



The effectiveness of using e-cigarettes for quitting smoking compared to other cessation methods among adults in the United Kingdom

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ABSTRACT

Background and aims Evidence on the effectiveness of electronic cigarettes (ECs) to facilitate abstinence from smoking is limited. The current study aimed to estimate the relative effectiveness of ECs and smoking cessation medication compared with using no help, accounting for frequency of use of ECs. **Design** Four consecutive wave-to-wave transitions (waves 1–2, 2–3, 3–4 or 4–5) of a longitudinal online survey collected between 2012 and 2017 were analysed. Time between waves ranged between 12 and 17 months. Cigarette smokers at the baseline wave who attempted to quit smoking between waves were included. **Setting** United Kingdom **Participants** A total of 1155 respondents (aged 18–81, 56.1% male, 64.6% in social grade C2DE, 93.8% white) provided 1580 pairs of observations for the primary analysis. **Measurements** Primary outcome: abstinence from smoking for at least 1 month at follow-up; secondary outcome: at least 1 month's abstinence from smoking between baseline and follow-up. The main predictor was stop smoking aid used (No help, nicotine replacement therapy only, smoking cessation medication only, disposable/cartridge EC, refill/modular EC, combination), adjusted for demographics. **Findings** Primary Compared with using no help, the odds of abstinence were increased by daily use of disposable/cartridge ECs (OR = 3.31 (1.32, 8.26), $P = .010$) and daily use of refill/modular ECs (OR = 5.47 (2.70, 11.11), $P < .001$). Odds were reduced by non-daily use of disposable/cartridge ECs (OR = 0.23 (0.08–0.63), $P = .005$), and by use of disposable/cartridge ECs to quit and no longer using at follow-up (OR = 0.10 (0.16–0.62), $P < .013$). **Secondary** Results were similar to the primary outcome; however, odds of abstinence were also increased by use of smoking cessation medication (OR = 4.15 (1.79, 9.62), $P = .001$). **Conclusions** When used daily, electronic cigarettes appear to facilitate abstinence from smoking when compared with using no help.

Keywords E-cigarettes, electronic cigarettes, longitudinal population study, nicotine replacement therapy, smoking cessation, smoking cessation medication.

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INTRODUCTION

Although smoking prevalence has continued to fall in England in recent years, from 19.8% in 2011 to 14.4% in 2018 [1], tobacco smoking remains the leading cause of preventable illness and death [1]. The adverse health effects of smoking are caused by the inhalation of multiple chemical compounds created by the combustion of tobacco [2]. Continued cigarette smoking is maintained over time by the addictive qualities of nicotine, which is delivered in

a highly effective manner in terms of speed and volume of absorption [3].

Electronic cigarettes (ECs) entered the marketplace in the UK in 2006/2007 [4] and were used by about 6% of the population by 2019 [5]. ECs are devices that do not involve combustion and can deliver nicotine to users at speeds and volume approaching that of conventional cigarettes [6]. Use is concentrated among smokers and recent (≤ 5 years since quitting) ex-smokers; any use of ECs in these groups has increased from 2% in 2011 to 19% in

2019, with daily use increasing from 2% to 12% over the same period [7]. In 2013, 81% of EC users were dual users (*i.e.* smoked and used ECs concurrently), this had dropped to 49% by the end of 2019 [7]. The most common reason for EC use amongst smokers is as an aid to quit smoking [5]. The level of debate regarding the potential harms and benefits of ECs has also increased across this same period. Some [5,8,9] have concluded that ECs carry a small fraction of the risks of smoking cigarettes and may help smokers to quit. Others, however, maintain that the long-term health effects are not yet known [10] and reject the potential for ECs to reduce smoking prevalence [11,12].

The 2018 evidence review of ECs published by Public Health England [6] identified seven meta-analyses examining the effectiveness of ECs for smoking cessation and/or smoking reduction. These seven meta-analyses produced inconsistent findings, with two finding a positive impact of ECs on cessation, four an inconclusive impact and one a negative impact. Authors of this report ascribed variability in findings to differences in inclusion criteria for each review, for example in which types of study, types of participants or types of outcomes or follow-up periods were combined. A further, more recent, review article by Villanti and colleagues [13] proposed six recommendations for assessing the impact of ECs on quitting with sufficient scientific rigour. Studies must: (1) examine outcome of interest (*i.e.* cigarette abstinence); (2) assess EC use for cessation as the exposure of interest; (3) employ an appropriate comparison group; (4) ensure measurement of exposure precedes the outcome; (5) evaluate dose and duration of the exposure; and (6) evaluate the type and quality of EC used. Authors of this review found that very few articles (only four of 91 screened, all from three randomised controlled trials) met all six of their recommendations. The three included trials suggested that ECs are effective in helping adult smokers to quit smoking.

Whilst RCTs provide the strongest evidence as to whether ECs help smokers to quit with the greatest internal validity, observational studies using data from representative populations of smokers have superior external validity and can provide vital evidence collected from smokers using ECs to quit under natural conditions. To our knowledge, no observational study has addressed the impact of ECs on cessation whilst meeting all six of the proposed criteria. Those observational studies using representative samples of smokers that have adhered most closely to these criteria have produced mixed findings. A study conducted in the USA [14] examined whether using ECs to quit increased smoking cessation compared to those not using ECs to quit. This study found that those using ECs were less likely to be abstinent for one month at 12-month follow-up. However, this study did not incorporate any information on dose used during the quit attempt. Dose was included in a second study [15], also conducted in the USA; respondents

who were smokers at baseline were followed up at one year and asked to report their smoking status, whether they had made a quit attempt, whether they had ever used ECs, whether they currently used ECs and if so on how many of the past 30 days. Results of the study indicated that, compared to those who had never used ECs, the odds of achieving three-month abstinence were lower for 'ever' EC users, higher for current EC users, with the odds of abstinence increasing incrementally for those reporting 5 + days and 20 + days of use in the previous 30 days. Although this study failed to examine whether ECs were used to facilitate cessation, the results indicate that frequency of EC use is likely a key determinant of quit success.

AIMS

The current study examines the relative effectiveness of electronic cigarettes, used specifically for quitting, and other cessation methods (NRT, bupropion, varenicline) to facilitate abstinence from smoking compared with using no help. Analyses will also account for frequency of use; thus, we are endeavouring to meet the six criteria set out by Villanti [13], above. We used data from a longitudinal survey to examine the effectiveness of ECs to facilitate (1) abstinence for at least one month at follow-up (primary outcome) and (2) at least one month of abstinence between baseline and follow-up waves (secondary outcome).

METHODS

Design

This study used longitudinal data collected as part of an online survey. Five waves of data were used, with the first completed in November/December 2012 and the fifth completed in September/October 2017. Analyses for this study utilized data from four consecutive wave-to-wave transitions (1-2, 2-3, 3-4, 4-5) with 12–17 months between each wave (12–13 months between each wave pair 1–2 and 2–3; 15 and 17 months between each wave pair 3–4 and 4–5).

Survey sample

Respondents were adult (18+) members of an online panel managed by Ipsos Interactive Services. Participants for the survey were recruited through Ipsos MORI, a market research organisation to take part in the survey on behalf of King's College London. Smokers, ex-smokers who had quit within one year prior to completing the survey and EC users from Great Britain were eligible to participate in the surveys. Quotas were imposed on demographics at recruitment to ensure a representative sample of age, sex and geographical region was included. As an incentive, those who completed surveys received points which could

be exchanged for shopping vouchers or prize draw entry. To date, five waves of surveys have been completed. The first wave was completed by 5000 respondents in November/December 2012. Wave 2 (December 2013) followed up with 2182, all of whom had taken part in the 2012 survey. Wave 3 was conducted in December 2014 with 1519 participants, again all followed up from the previous two waves. Wave 4 was conducted in May/June 2016. In addition to those followed up from previous waves ($n = 930$), 2403 participants were newly recruited, with quotas to ensure the overall sample retained broad representativeness of Great Britain by sex, age and region. At this wave, current EC users who had never smoked were also eligible. Wave 5 was conducted in September/October 2017 and was completed by 1775, all of whom had taken part in the 2016 survey. Analyses for this study utilised data from four consecutive survey wave-to-wave transitions (1–2, 2–3, 3–4, 4–5). In each wave-to-wave transition, data from the earlier wave is referred to as the baseline wave, and the later wave referred to as the follow-up wave. The time elapsed between wave-to-wave transitions 1–2 and 2–3 was between 12 and 13 months. Between wave-to-wave transitions 3–4 and 4–5 the time elapsed was between 15 and 17 months.

Analytic sample: Inclusion criteria and selection of participants

For the primary analysis we included participants who: provided data for at least one wave-to-wave transition; were smoking tobacco in the form of cigarettes (either factory made or roll-your-own) at the baseline wave; and had made an attempt to quit smoking between waves. Ex-smokers and pure EC users (those who had never smoked) at baseline were excluded. Respondents were able to provide more than one set of data. This resulted in a final sample of $n = 1155$ unique participants (smokers and recent ex-smokers), who provided 1580 pairs of observations over the four survey wave to wave transitions included in the primary analysis. A total of 28 respondents provided data from all four wave to wave transitions, 72 from three, 197 from two and 858 from one transition.

The selection criteria for the secondary analysis were identical, however, due to differences in how the outcome was coded, a greater number of participants were excluded due to missing data resulting in a sample of 1130 unique participants providing 1531 observations. Full details of how participants were selected for analyses are provided in Supplementary File S1 and in the flow diagram presented in Fig. 1.

Ethical clearance

Ethical approval for each wave of the survey was granted by the research ethics committees of King's College

London and University College London. All respondents provided consent to participate.

Measures

Full details of measures related to smoking, vaping and quit attempts, and how these vary across waves, are provided in File S1.

Primary outcome: Abstinent for at least one month at follow-up

The primary outcome was being abstinent for smoking for at least one month at the follow-up wave. This outcome was derived from the responses to several items. At each baseline wave of the survey, respondents were asked to describe their current smoking status from several options. At the follow-up wave, respondents were asked: "How many serious attempts to stop smoking have you made in the last 12 months?" Those reporting that they smoked cigarettes (including hand rolled cigarettes) and had made at least one attempt to quit were included in the analysis. Respondents were also asked "How long ago did your most recent serious quit attempt start?". Those who were classified as non-smoking at follow-up and reported they had started their quit attempt at least one month earlier were coded as abstinent and compared to all others who had made a quit attempt.

Secondary outcome: At least one month of abstinence between baseline and follow-up

Those who indicated that they had made a quit attempt were also asked "How long did your most recent serious quit attempt last before you went back to smoking?" to which respondents could either indicate that they were still not smoking or provide the length of their most recent quit attempt. Those reporting that they had achieved at least one month of abstinence, regardless of smoking status at follow-up were coded as having achieved abstinence and compared to all others who had made a quit attempt.

Predictor variable: Type of stop smoking aid used on last quit attempt

At each wave, respondents were asked what type of help, if any, they had used on their most recent quit attempt. Respondents were then presented with a broad range of options including stop smoking aids (ECs, nicotine replacement therapy (NRT), smoking cessation medication (*i.e.* varenicline and bupropion)), behavioural support (*e.g.* attending a stop smoking group, phoning a smoking helpline) or alternative therapies (hypnotherapy, acupuncture). Respondents could select multiple options or indicate that they had used no help, as appropriate. Responses to this question were used to code a number of variables for what was used to support the most recent quit attempt:

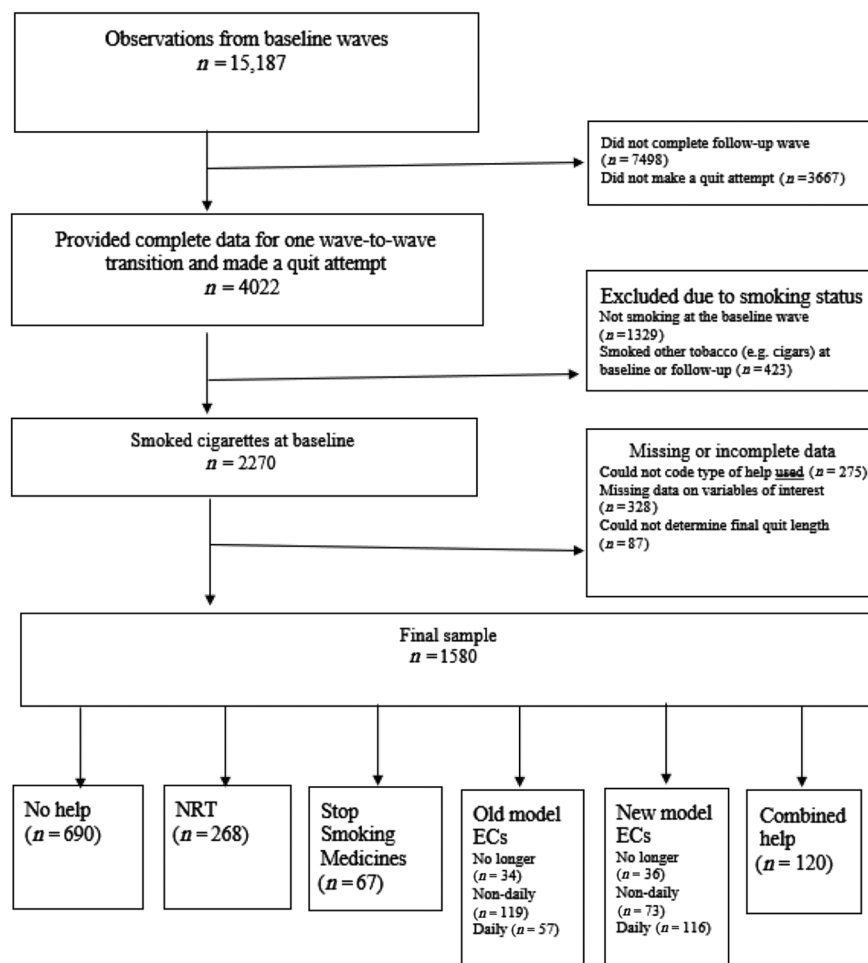


Figure 1 Flow Diagram for inclusion in primary analysis

type of stop smoking aid, use of behavioural support, and cutting down to quit (see below).

Type of stop smoking aid used on the last quit attempt was categorised as (1) only NRT (single or combination use); (2) only smoking cessation medication; (3) only disposable/ cartridge - ECs (defined as either a disposable EC or vaping device (non-rechargeable), or an EC or vaping device that uses replaceable pre-filled cartridges (rechargeable))¹; (4) only refill/modular ECs (defined as either an EC or vaping device with a tank that you refill with liquids, or a modular system that you refill with liquids (using a combination of separate devices: batteries, atomisers, etc.); (5) combination of any of 1–4; (6) no help. These categories were mutually exclusive. Model of EC used in the last quit attempt was only asked for waves 4–5 only. For waves 1–3 respondents were asked whether they had used an EC on their most recent quit attempt, but not what model they had used. Model of EC used in the most recent quit attempt for these waves was derived from the model of EC they reported using at the follow-up wave. Data from

waves 4 and 5 suggest a high level of correspondence (94%) between current model of EC used and model of EC used during last quit attempt. Model of EC used was further sub-divided according to frequency of use. Frequency of current EC use was measured at the outcome wave to assess its relationship to smoking abstinence at outcome. This resulted in six categories of EC use with use of disposable/ cartridge and refill/modular ECs each analysed according to whether use was daily, non-daily, or no longer occurring at the follow-up wave.

Covariates

We included as covariates in the analyses whether respondents had cut down the amount smoked before their most recent quit attempt and whether they had used any form of behavioural support. This latter variable was coded based on responses given for the type of stop smoking aid used on the last quit attempt according to the criteria in [16] (see File S1). Other covariates included in all multivariable

¹Due to the dates at which data were collected, ECs with pre-filled cartridges relate to earlier generation devices rather than pods (e.g. JUUL).

analyses were age (continuous), sex (female/male), ethnicity (white/non-white) and social grade, assessed using a categorization (ABC1/C2DE) commonly used in the UK (National Readership Survey [17]). We also controlled for a number of smoking-related variables: frequency and strength of urges to smoke (continuous variables with higher scores indicating greater frequency and strength); recency of quit attempt prior to current quit attempt (within last 6 months/ 6 months ago or longer, measured at baseline); time since most recent quit attempt started (within last 6 months/6 months ago or longer, measured at follow-up); number of quit attempts between baseline and follow-up waves (1, 2, 3 or more, or 'not sure, but at least one', measured at follow-up); motivation to stop smoking [18] dichotomised as: no interest/interested. We also included survey year, measured at baseline, as a study design variable.

Data analysis

Bivariate associations between the different quitting methods and covariates were assessed using χ^2 tests and one-way analyses of variance (ANOVAs). To examine the association between different stop smoking aids and outcome variables (abstinence for at least one month at follow-up or at least one month of abstinence between baseline and follow-up) we used clustered binary logistic random effects regression analyses with maximum likelihood estimation and a robust variance estimator. For each outcome, we conducted two sets of analyses: in the first we looked at the unadjusted effect of each variable on each outcome, and in the second, we looked at the fully adjusted effect with all covariates included concurrently. These analyses were not pre-registered and as such all results should be considered exploratory. Data were not weighted and there were no missing data (see Fig. 1). Analyses were conducted using Stata version 15.

RESULTS

Sample characteristics

Demographic and smoking-related characteristics (from baseline waves) for the sample in the primary analysis are presented in Table 1. Age ranged between 18 and 81, the majority were male (56.1%), in social grade C2DE (64.6%) and white (93.8%). Of the $n = 1155$ who provided data for the primary analysis, 85.4% ($n = 986$) were from England, 9.3% ($n = 107$) were from Scotland, 4.3% ($n = 50$) were from Wales and 0.8% ($n = 12$) were from Northern Ireland (we did not recruit respondents from Northern Ireland, but retained those who moved their during the follow-up period). There were no significant differences in age, sex, social grade or ethnicity by type of stop

smoking aid used on the most recent quit attempt. There were significant differences by type of stop smoking aid used on the most recent quit attempt for all other smoking and quit attempt related variables.

Associations between use of stop smoking aids and abstinence for at least one month at follow-up

In total, 22.7% ($n = 359$) of respondents were abstinent for at least one month at follow-up. The proportion of respondents achieving abstinence varied widely by quitting method, ranging from 5.9% of those who used disposable/ cartridge ECs to quit and were no longer using at follow-up, to 48.3% of those who used refill/modular ECs to quit and were using daily at follow-up with those using other methods in between these two extremes. Results from the multivariable logistic regression analysis are shown in Table 2. From the fully adjusted analyses, compared to using no help, the odds of achieving abstinence for at least one month at follow-up were increased by daily use of disposable/ cartridge ECs and daily use of refill/modular ECs. Odds of achieving abstinence were reduced by non-daily use of disposable/ cartridge ECs and by use of disposable/cartridge ECs to quit and no longer using at follow-up.

Analyses also indicated that the odds of achieving abstinence for at least one month at follow-up were increased by having made a previous quit attempt more than six months previously compared to within the last six months and having started the quit attempt more than six months prior to follow-up compared to within the last six months. Odds of abstinence were reduced by having made two prior quit attempts compared with one, increasing baseline frequency of urges to smoke and cutting down on smoking prior to quitting.

Associations between use of stop smoking aids and at least one month of abstinence between baseline and follow-up

A total of 43.8% ($n = 670$) of respondents achieved at least one month's abstinence between waves. Again, abstinence varied widely by quitting method, from 26.7% of those who used disposable/ cartridge ECs to 69.8% of those who used smoking cessation medication on their quit attempt. Results from the multivariable logistic regression analysis are shown in Table 3. Using fully adjusted analyses, compared to using no help, the odds of achieving abstinence for at least one month were increased by use of smoking cessation medication and daily use of refill/modular ECs. Odds of achieving abstinence were reduced by non-daily use of disposable/cartridge ECs.

Analyses also indicated that the odds of achieving one month of abstinence, irrespective of smoking status at follow-up were increased by having made a previous quit attempt more than six months previously compared to

Table 1 Sample characteristics.

	Total Obs n = 1580	Disposable/cartridge EC				Refill/modular EC				Comb. n = 120	P	
		No help n = 690	NRT n = 268	SCM n = 67	No longer n = 34	Non-daily n = 119	Daily n = 57	No longer n = 36	Non-daily n = 73			Daily n = 116
Abstinent for one month at follow-up (Outcome 1)	22.7 (359)	24.4 (168)	15.3 (41)	34.3 (23)	5.9 (2)	6.7 (8)	31.6 (18)	27.8 (10)	16.4 (12)	48.3 (56)	17.5 (21)	<.001
Achieved at least one month abstinence on most recent quit attempt (Outcome 2, n = 1531)	43.8 (670)	43.6 (293)	40.1 (105)	69.8 (44)	39.4 (13)	26.7 (31)	52.9 (27)	44.4 (16)	34.3 (24)	64.2 (70)	39.5 (47)	<.001
Age in years (M, (SD))	46.0 (15.2)	46.5 (15.7)	46.2 (15.4)	46.2 (13.1)	47.1 (19.1)	42.0 (14.6)	43.7 (14.5)	44.7 (14.6)	48.5 (15.4)	46.3 (13.6)	46.2 (14.5)	0.171
Sex (%)												
Female	43.9 (694)	44.4 (306)	37.7 (101)	41.8 (28)	44.1 (15)	51.3 (61)	36.8 (21)	47.2 (17)	48.0 (35)	49.1 (57)	44.2 (53)	0.343
Male	56.1 (886)	55.6 (384)	62.3 (167)	58.2 (39)	55.9 (19)	48.7 (58)	63.2 (36)	52.8 (19)	52.0 (38)	50.9 (59)	55.8 (67)	
Social Grade (%)												
C2DE	64.6 (1021)	66.2 (457)	68.3 (183)	64.2 (43)	61.8 (21)	63.0 (75)	54.4 (31)	69.4 (25)	68.5 (50)	59.5 (69)	55.8 (67)	0.245
ABC1	35.4 (559)	33.8 (233)	31.7 (85)	35.8 (24)	38.2 (13)	37.0 (44)	45.6 (26)	30.6 (11)	31.5 (23)	40.5 (47)	44.2 (53)	
Ethnicity (%)												
White	93.8 (1482)	93.8 (647)	93.7 (251)	92.5 (62)	94.1 (32)	91.6 (109)	89.5 (51)	97.2 (35)	94.5 (69)	97.4 (113)	94.2 (113)	0.694
Not White	6.2 (98)	6.2 (43)	6.3 (17)	7.5 (5)	5.9 (2)	8.4 (10)	10.5 (6)	2.8 (1)	5.5 (4)	2.6 (3)	5.8 (7)	
Recency of quit attempt prior to current quit attempt (%)												
Within last 6 months	47.7 (754)	43.9 (303)	54.1 (145)	52.2 (35)	29.4 (10)	57.1 (68)	54.4 (31)	41.7 (15)	41.1 (30)	40.5 (47)	58.3 (70)	<.001
6 months ago or longer	52.3 (826)	56.1 (387)	45.9 (123)	47.8 (32)	70.6 (24)	42.9 (51)	45.6 (26)	58.3 (21)	58.9 (43)	59.5 (69)	41.7 (50)	
Time since most recent quit attempt started (%)												
Within last 6 months	60.3 (953)	58.4 (403)	61.6 (165)	47.8 (32)	50.0 (17)	69.8 (83)	79.0 (45)	41.7 (15)	61.6 (165)	54.3 (63)	70.8 (85)	<.001
6 months ago or longer	39.7 (627)	41.6 (287)	38.4 (103)	52.2 (35)	50.0 (17)	30.2 (36)	21.0 (12)	58.3 (21)	38.4 (103)	45.7 (53)	29.2 (35)	
Number of baseline to outcome quit attempts (%)												
1	58.1 (918)	60.9 (420)	55.2 (148)	62.7 (42)	52.9 (18)	56.3 (67)	54.4 (31)	58.3 (21)	56.2 (41)	60.3 (70)	50.0 (60)	0.004
2	25.4 (401)	23.8 (164)	26.1 (70)	25.4 (17)	20.6 (7)	24.4 (29)	31.6 (18)	22.2 (8)	28.8 (21)	21.6 (25)	35.0 (42)	
3 or more	11.1 (175)	9.1 (63)	14.2 (38)	9.0 (6)	17.7 (6)	16.0 (19)	12.3 (7)	2.8 (1)	11.0 (8)	7.8 (9)	15.0 (18)	

(Continues)

Table 1. (Continued)

	Total Obs n = 1580	Disposable/cartridge EC					Refill/modular EC					Comb. n = 120	P		
		No help n = 690	NRT n = 268	SCM n = 67	No longer		No longer		Non-daily n = 73	Daily n = 116	Daily n = 57			Non-daily n = 73	Daily n = 116
					Non-daily n = 119	Daily n = 57	Non-daily n = 36	Daily n = 36							
Not sure, but at least 1	5.4(86)	6.2 (43)	4.5 (12)	3.0 (2)	8.8 (3)	3.4 (4)	1.8 (1)	16.7 (6)	4.1 (3)	10.3 (12)	0.0 (0)				
Baseline frequency of urges to smoke (M, (SD))	2.2 (1.1)	2.0 (1.2) ^a	2.4 (1.1) ^b	2.3 (0.9) ^{ab}	2.1 (0.7) ^{ab}	2.2 (0.8) ^{ab}	2.4 1.0) ^{ab}	2.5 (0.9) ^{ab}	2.4 (1.0) ^{ab}	2.4 (1.0) ^{ab}	2.5 (1.2) ^b	2.5 (1.0) ^b	<.001		
Baseline strength of urges to smoke (M, (SD))	2.4 (1.0)	2.2 (1.1) ^a	2.5 (0.9) ^b	2.3 (0.9) ^{ab}	2.2 (0.5) ^{ab}	2.4 (0.7) ^{ab}	2.5 (0.9) ^{ab}	2.4 (1.0) ^{ab}	2.5 (0.8) ^{ab}	2.6 (1.1) ^b	2.7 (1.0) ^b		<.001		
Baseline interest in quitting (%)															
No	24.7 (390)	27.5 (190)	20.5 (55)	13.4 (9)	52.9 (18)	20.2 (24)	17.5 (10)	27.8 (10)	30.1 (22)	30.2 (35)	14.2 (17)		<.001		
Yes	75.3 (1190)	72.5 (500)	79.5 (213)	86.6 (58)	47.1 (16)	79.8 (95)	82.5 (47)	72.2 (26)	69.9 (51)	69.8 (81)	85.8 (103)				
Used behavioural help on quit attempt (outcome) (%)															
No	86.2 (1362)	88.7 (612)	75.8 (203)	77.6 (52)	97.1 (33)	88.2 (105)	89.5 (51)	97.2 (35)	95.9 (70)	97.4 (113)	73.3 (88)		<.001		
Yes	13.8 (218)	11.3 (78)	24.3 (65)	22.4 (15)	2.9 (1)	11.8 (14)	10.5 (6)	2.8 (1)	4.1 (3)	2.6 (3)	26.7 (32)				
Cut down first on last quit attempt (outcome) (%)															
No	60.6 (957)	64.8 (447)	59.7 (160)	64.2 (43)	82.4 (28)	32.8 (39)	54.4 (31)	91.7 (33)	57.5 (42)	70.7 (82)	43.3 (52)		<.001		
Yes	39.4 (623)	35.2 (243)	40.3 (108)	35.8 (24)	17.6 (6)	67.2 (80)	45.6 (26)	8.3 (3)	42.5 (31)	29.3 (34)	56.7 (68)				
Baseline wave year															
2012		32.3 (223)	45.2 (121)	47.8 (32)	0.0 (0)	51.3 (61)	40.4 (23)	0.0 (0)	26.0 (19)	26.7 (31)	39.2 (47)		<.001		
2013		20.6 (142)	16.0 (43)	19.4 (13)	0.0 (0)	26.9 (32)	24.6 (14)	0.0 (0)	19.2 (14)	21.6 (25)	23.3 (28)				
2014		18.1 (125)	16.8 (45)	13.4 (9)	58.8 (20)	4.2 (5)	15.8 (9)	30.6 (11)	21.9 (16)	22.4 (26)	10.8 (13)				
2016		29.0 (200)	22.0 (59)	19.4 (13)	41.2 (14)	17.7 (21)	19.3 (11)	69.4 (25)	32.9 (24)	29.3 (34)	26.7 (32)				

Key: Total Obs = Total observations. No help = used no stop smoking aid on most recent quit attempt. NRT = used NRT only. SCM = used smoking cessation medication only. Comb = used any combination of NRT, Rx, Disposable/cartridge EC or Refill/modular EC. P-values are for χ^2 tests (for categorical) and one-way ANOVAs for continuous variables. For continuous variables, groups that do not have any superscripts in common are significantly different after Sidak adjustments for multiple comparisons.

within the last six months and having started the quit attempt more than six months prior to follow-up compared to within the last six months. Odds of abstinence were reduced by having had three or more previous attempts to quit smoking, increasing baseline frequency of urges to smoke and cutting down on smoking prior to quitting.

DISCUSSION

The results of this study indicate a clear benefit of daily use of ECs to quit smoking. Compared to using no help, the odds of achieving abstinence for one month at follow up were over three times greater for those who used an disposable/cartridge EC to quit and were using daily at follow up and over five times greater for those who used a refill/modular EC to quit and were using daily at follow-up. Daily use of ECs showed clear benefit over other evidence-based [19–21] methods of quitting; neither nicotine replacement therapy, smoking cessation medication such as bupropion or varenicline, nor any combination of these aids were associated with abstinence from smoking at the follow-up wave when compared with using no help. The use of prescription medicine was, however, associated with achieving at least one month of abstinence in the secondary analysis; those taking smoking cessation medication had over four times greater odds of achieving one month of abstinence compared to those using no help to quit. However, this effect was not evident in the primary analysis. Overall, these findings are in line with previous studies that have found the use of ECs for cessation to be more effective than NRT and prescribed smoking cessation medication [16,22].

These results highlight the importance of incorporating a measure of frequency of use into studies examining the effectiveness of ECs to facilitate abstinence from smoking. Non-daily or discontinued use at follow-up where refill/modular ECs were used to quit smoking were not associated with abstinence at follow-up. Further, non-daily or discontinued use at follow-up of old ECs used to quit were associated with significantly lower odds of achieving abstinence at follow-up. This finding is in keeping with previous observational studies using representative samples of smokers that have also found that the effectiveness of ECs to facilitate abstinence varied depending on frequency of use [15,23]; although this was not found in the UK sample in another study [16]. To an extent, these results are analogous to findings that greater consumption of NRT increases the odds of abstinence in those trying to quit [24]. However, results of the current study differ from previous studies in that both disposable/ cartridge and refill/modular ECs, if used daily, were associated with abstinence. A previous study, using two waves of data from the current study [23], found that daily refill/modular EC use was associated with abstinence from smoking, whereas findings were inconclusive regarding whether there

was an association between abstinence and daily disposable/cartridge EC use.

Those who achieved abstinence at follow-up in the current study were more likely to be still using ECs daily at follow-up. The propensity of those using ECs to quit smoking to maintain use over time was also found in a recent randomised controlled trial [25]. This trial found a clear benefit of using ECs to quit smoking over NRT, but also that, amongst those who abstained, 80% of those assigned to use ECs were still using them at 12 months compared to 9% of those assigned to use NRT. Thus, the effectiveness of using ECs to quit smoking may be predicated on using ECs daily for a sustained period. We do not know how long respondents used other stop smoking aids for or whether they were still using these at follow-up. There is some evidence that longer-term use of varenicline can prevent relapse [26] but the evidence for NRT and bupropion is mixed [26,27].

There was no evidence in the current study that participant demographics, sex, social grade or ethnicity, were associated either with the use of any specific type of stop smoking aid nor with either measure of abstinence. Aspects of the quit attempt were, however, associated with abstinence. Our findings relating to the recency and frequency of previous quit attempts were consistent with previous studies [28,29] suggesting that fewer quit attempts and longer times between attempts are associated with increased likelihood of abstinence. Nicotine dependence was also associated with abstinence; those with greater frequency of urges to smoke were less likely to be abstinent. Despite evidence from RCTs suggesting that cutting down to quit smoking is as efficacious as quitting abruptly [30], those who reported cutting down on their smoking prior to quitting in the current study had significantly reduced odds of being abstinent on both measures.

Strengths and limitations

This study had a number of strengths. First, based on the criteria established by Villanti and colleagues [13] this study supplies the most robust observational evidence on whether ECs facilitate abstinence from smoking, clearly meeting four of the six criteria (1, 2, 3 and 6). We did not establish temporality by ensuring that respondents reported use of ECs for quitting prior to assessing for abstinence, rather, participants retrospectively reported use. Whilst logically, this precludes us from establishing whether EC use predicted abstinence from smoking, we feel little demand on participants to intentionally misreport their use of ECs for cessation. It is possible, however, that their recall was not accurate. Longitudinal studies with increased frequency of measurement, for example every three months, may be warranted in order to meet this criterion more reliably.

Table 2 Logistic regression analyses examining correlates of achieving abstinence for at least one month at follow-up (*n* = 1580).

	Model 1 (unadjusted)				Model 2 (fully adjusted)			
	Odds Ratio	95% confidence interval		P	Odds Ratio	95% confidence interval		P
Quitting Method								
No help (<i>n</i> = 690)	ref				ref			
NRT only (<i>n</i> = 268)	0.45	0.26	0.77	0.004	0.59	0.34	1.02	0.061
Stop smoking medication only (<i>n</i> = 67)	1.80	0.81	3.97	0.148	1.99	0.89	4.45	0.093
Disposable/cartridge ECs only (daily) (<i>n</i> = 57)	1.85	0.77	4.45	0.170	3.31	1.32	8.26	0.010
Disposable/cartridge ECs only (non-daily) (<i>n</i> = 119)	0.12	0.04	0.33	<.001	0.23	0.08	0.63	0.005
Disposable/cartridge ECs (no longer) (<i>n</i> = 34)	0.12	0.02	0.72	0.021	0.10	0.16	0.62	0.013
Refill/modular ECs only (daily) (<i>n</i> = 116)	4.92	2.50	9.72	<.001	5.47	2.70	11.11	<.001
Refill/modular ECs only (non-daily) (<i>n</i> = 73)	0.58	0.24	1.42	0.233	0.80	0.33	1.91	0.611
Refill/modular ECs only (no longer) (<i>n</i> = 36)	1.27	0.15	0.31	0.668	1.00	0.34	2.96	0.996
Combination of stop smoking aids (<i>n</i> = 120)	0.65	0.32	1.30	0.224	1.38	0.67	2.83	0.381
Age (years)	1.00	0.99	1.02	0.427	1.00	0.98	1.01	0.561
Sex								
Female	ref				ref			
Male	0.95	0.67	1.36	0.792	0.99	0.69	1.43	0.974
Social grade								
C2DE	ref				ref			
ABC1	1.18	0.83	1.69	0.360	1.08	0.73	1.58	0.711
Ethnicity								
White	ref				ref			
Not white	0.35	0.15	0.82	0.015	0.48	0.20	1.16	0.105
Recency of quit attempt prior to current quit attempt								
Within last 6 months	ref				ref			
6 months ago or longer	2.04	1.49	2.79	<.001	1.46	1.00	2.13	0.049
Time since most recent quit attempt started								
Within last 6 months	ref				ref			
6 months ago or longer	4.81	3.11	7.44	<.001	3.55	2.27	5.57	<.001
Number of baseline to outcome quit attempts								
1	ref				ref			
2	0.30	0.19	0.47	<.001	0.48	0.30	0.77	0.003
3 or more	0.27	0.14	0.51	<.001	0.58	0.30	1.13	0.111
Not sure, but at least 1	1.06	0.54	2.08	0.854	0.90	0.44	1.85	0.767
Baseline frequency of urges to smoke	0.71	0.61	0.83	<.001	0.74	0.58	0.94	0.014
Baseline strength of urges to smoke	0.70	0.59	0.83	<.001	0.92	0.71	1.19	0.522
Baseline interest in quitting								
No	ref				ref			
Yes	0.62	0.43	0.89	0.010	0.84	0.56	1.27	0.418
Used behavioural help on quit attempt (outcome)								
No	ref				ref			
Yes	0.61	0.37	1.02	0.064	1.07	0.61	1.86	0.817
Cut down first on quit attempt (outcome)								
No	ref				ref			
Yes	0.23	0.16	0.35	<.001	0.28	0.18	0.43	<.001
Baseline wave year								
2012	ref				ref			
2013	2.10	1.16	3.83	0.014	1.38	0.82	2.30	0.216
2014	2.64	1.34	5.20	0.005	0.85	0.50	1.43	0.535
2016	1.76	1.01	3.09	0.048	0.91	0.57	1.45	0.691

Note: Model 1 is the unadjusted effect, separately for each predictor variable, Model 2 is adjusted for all covariates. Significant associations are in bold.

We also did not fully meet the criterion for establishing dose of EC use. Whilst analyses did incorporate a measure of frequency of EC use, this was derived from respondents'

frequency of EC use at follow-up. Given the high correspondence between model of EC used during the most recent quit attempt and the model of EC respondents were using

Table 3 Logistic regression analyses examining correlates of at least one month of abstinence between baseline and follow-up ($n = 1531$).

	Model 1 (unadjusted)			Model 2 (fully adjusted)					
	Odds Ratio	95% confidence interval		P	Odds Ratio	95% confidence interval		P	
Quitting Method									
No help ($n = 672$)	ref				ref				
NRT only ($n = 262$)	0.84	0.56	1.25	0.383	0.99	0.64	1.55	0.997	
Stop smoking medication only ($n = 63$)	3.96	1.82	8.62	0.001	4.15	1.79	9.62	0.001	
Disposable/cartridge ECs only (daily) ($n = 51$)	1.78	0.80	3.97	0.160	3.34	1.37	8.11	0.008	
Disposable/cartridge ECs only (non-daily) ($n = 116$)	0.35	0.19	0.64	0.001	0.52	0.27	0.99	0.048	
Disposable/cartridge ECs only (no longer) ($n = 33$)	0.77	0.29	2.05	0.607	0.68	0.24	1.92	0.460	
Refill/modular ECs only (daily) ($n = 109$)	3.31	1.81	6.03	<.001	3.85	2.00	7.46	<.001	
Refill/modular ECs only (non-daily) ($n = 70$)	0.60	0.29	1.22	0.159	0.75	0.35	1.58	0.447	
Refill/modular ECs only (no longer) ($n = 36$)	1.12	0.44	2.85	0.817	0.84	0.31	2.34	0.745	
Combination stop smoking aids ($n = 119$)	0.89	0.52	1.55	0.685	1.52	0.83	2.77	0.176	
Age (years)	1.00	0.99	1.01	0.411	1.00	0.99	1.01	0.732	
Sex									
Female	ref				ref				
Male	0.96	0.71	1.30	0.796	1.02	0.74	1.42	0.905	
Social grade									
C2DE	ref				ref				
ABC1	1.31	0.96	1.78	0.087	1.24	0.88	1.76	0.214	
Ethnicity									
White	ref				ref				
Not white	0.59	0.31	1.11	0.101	0.71	0.35	1.41	0.328	
Recency of quit attempt prior to current quit attempt									
Within last 6 months	ref				ref				
6 months ago or longer	1.79	1.36	2.35	<.001	1.49	1.07	2.07	0.018	
Time since most recent quit attempt started									
Within last 6 months	ref				ref				
6 months ago or longer	6.40	4.38	9.35	<.001	5.49	3.71	8.13	<.001	
Number of baseline to outcome quit attempts									
1	ref				ref				
2	0.44	0.31	0.62	<.001	0.75	0.52	1.10	0.140	
3 or more	0.26	0.15	0.43	<.001	0.52	0.30	0.90	0.020	
Not sure, but at least 1	1.01	0.55	1.86	0.974	0.90	0.46	1.77	0.767	
Baseline frequency of urges to smoke	0.76	0.67	0.87	<.001	0.76	0.62	0.93	0.009	
Baseline strength of urges to smoke	0.78	0.67	0.89	<.001	0.97	0.78	1.21	0.801	
Baseline interest in quitting									
No	ref				ref				
Yes	0.73	0.52	1.01	0.054	0.94	0.65	1.38	0.765	
Used behavioural help on quit attempt (outcome)									
No	ref				ref				
Yes	0.91	0.61	1.38	0.668	1.32	0.82	2.11	0.243	
Cut down first on quit attempt (outcome)									
No	ref				ref				
Yes	0.40	0.29	0.55	<.001	0.49	0.35	0.70	<.001	
Baseline wave year									
2012	ref				ref				
2013	1.22	0.83	1.80	0.300	1.08	0.71	1.63	0.720	
2014	1.81	1.18	2.77	0.006	0.89	0.56	1.39	0.601	
2016	1.19	0.82	1.72	0.348	0.85	0.56	1.27	0.427	

Note: Model 1 is the unadjusted effect, separately for each predictor variable, Model 2 is adjusted for all covariates. Significant associations are in bold.

currently at follow-up for waves 4 and 5 it seems possible that frequency of use would follow a similar pattern. Future studies should include measures of frequency of use during

quit attempts, alongside other important information not included here, for example whether ECs used during the quit attempt used nicotine and at what strength. We also

did not collect data on frequency of NRT use which would have allowed for a more complete comparison.

Cell sizes for some comparisons were small, particularly for some of the EC use categories in the multivariable analysis examining associations with abstinence for at least one month at follow-up, meaning that power to detect differences may have been limited. However, results for the analysis examining associations with achieving at least one month of abstinence between baseline and follow-up had larger numbers of abstainers, and were similar, suggesting this was not an issue. Finally, although representative samples of smokers were recruited for the survey from which the analytic sample was drawn, due to the level of attrition between waves and the selection of participants according to eligibility criteria, the analytic sample itself cannot be considered representative of the UK population. The extent to which these findings are generalizable is therefore not known.

CONCLUSIONS

Data from a large sample of smokers attempting to quit smoking in real-world conditions indicate that when used daily, both refill/modular and disposable/cartridge ECs facilitate abstinence from smoking. The relative effectiveness of ECs to facilitate abstinence compared to using no help was demonstrated alongside evidence-based stop smoking aids in analyses adjusted for demographics and smoking variables.

Declaration of interests

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Author contributions

Mairtin McDermott: Conceptualization; formal analysis; project administration. **Katherine East:** Formal analysis. **Leonie Brose:** Conceptualization; formal analysis; methodology; project administration; supervision. **Ann McNeill:** Conceptualization; funding acquisition; investigation; methodology; supervision. **Sara Hitchman:** Conceptualization; funding acquisition; methodology; formal analysis. **Timea Partos:** Conceptualization; formal analysis; investigation; methodology; project administration; supervision.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

File S1 Measures related to smoking, vaping and quit attempts
File S2.