cut-off to categorise results as statistically significant or not.

3. Results

The baseline survey was answered by 1329 participants, of whom 773 provided an e-mail address (58%). Of these 773 people, 477 answered the follow-up survey after one month, a 62% response rate (36% of 1329) and 367 after **one year**, a 47% response rate (28% of 1329). Table 1 shows that participants in the follow-up surveys were more likely than non-respondents to be daily users of e-cigarettes and

former smokers, were older than non-respondents and their income was slightly higher, and among daily smokers, respondents were more motivated to quit than non-respondents. There were no differences between respondents and non-respondents for education, reasons for using e-cigarettes, puffs per day on e-cigarettes, duration of e-cigarette use and among smokers, cigarettes per day. In former smokers, the correlation between cigarettes per day before they quit smoking and puffs per day on e-cigs per day was $r = 0.30$ ($p < .001$) and the correlation between cigarettes per day before they quit and nicotine concentration in e-liquids was 0.12 ($p = 0.3$).

All further analyses were limited to people who answered the follow-up surveys. Distribution of respondents by country was: U.S. (34%), France (24%), U.K. (8%), Switzerland (6%) and other countries (28%). Most participants were former smokers, and they had been abstinent for a median of 10 weeks. Most participants (76%) were using e-cigarettes daily (2% occasionally, 5% past users, 17% never users), and current users had been vaping for 3 months on average. The most used e-cigarette brands were *Joye* ($n = 105$, 22%), *Ego* ($n = 50$, 11%), and *Provape* ($n = 23$, 5%). The most used models, sold under different brand names, were *Ego* ($n = 104$, 22%) and *510* ($n = 24$, 5%). “Dual users” (those who smoked daily and used e-cigarettes daily at baseline) reduced cigarette consumption by 10.5 cigarettes per day since they started vaping: from 24.3 cigarettes per day before they started to vape to 13.8 cigarettes per day at baseline (paired samples t -test: $t = 4.5$, $p < 0.001$).

3.1. Change between baseline and follow-up

Almost all (98%) the daily vapers at baseline were still vaping daily after one month and after one year (89%). Of recent vapers (those who had been vaping daily for less than one month at baseline) 93% were still vaping daily after one month and 81% after one year. Of those who were not vaping at baseline, 15% had started to use e-cigarettes (daily or occasionally) after one month and 13% after one year. In the 229 participants who were vaping daily at both time points, the number of puffs per day on e-cigarettes remained

Table 1
Baseline characteristics of e-cigarette users enrolled on the Internet, 2011–2013.

At baseline:	Took part in 1-month survey			Took part in 1-year survey		
	Yes	No	<i>p</i> -value	Yes	No	<i>p</i> -value
<i>N</i> participants (%)	477 (62%)	296 (38%)		367 (47%)	406 (53%)	
Age, median (25th and 75th percentiles)	42 (33, 51)	38 (27, 47)	0.032	43 (34, 51)	38 (28, 48)	0.002
Men (%)	59	48	0.003	58	52	0.08
Have a diploma giving access to university (%)	59	65	0.16	59	63	0.21
Household income above average (%)	38	30	0.007	37	33	0.04
Use e-cig to quit smoking or avoid relapse (%)	92	93	0.64	90	94	0.46
Former smokers (the rest were daily and occasional smokers) (%)	72	53	<.001	76	53	<.001
Former smokers: days since quit smoking, median (25th, 75th centiles)	72 (24, 194)	67 (18,239)	0.69	87 (28,242)	53 (18,189)	0.007
Former smokers: cigarettes per day before they quit, median (25th, 75th centiles)	25 (18, 30)	20 (18, 30)	0.16	25 (18, 30)	20 (18, 30)	0.55
Use e-cigarettes daily (%)	76	58	<.001	79	58	<.001
Duration of current episode of e-cigarette use, days, median (25th, 75th centiles)	91 (21, 152)	49 (14,274)	0.43	91 (21, 274)	49 (21,152)	0.24
Puffs per day on e-cigarette, median (25th and 75th centiles)	150 (90, 250)	150 (80,250)	0.87	150 (90, 275)	120 (80,250)	0.40
Use nicotine-containing e-cigarettes (%)	95	95	0.77	96	93	0.25
Number of refills per day, median (25th, 75th centiles)	2 (1, 4)	2 (1, 4)	0.88	2 (1, 4)	2 (1, 4)	0.47
Duration of use for one refill or cartridge, hours, median (25th, 75th centiles)	6 (3, 12)	8 (3, 17)	0.02	6 (3, 12)	6 (3, 15)	0.40
Concentration of nicotine in liquid, mg/ml, median (25th, 75th centiles)	16 (11, 18)	18 (12, 24)	0.05	16 (11, 18)	18 (12, 18)	0.74
Daily smokers: cig. per day	18.2	17.3	0.88	16.3	18.4	0.07
Daily smokers: plans to quit smoking in next 6 month (%)	90.1	72.6	0.006	88.5	76.9	0.014
Daily smokers: currently trying to quit (%)	61.6	68.9	0.04	60.7	67.8	0.04

unchanged between baseline and one-year follow-up (median = 200 puffs per day, Wilcoxon signed rank test = 10.1, $p = 0.05$) (Table 2).

Among former smokers who were vaping daily at baseline, 6% had relapsed to smoking after one month and also 6% after one year. Among recent quitters who had quit smoking for less than 1 month and were vaping daily at baseline, 8% relapsed to occasional smoking after one month and 5% after one year (none relapsed to daily smoking).

Among daily or occasional smokers who were vaping daily at baseline, 22% had stopped smoking after one month and 46% after one year (using the criterion of not a single puff of tobacco in the previous 7 days). In dual users who vaped and smoked daily or occasionally both at baseline and at follow-up, cigarette consumption decreased significantly, by 5.3 cigarettes per day between baseline and 1-month follow-up (from 11.3 at baseline to 6.0 cigarettes per day at 1-month follow-up, paired-samples t -test: $t = 2.9$, $p = 0.006$) but remained unchanged between baseline and 1-year follow-up.

4. Discussion

Our study provides the most detailed information to date on the 'natural behavior' of an international cohort of vapers over 12 months outside clinical settings or efficacy trials (Adkison et al., 2013; Vickerman et al., 2013). Most e-cigarette users were former smokers, who used e-cigarettes much like nicotine medications, to assist quitting, but with a longer duration of use. During the course of one year, use of e-cigarettes was remarkably stable in this group, even in those who had recently started to vape. Among vapers, very few ex-smokers relapsed to smoking, even among recent quitters. Dual users of e-cigarettes and conventional cigarettes reduced their cigarette consumption after they started to vape, and about half had stopped smoking at 1-year follow-up. While we are unable to establish causal links between vaping and smoking behavior from these observational data, our findings are consistent with the hypotheses that e-cigarettes provide an alternative to smoking; help former smokers avoid relapse; and help current smokers stop smoking. Our results align with most previous longitudinal studies of vapers and clinical trials (Adkison et al., 2013; Bullen et al., 2013;

Caponnetto, Auditore, Russo, Cappello, & Polosa, 2013; Caponnetto, Campagna, et al., 2013; Polosa et al., 2011, 2013; Vickerman et al., 2013).

Our study has a number of limitations. First, we relied on self-reports of the use of e-cigarettes and tobacco. Daily vapers enrolled on e-cigarette forums or commercial websites have more positive opinions about e-cigarettes than other daily vapers (Etter & Bullen, 2011a). However, the patterns of e-cigarette use in this study (puffs per day, refills per day) are comparable to those observed in previous studies of vapers (Dawkins, Turner, Roberts, & Soar, 2013; Etter & Bullen, 2011b; Farsalinos, Romagna, Tsiapras, Kyrzopoulos, & Voudris, 2013; Foulds, Veldheer, & Berg, 2011; Goniewicz, Lingas, & Hajek, 2012), suggesting that participants in this study were not particularly intensive users, and that our results are generalizable to most daily vapers.

Second, participants in our study were self-selected and most were former smokers, whereas studies conducted in representative samples of the general population have found that most vapers are current smokers (ASH, 2013; Regan, Promoff, Dube, & Arrazola, 2011). It is possible that people who purchase e-cigarettes in shops rather than online differ from participants in our study. Also, our follow-up surveys oversampled daily vapers, former smokers and older individuals, and the incomplete participation at follow-up further limits the generalizability of our results. Finally, because new brands and models of e-cigarettes appear regularly, our results may not apply to "next generation" brands and models.

Of all the published longitudinal studies of the 'natural behavior' of vapers outside clinical settings or efficacy trials (Adkison et al., 2013; Vickerman et al., 2013), this study provides the most detailed analysis of behavior change over time. While these results need replication in larger and more representative samples, they suggest that for many people, vaping is a stable, long-term behaviour. Further research is therefore needed on the health consequences of e-cigarette use in the long-term. Importantly, our findings also suggest no deleterious effects of vaping on smoking behaviour, indeed they suggest e-cigarette use facilitates quitting, cutting down the number of cigarettes smoked and prevents relapse to smoking.

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Funding for this study was provided by Swiss Tobacco Prevention Fund (TPF), grant 12.000489. The TPF had no role in the study design, collection, analysis or interpretation of the data, writing the manuscript, or the decision to submit the paper for publication.

Contributors

JFE and CB designed the study and wrote the protocol. JFE collected the data and conducted the statistical analysis. JFE wrote the first draft of the manuscript and all authors contributed to and have approved the final manuscript.

Conflict of interest

JFE's salary is paid by the University of Geneva. He was reimbursed by a manufacturer of e-liquids for traveling to London and to China.

CB's salary is paid by the University of Auckland. CB has no financial or non-financial interests relevant to the submitted work. He has previously undertaken research funded by HealthNew Zealand Ltd via an arrangement with Ruyan (an e-cigarette manufacturer) and has previously undertaken research on behalf of NicoNovum prior to the purchase of the company by RJ Reynolds. He was involved in a previous trial investigating the effect of Quest 3 reduced nicotine cigarettes on smoking cessation, purchased from Vector Group Ltd, USA, but Vector had no role in development of the study design, data collection, analysis, interpretation or writing of publications.

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Table 2

Behavior change after one month and one year in e-cigarette users.

	After one month	After one year
N participants	477	367
Interval between baseline and follow-up, days, median (25th, 75th centiles)	31 (31, 34)	380 (236, 524)
Among daily vapers at baseline, percent (N) still vaping daily at follow-up (1 m: n = 356; 1y: n = 291)	98% (347)	89% (260)
Among daily vapers who had been vaping for less than 1 month at baseline, percent (N) still vaping daily at follow-up (1 m: n = 94; 1y: n = 77)	93% (87)	81% (62)
Among daily smokers who were vaping daily at baseline, percent (N) vaping daily at follow-up (1 m: n = 21; 1y: n = 18).	91% (19)	72% (13)
Among ex-smokers who were vaping daily at baseline, percent (N) still vaping daily at follow-up (1 m: n = 270; 1y: n = 233)	99% (268)	92% (214)
Among non-vapers at baseline, percent (N) vaping daily or occasionally at follow-up (1 m: n = 104; 1y: n = 63)	15% (16)	13% (8)
Ex-smokers		
Among daily vapers at baseline, percent (N) baseline ex-smokers who relapsed to smoking daily or occasionally at follow-up (1 m: n = 270; 1y: n = 233)	6% (15)	6% (13)
Dual users		
Smoking cessation rate at follow-up, in those who were vaping daily and smoking daily or occasionally at baseline (1 m: n = 50; 1y: n = 35)	22% (11)	46% (16)

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