

Moderators of real-world effectiveness of smoking cessation aids: a population study

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Key words: smoking cessation; cessation aids; real-world effectiveness; varenicline; bupropion; nicotine replacement therapy; behavioural support; e-cigarettes.

Abstract

Background/Aims: Understanding whether and how far smokers' characteristics influence the effectiveness of treatment may be important for tailoring recommendations on cessation aids to those most likely to help the user achieve abstinence. This study aimed to estimate the effectiveness of commonly-used smoking cessation aids and test whether their effectiveness differs according to cigarette addiction, socioeconomic status, age, or sex.

Design: Correlational design using cross-sectional survey data collected monthly between 2006 and 2018.

Setting: England.

Participants: 18,929 adults (aged ≥ 16 y, 52.0% female) who had smoked within the previous 12 months and had made at least one quit attempt during that period.

Measurements: The outcome was self-reported abstinence from quit date to survey. Independent variables were self-reported use during the most recent quit attempt of: prescription nicotine replacement therapy (NRT), NRT over-the-counter, varenicline, bupropion, e-cigarettes, face-to-face behavioural support, telephone support, written self-help materials, websites, and hypnotherapy. Moderators were cigarette addiction, social grade, age, and sex.

Findings: After adjustment for covariates and use of other cessation aids, users of e-cigarettes (OR=1.95, 95%CI:1.69-2.24) and varenicline (OR=1.82, 95%CI:1.51-2.21) had significantly higher odds of reporting abstinence than those who did not report use of these cessation aids. Use of prescription NRT was associated with increased abstinence in older (≥ 45 y) (OR=1.58, 95%CI:1.25-2.00) but not younger (< 45 y) smokers (OR=1.09, 95%CI:0.85-1.42). Use of websites was associated with increased abstinence in smokers from lower (OR=2.20, 95%CI:1.22-3.98) but not higher social grades (OR=0.74, 95%CI:0.40-1.38). There was little evidence of benefits of using other cessation aids.

Conclusions: Use of e-cigarettes and varenicline are associated with higher abstinence rates following a quit attempt in England. Use of prescription of NRT was also associated with higher abstinence rates but only in older smokers, and use of websites only in smokers from lower SES.

Introduction

Stopping smoking reduces the risk of chronic diseases and increases life expectancy (1). Benefits are greater the younger smokers are when they quit, with those who stop in early adulthood avoiding almost all of the excess mortality and recovering on average 10 years of life (1,2). It is therefore important that every quit attempt has the best possible chance of success. A range of aids to smoking cessation are in common use and evidence is accumulating of their effectiveness in real-world settings (i.e., outside of the trial context) (3–10). This study extends the evidence on real-world effectiveness of these aids and assesses how far their effectiveness differs by four key potential moderators: level of cigarette addiction, socioeconomic status (SES), age, and sex.

There is strong evidence from multiple randomised controlled trials (RCTs) that nicotine replacement therapy (NRT), bupropion, varenicline, face-to-face behavioural support, telephone support, interactive websites, and written self-help materials can increase smoking cessation rates when used in a quit attempt (11–19). In addition, two RCTs suggest that e-cigarettes used in a quit attempt may aid cessation (20,21).

It is important to be able to generalise the findings of RCTs to populations and settings beyond those used in RCTs. Evidence from comparative observational studies in real-world settings has confirmed the effectiveness of prescription NRT, bupropion, varenicline, e-cigarettes, and face-to-face behavioural support (3–5,7–9). Comparative observational studies have found no benefit for NRT bought over the counter (4,5). The effectiveness of telephone support, websites and written self-help materials have not been evaluated in comparative observational studies. It is useful to provide further confirmation of the real-world effectiveness of aids that have thus far been found to be effective and to extend the assessment to popular aids not yet studied, such as hypnotherapy.

Level of cigarette addiction and SES are two smoker characteristics that have been consistently found to be associated with quit success rates in RCTs (22,23) and prospective observational studies (24–26). However, it is not clear how far these key variables moderate the effectiveness of smoking cessation aids. A large, multi-centre RCT did not find significant moderation of efficacy of NRT, varenicline or bupropion by Fagerström Test for Cigarette Dependence score or educational level (22). Evidence from other RCTs on moderation of efficacy of smoking cessation aids by variables related to cigarette addiction and SES is limited.

Understanding whether and how far cigarette addiction and SES, and other sociodemographic characteristics like age and sex, moderate the effectiveness of smoking cessation aids in the real world would have important implications. It could help treatment providers to tailor recommendations on

cessation aids to those most likely to help the user achieve abstinence. In the UK, the relative efficacy of varenicline and NRT varies across different local National Health Service (NHS) Stop Smoking Services (27), but the service characteristics that drive these differences have not been established. Additionally, it may offer insight into why some smokers find it easier to quit than others. Socioeconomic inequalities in smoking are well documented, with the most disadvantaged members of society substantially more likely to smoke and less likely to quit than the most affluent people (28,29). There are concerns that current population-level tobacco control interventions may exacerbate inequalities (23,28,30,31). Despite successfully reaching a high proportion of disadvantaged smokers (32), a review found consistent evidence that mainstream smoking cessation services produce substantially higher quit rates in smokers from higher socioeconomic groups (30). It is also true that unsupported quit rates are higher among higher socioeconomic groups. It is not clear whether the treatment disparity in absolute quit rates results from a failure to mitigate these baseline differences, or whether there is also a contribution from differential treatment efficacy.

The Smoking Toolkit Study is an ongoing national surveillance programme that involves surveys of nationally representative samples of adults in England every month (33). It has been used to assess the real-world effectiveness of a range of smoking cessation aids by comparing the success rates of smokers trying to quit with different methods and adjusting statistically for a wide range of factors that could bias the results, such as level of cigarette addiction (3–5,34,35). The accumulated data in the Smoking Toolkit Study now provide adequate statistical power to enable comparative real-world effectiveness estimates of a wider variety of quitting methods and to assess the potential moderating effects of level of cigarette addiction, SES, age, and sex.

We analysed accumulated data from the Smoking Toolkit Study, including data used in our previous real-world evaluation of smoking cessation aids (3–5), to address the following research questions:

1. Among smokers making a quit attempt in England, is use in the quit attempt of prescription NRT, NRT bought over the counter, varenicline, bupropion, e-cigarettes, face-to-face behavioural support, telephone support, written self-help materials, websites, and hypnotherapy associated with increased chances of success relative to non-use of these aids, after adjusting for potential confounding variables and the other quitting aids?
2. Do the above associations differ according to smokers' level of cigarette addiction, SES, age, or sex?

Method

Design

The Smoking Toolkit Study is an ongoing monthly survey designed to provide information about smoking prevalence and factors associated with cessation in England at a population level (33). The study uses hybrid random location and quota sampling to select a new sample of approximately 1,700 adults aged ≥ 16 years each month. The survey typically covers 200-300 output areas each wave, which are sampled at random (after stratification by geo-demographic analysis of the population) from more than 170,000. Participants complete a face-to-face computer-assisted survey with a trained interviewer. Full details of the study's methods are available elsewhere (33). Comparisons with national data indicate that key variables such as socio-demographics and smoking prevalence are nationally representative (33).

Study population

We used data from respondents to the survey in the period November 2006 (the start of the survey) to July 2018 (the latest wave of the survey for which data were available), who smoked cigarettes (including hand-rolled) or any other tobacco product (e.g., pipe or cigar) daily or occasionally at the time of the survey or during the preceding 12 months. We included those who reported having made at least one quit attempt in the preceding 12 months, assessed with the question "*How many serious attempts to stop smoking have you made in the past 12 months? By serious I mean you decided that you would try to make sure you never smoked again.*"

Measures

The outcome variable was self-reported continuous abstinence from the start of the most recent quit attempt up to the time of survey. Respondents were asked "*How long did your most recent quit attempt last before you went back to smoking?*" Responses were coded 1 for those who responded that they were still not smoking and 0 otherwise.

Independent variables were self-reported use or not (dummy coded) of smoking cessation aids in the most recent quit attempt: (i) prescription NRT (available in England from prescribing health professionals, including advisors at specialist stop smoking services), (ii) NRT bought over the counter, (iii) varenicline, (iv) bupropion, (v) e-cigarettes, (vi) face-to-face behavioural support, (vii) telephone support, (viii) written self-help materials, (ix) websites, and (x) hypnotherapy. Respondents were asked to indicate all that applied, and data for each was coded 1 if chosen and 0 if not.

Covariates were selected *a priori*. Level of cigarette addiction was assessed by self-reported ratings of the strength of urges to smoke over the last 24 hours (*not at all* (coded 0), *slight* (1), *moderate* (2), *strong* (3), *very strong* (4), *extremely strong* (5)). This question was also coded '0' for smokers who

responded ‘not at all’ to the (separate) question “*How much of the time have you spent with the urge to smoke?*” (36). This measure has been validated and performs at least as well as the Fagerström Test of Cigarette Dependence and the Heaviness of Smoking Index in predicting the outcome of cessation while not being subject to bias due to population-level changes in cigarette consumption over the time period of the study (37). We also included variables relating to the most recent quit attempt, including time since the quit attempt started (less vs. more than 6 months), the number of prior quit attempts in the past year (categorised as 1, 2, 3 or ≥ 4), whether the quit attempt was planned or occurred immediately the decision to quit was made, and whether the respondent cut down first or stopped abruptly (full details of these items are available at <https://osf.io/2qnef/>). The socio-demographic variables assessed were age, sex, and social grade (ABC1, which includes managerial, professional and intermediate occupations, vs. C2DE, which includes small employers and own-account workers, lower supervisory and technical occupations, and semi-routine and routine occupations, never worked and long-term unemployed). This occupational measure of social grade is a widely used and valid index of SES that is widely used in research in UK populations. It has been identified as particularly relevant in the context of tobacco use and quitting (38) and other addictive behaviours (39). The month and year of survey were also included to take account of seasonal variation in quit attempts (e.g., in January or “Stoptober”) and changes in the availability and regulation of different smoking cessation aids over the study period.

Statistical analyses

Our analysis plan was pre-registered on Open Science Framework (<https://osf.io/7fztg/>). We made two amendments following peer review, which involved: (i) adding covariate-only adjusted models to our primary analyses, to provide additional insight into the effect of separate adjustment components, and (ii) testing interactions with age and sex, to broaden the scope of the moderation analyses and evaluate the extent to which effectiveness of the different cessation aids differs according to these variables.

Bivariate associations between the use of different smoking cessation aids and potential confounders were assessed using *t*-tests for continuous variables and chi-square tests for categorical variables.

We used multiple logistic regression to analyse associations between self-reported abstinence (abstinent yes vs. no) and use of different smoking cessation aids (use of a specific aid vs. no use of that specific aid). Step 1 was a model including all other cessation aids (to estimate the unique association between each cessation aid and abstinence), but no covariates (model 1). Step 2 was a model including covariates, but no other cessation aids (model 2). Step 3 was a model that included all cessation aids plus covariates (model 3). Step 4 was a series of fully-adjusted models in which the two-way interactions between the cessation aids and (i) cigarette addiction (continuous variable), (ii) social grade (ABC1 vs. C2DE), (iii) age (16-44 vs. ≥ 45 years), and (iv) sex (male vs. female) were added. Where there was

evidence of moderation of treatment effectiveness, we reran model 3 in stratified analyses to provide more information as to the nature of the differences between groups. For the purpose of stratified models, we defined low cigarette addiction as a score of 0-2 and high cigarette addiction as a score of 3-5 on the rating of strength of urges to smoke.

To aid in the interpretation of non-significant results, we calculated Bayes factors (planned *a priori*) for non-significant results pertaining to the main effects of cessation aids and interactions with cigarette addiction and social grade. These enabled us to examine whether these associations could best be characterised as evidence of no effect, evidence of an effect, or whether data were insensitive to detect an effect (40,41). For main effects of cessation aids, alternative hypotheses were represented by half-normal distributions and the expected effect size was set to OR=1.5 as a conservative estimate while being in the ballpark of interventions that are known to be effective (14). For interactions, alternative hypotheses were represented by a fully normal distribution (because we did not have strong grounds for directional hypotheses) centred on OR=1.0 with a standard deviation representing OR=1.5 and OR=0.67.

All analyses were performed using SPSS version 25, with complete cases. Respondents with missing data on one or more of the variables were excluded (5.8% of the initial sample).

Results

The study population comprised 18,929 respondents who reported a quit attempt in the last 12 months, of whom 15,949 (84.3%) were current smokers and 2,980 (15.7%) were abstinent at the time of the survey. Demographic and smoking-related characteristics of the full sample are shown in Table 1. A total of 10,581 respondents (55.9%) had used one or more of the smoking cessation aids during their most recent quit attempt. The majority had used NRT bought over the counter (27.5%), followed by e-cigarettes (12.7%), prescription NRT (8.5%), varenicline (5.5%) and face-to-face behavioural support (4.6%). The remainder of cessation aids had been used by <2% of participants. Most participants who reported using a cessation aid reported using just one aid in their most recent quit attempt.

[Table 1 here]

Associations between characteristics of the sample and use of different smoking cessation aids are shown in Table 2. Usage of the different aids varied by age, sex, social grade, level of cigarette addiction, and past quit attempts, but use of almost all the different aids was associated with increased likelihood of making a planned rather than unplanned quit attempt and cutting down prior to the quit date.

[Table 2 here]

Interactions between use of each cessation aid and cigarette addiction, social grade, age, and sex are shown in Table 3. There were significant interactions between level of cigarette addiction and use of telephone support, written self-help materials, and websites; between social grade and use of telephone support and websites; and between age and use of prescription NRT. Associations between use of the other cessation aids and abstinence did not differ significantly by cigarette addiction, social grade, age, or sex. Bayes factors indicated that the majority of non-significant interactions provided moderate evidence for the null hypothesis or, as a result of the small number of participants using certain cessation aids, were insensitive to detect differences in effectiveness between groups (Supplementary Table 1). Exceptions were interactions between cigarette addiction and hypnotherapy, and sex and e-cigarettes, which provided moderate evidence for the experimental hypothesis, and the interaction between age and websites, which provided strong evidence for the experimental hypothesis.

[Table 3 here]

Table 4 presents unadjusted abstinence rates and sequentially adjusted models testing associations between each cessation aid and abstinence. Self-reported abstinence rates were highest among users of e-cigarettes (21.2%), followed by varenicline (20.4%) and websites (18.6%). Analyses that adjusted for use of other cessation aids, but no covariates (model 1, Table 4) indicated that users of e-cigarettes and varenicline were significantly more likely to be abstinent than those who did not use these cessation aids. Users of NRT bought over the counter were significantly less likely to be abstinent, as were younger smokers who used prescription NRT and those from lower social grades who used telephone support. Use of bupropion, face-to-face behavioural support, written self-help materials, websites, and hypnotherapy were not significantly associated with abstinence after adjustment for use of other cessation aids.

After adjustment for sociodemographic variables, cigarette addiction, factors relating to the quit attempt, and month and year of the survey, but excluding other cessation aids (model 2, Table 4), the odds of abstinence were significantly higher among smokers who used e-cigarettes (with a particularly strong association in men) or varenicline, older smokers who used prescription NRT, and smokers from lower social grades who used websites. The odds of abstinence were significantly lower among users of NRT bought over the counter. There was no significant association between use of any other cessation aid and abstinence after adjusting for covariates. A similar pattern of results was observed when use of other cessation aids were adjusted for (model 3, Table 4), the only exception being that the association between NRT bought over the counter and abstinence was no longer statistically significant.

Bayes factors based on results from the fully adjusted model (model 3) indicated that there was moderate to strong evidence of no benefit on abstinence of NRT bought over the counter, telephone

support for smokers with low levels of addiction, written self-help materials for smokers with high levels of addiction, and websites for older smokers and those from lower social grades (Supplementary Table 2). Data were insensitive to detect small effects of prescription NRT, bupropion, and face-to-face behavioural support; telephone support for smokers with high levels of addiction and from higher social grades; written self-help materials for smokers with low levels of addiction; websites for younger smokers and those with low and high levels of addiction; and hypnotherapy for smokers with low and high levels of addiction.

[Table 4 here]

Discussion

Respondents who reported using e-cigarettes, varenicline, prescription NRT (older [≥ 45 y] smokers only), and websites (smokers from lower social grades only) during their most recent quit attempt were significantly more likely to report abstinence than those who did not use these aids after adjustment for age, sex, social grade, month and year of the survey, time since the quit attempt started, number of prior quit attempts in the past year, whether the quit attempt was planned, whether the respondent quit abruptly versus gradually, cigarette addiction, and use of other cessation aids. Use of NRT bought over the counter, bupropion, face-to-face behavioural support, telephone support, written self-help materials, and hypnotherapy were not significantly associated with abstinence in the adjusted analysis. Telephone support and websites were significantly more effective, and written self-help materials were less effective, for smokers with a higher compared with lower level of cigarette addiction. In addition, websites were found to be significantly more effective, and telephone support was significantly less effective, for smokers from lower compared with higher social grades. Prescription NRT was significantly more effective for older compared with younger smokers. There was also some evidence that e-cigarettes were more effective for men than women, websites were less effective for older compared with younger smokers, and hypnotherapy was less effective for smokers with a higher compared with lower level of cigarette addiction.

For the majority of cessation aids, our adjusted ORs were lower than estimates of effectiveness from meta-analyses of RCTs. Consistent with RCT evidence, abstinence rates were higher among smokers who had attempted to quit using e-cigarettes (OR=1.95 vs. 2.29 in RCTs (42)), varenicline (OR=1.82 vs. 2.27 in RCTs (43)) and prescription NRT (OR=1.34 vs. 1.60 in RCTs (44)). However, while face-to-face behavioural support, telephone support, written self-help materials, and websites have been shown to significantly increase abstinence rates in RCTs (with relative risks of 1.24-1.88, 1.37, 1.19 and 1.15, respectively)

(14,15,17,19,45), these aids were not significantly associated with abstinence after adjustment for use of other cessation aids and smoker characteristics in the present analyses (OR=1.20 [0.95-1.50], 0.75 [0.42-1.35], 0.91 [0.63-1.32] and 1.25 [0.81-1.92], respectively). In England, the reality is that the majority of behavioural support is received alongside pharmacotherapy and these results are consistent (even if not significant) with that effect size. Meta-analytic data are not currently available for RCTs of hypnotherapy. A Cochrane review identified 11 RCTs of hypnotherapy, with conflicting results, but did not attempt meta-analysis because there was substantial heterogeneity between studies (46).

While the more popular cessation aids (NRT, e-cigarettes, varenicline, and face-to-face behavioural support) were equally effective across smokers with different levels of cigarette addiction, there were significant interactions between addiction and treatment efficacy for several of the lesser used aids. Use of telephone support and websites was associated with higher abstinence rates among smokers who were more vs. less addicted. A previous secondary analysis of data from the EAGLES trial reported no statistically significant moderation of pharmacotherapies by level of addiction, which is consistent with the current findings and suggests that it is only the effect of behavioural support that is moderated by level of addiction (30). One interpretation is that pharmacotherapy helps with the aspects of cigarette addiction that are experienced almost universally when stopping smoking whereas behavioural support targets and mitigates environments, psychology and behaviour particularly relevant to smokers who self-report greater addiction to cigarettes. Telephone support was also moderated by level of addiction but it was unclear why support should be less effective for more addicted smokers.

The finding that the effectiveness of the majority of smoking cessation aids did not differ across socioeconomic groups is encouraging, but contrasts with previous evidence indicating that mainstream treatments tend to be less effective for disadvantaged smokers (30). The only significant interactions we observed between treatment efficacy and social grade were for telephone support and websites. Consistent with previous studies evaluating the effectiveness of quitline services by socioeconomic status (30), the present results showed that use of telephone support was associated with significantly higher abstinence rates among smokers from higher than lower social grades. We found that while smokers from lower social grades were less likely than those from higher social grades to report use of websites in their most recent quit attempt, effectiveness was higher among the more disadvantaged group. A review across disadvantaged populations reported a relatively sparse literature but found promising quit rates for technology-based interventions (47) including a large RCT (n=4,613) in England, which found an interactive and targeted website was more effective than an information-only website in smokers of low, but not high, SES (48). Less advantaged socioeconomic groups present particular challenges. Websites can allow support to be tailored according to literacy and may help to overcome barriers to access imposed by limited finances and time.

The finding that the majority of mainstream smoking cessation aids appeared equally effective across smokers from different socioeconomic backgrounds is important to understanding the impact of 'individual-level' smoking cessation support on inequalities. The implication is that the well-established finding that support produces substantially higher quit rates in smokers from higher socioeconomic groups is likely attributable to a failure to mitigate differences arising in unsupported smokers rather than differential treatment efficacy (30). An equally important factor is reach. The current study found that the majority of aids were equally popular across social grades with the exception of prescription NRT and e-cigarettes. The difference in the use of e-cigarettes appears to have narrowed more recently (49) and the gradient in prescription NRT may be a priority for primary or secondary care smoking cessation policy. Overall, the implication is that the wide availability and popularity of individual-level smoking cessation support in England is unlikely to have exacerbated health inequalities but is likely to have saved thousands of lives across the social spectrum.

A clear strength of this study is the use of a large, representative sample of the English population. England is a country with the most extensive and comprehensive coverage of medications and behavioural support in the world, and the highest rate of use of these cessation aids (50). Consequently, it is probably the only country where a population-level study of this type could be carried out. Medication and behavioural support is available to all smokers either for free or for a nominal charge. In addition, all forms of NRT can be purchased over the counter. Another strength was the use of aggregated data from monthly surveys over a period of 11.5 years and adjustment for month of survey, which limited potential bias from the fact that the rate of attempts to quit in smokers is different at different times of the year.

There were also a number of limitations. A focus on moderation of the efficacy of aids by level of cigarette addiction and social grade prevented the current study also assessing combinations of support, including face-to-face behavioural support and prescription medication, which produce the highest success rates (4,5,18). We did not examine multi-factor interactions (e.g. between cigarette addiction *and* social grade) with treatment effectiveness. With both of these variables identified as significant moderators of the effectiveness of telephone support and websites, further research would be useful to explore these relationships in more detail. Self-reports of abstinence were not verified biochemically. While this would represent a serious limitation in RCTs because smokers receiving treatment often feel social pressure to report abstinence, in population surveys the social pressure and related rate of misreporting is low and it is generally considered acceptable to rely upon self-reported data (51). Abstinence was assessed by asking respondents whether they were 'still not smoking', with participants classified as abstinent if they had had one or more lapses but resumed not smoking. It is not known whether the rate of lapsing differs according to quitting method, which would represent a significant

limitation, however this measure offers several advantages including assessment of prolonged abstinence, as advocated in the Russell Standard, a clear relationship to the quit attempt in question, and no demand for recall. The assessment of the most recent quit attempt involved recall of the previous 12 months, introducing potential for bias. Another potential limitation is that there was no standardised duration of abstinence. The study design does not enable causal inferences to be drawn, although the results provide important information on the extent to which findings from RCTs generalise to population samples. While we adjusted for a range of potential confounders, residual confounding may have occurred as data on other factors associated with self-selection of cessation aids (e.g. motivation to quit, chronic medical conditions or mental health (52,53)) were not available. The extent to which participants adhered to their chosen cessation aid was also not assessed. Estimates for cessation aids with low prevalence of use (e.g. bupropion, websites) should be interpreted with caution due to the very small absolute number of quitters reporting having used these methods. Bayes factors indicated that data were insensitive to detect significant main effects on abstinence, or significant interactions with cigarette addiction, social grade, age, or sex, for the majority of the cessation aids of interest (Supplementary Tables).

Conclusions

This is the first evidence from a population sample of the comparative real-world effectiveness of all of the main smoking cessation aids. Use of e-cigarettes, varenicline, or prescription NRT was found to increase the chances of successful quitting, but there was limited evidence that other cessation aids independently promoted abstinence in adjusted models. It is also the first study to evaluate the extent to which treatment efficacy is moderated by level of cigarette addiction and social grade in a real-world setting, providing useful insight that could enable treatment providers to tailor advice on which cessation aids may be most likely to help the user to achieve abstinence. While the majority of mainstream smoking cessation aids appeared to be equally effective across smokers with varying levels of addiction and from different socioeconomic backgrounds, telephone support and websites were found to be more effective, and written self-help materials were less effective, among smokers who were more addicted, and websites were more effective and telephone support was less effective among smokers who were more deprived. In addition, prescription NRT was found to be more effective among older smokers. Healthcare professionals should consider these factors when making decisions about how best to support smokers in a quit attempt.

Declarations

Ethics approval and consent to participate

Ethical approval for the Smoking Toolkit Study was granted originally by the UCL Ethics Committee (ID 0498/001) and participants provided full informed consent. The data are not collected by UCL and are anonymised when received by UCL.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

JB received unrestricted research funding from Pfizer, who manufacture smoking cessation medications. RW undertakes research and consultancy for and receives travel funds and hospitality from manufacturers of smoking cessation medications (Pfizer, GlaxoSmithKline and Johnson and Johnson). All authors declare no financial links with tobacco companies or e-cigarette manufacturers or their representatives.

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Authors' contributions

SEJ, DK, RW and JB conceived and designed the study. SEJ analysed and interpreted the data and drafted the manuscript. DK, RW and JB revised the manuscript critically for intellectual content. All authors read and approved the final manuscript.

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Tables

Table 1 Sample characteristics ($n=18929$)

Demographic characteristics¹	
Age in years	
16-24	20.4 (3862)
25-34	23.3 (4403)
35-44	20.2 (3815)
45-54	15.8 (2994)
55-64	11.7 (2207)
65+	8.7 (1648)
Female sex	52.0 (9845)
Social grade C2DE	62.9 (11906)
Smoking characteristics	
Currently abstinent	15.7 (2980)
Strength of urges to smoke ² , mean (SD) ³	1.95 (1.18)
Time since the quit attempt started	
≤1-26 weeks	62.8 (11896)
26-52 weeks	37.2 (7033)
Number of prior quit attempts in the past year	
1	65.3 (12353)
2	21.2 (4014)
3	7.4 (1399)
4 or more	6.1 (1163)
Planned attempt	46.9 (8887)
Abrupt attempt (no cutting down first)	55.3 (10465)
Use of smoking cessation aids	
Prescription NRT ⁴	8.5 (1600)
NRT bought over the counter	27.5 (5206)
Varenicline	5.5 (1039)
Bupropion	1.6 (307)
E-cigarettes	12.7 (2397)
Face-to-face behavioural support	4.6 (876)
Telephone support	0.9 (162)
Written self-help materials	1.6 (309)
Websites	1.1 (204)
Hypnotherapy	0.8 (156)
None of the above	44.1 (8348)
Number of cessation aids used	
0	44.1 (8348)
1	49.1 (9298)
2	5.4 (1014)
3	1.0 (189)
≥4	0.4 (80)

¹ Figures are presented as percentage (n), unless stated otherwise.

² Strength of urges to smoke: 0 (no urges) to 5 (extremely strong urges).

³ SD = standard deviation.

⁴ NRT = nicotine replacement therapy.

Table 2 Associations between characteristics of the sample and use of different smoking cessation aids

	NRT Rx			NRT OTC			Varenicline			Bupropion		
	Yes (n=1600)	No (n=17329)	<i>p</i>	Yes (n=5206)	No (n=13723)	<i>p</i>	Yes (n=1039)	No (n=17890)	<i>p</i>	Yes (n=307)	No (n=18622)	<i>p</i>
Demographic characteristics												
Age												
16-24	11.9	21.2	<0.001	15.2	22.4	<0.001	6.9	21.2	<0.001	6.2	20.6	<0.001
25-34	19.1	23.6	-	21.2	24.1	-	21.3	23.4	-	13.7	23.4	-
35-44	20.6	20.1	-	23.5	18.9	-	25.0	19.9	-	27.7	20.0	-
45-54	18.8	15.5	-	18.4	14.8	-	21.4	15.5	-	23.1	15.7	-
55-64	17.4	11.1	-	12.8	11.2	-	15.4	11.4	-	19.5	11.5	-
65+	12.2	8.4	-	8.9	8.6	-	10.0	8.6	-	9.8	8.7	-
Female	58.9	51.4	<0.001	46.4	48.6	0.006	55.1	51.8	0.037	55.0	52.0	0.283
Social grade C2DE	69.4	62.3	<0.001	63.8	62.6	0.125	62.7	62.9	0.868	67.4	62.8	0.098
Smoking characteristics												
Strength of urges to smoke, mean (SD)	1.92 (1.18)	2.30 (1.21)	<0.001	2.19 (1.13)	1.86 (1.19)	<0.001	2.11 (1.27)	1.94 (1.18)	<0.001	2.36 (1.14)	1.94 (1.18)	<0.001
Time since the quit attempt started												
≤1-26 weeks	60.0	63.1	0.014	63.5	62.6	0.262	57.4	63.2	<0.001	55.4	63.0	0.006
26-52 weeks	40.0	36.9	-	36.5	37.4	-	42.6	36.8	-	44.6	37.0	-
Number of prior quit attempts in the past year												
1	65.2	65.3	0.998	62.9	66.2	<0.001	71.6	64.9	<0.001	58.6	65.4	0.005
2	21.3	21.2	-	22.3	20.8	-	18.9	21.3	-	28.0	21.1	-
3	7.4	7.4	-	8.3	7.0	-	6.3	7.5	-	5.2	7.4	-
4 or more	6.1	6.2	-	6.5	6.0	-	3.3	6.3	-	8.1	6.1	-
Planned attempt	56.9	46.0	<0.001	52.2	44.9	<0.001	66.0	45.8	<0.001	63.2	46.7	<0.001
Abrupt attempt (no cutting down first)	54.6	55.4	0.543	53.6	55.9	0.005	42.0	56.1	<0.001	44.0	55.5	<0.001

Figures are presented as percentages, unless stated otherwise. Strength of urges to smoke: 0 (no urges) to 5 (extremely strong urges).

NRT = nicotine replacement therapy; SD = standard deviation.

Table 2 continued

	E-cigarettes			Face-to-face behavioural support			Telephone support			Written self-help materials		
	Yes (n=2397)	No (n=16532)	<i>p</i>	Yes (n=876)	No (n=18053)	<i>p</i>	Yes (n=162)	No (n=18767)	<i>p</i>	Yes (n=309)	No (n=18620)	<i>p</i>
Demographic characteristics												
Age												
16-24	20.6	20.4	0.018	11.4	20.8	<0.001	17.3	20.4	0.900	13.3	20.5	0.009
25-34	23.5	23.2	-	18.8	23.5	-	24.1	23.3	-	29.8	23.2	-
35-44	19.1	20.3	-	20.9	20.1	-	22.8	20.1	-	22.0	20.1	-
45-54	16.2	15.8	-	19.2	15.7	-	16.7	15.8	-	16.8	15.8	-
55-64	13.2	11.4	-	18.4	11.3	-	11.1	11.7	-	9.7	11.7	-
65+	7.3	8.9	-	11.3	8.6	-	8.0	8.7	-	8.4	8.7	-
Female	49.3	52.4	0.004	62.9	51.5	<0.001	56.8	52.0	0.221	55.3	52.0	0.238
Social grade C2DE	58.1	63.6	<0.001	64.6	62.8	0.282	61.7	62.9	0.757	48.9	63.1	<0.001
Smoking characteristics												
Strength of urges to smoke, mean (SD)	1.94 (1.22)	1.95 (1.18)	0.740	2.20 (1.19)	1.94 (1.18)	<0.001	2.24 (1.19)	1.95 (1.18)	0.002	1.97 (1.20)	1.95 (1.18)	0.731
Time since the quit attempt started												
≤1-26 weeks	66.9	62.3	<0.001	54.1	63.3	<0.001	62.3	62.8	0.895	60.2	62.9	0.331
26-52 weeks	33.1	37.7	-	45.9	36.7	-	37.7	37.2	-	39.8	37.1	-
Number of prior quit attempts in the past year												
1	66.6	65.1	0.239	66.3	65.2	0.013	55.6	65.3	0.016	62.5	65.3	0.308
2	20.7	21.3	-	18.6	21.3	-	28.4	21.1	-	20.7	21.2	-
3	6.5	7.5	-	6.7	7.4	-	6.2	7.4	-	10.0	7.3	-
4 or more	6.2	6.1	-	8.3	6.0	-	9.9	6.1	-	6.8	6.1	-
Planned attempt	49.8	46.5	0.003	60.3	46.3	<0.001	56.8	46.9	0.012	57.0	46.8	<0.001
Abrupt attempt (no cutting down first)	50.7	56.0	<0.001	51.1	55.5	0.012	46.9	55.4	0.031	51.1	55.4	0.139

Figures are presented as percentages, unless stated otherwise. Strength of urges to smoke: 0 (no urges) to 5 (extremely strong urges). NRT = nicotine replacement therapy; SD = standard deviation.

Table 2 continued

	Websites			Hypnotherapy		
	Yes (n=204)	No (n=18725)	<i>p</i>	Yes (n=156)	No (n=18773)	<i>p</i>
Demographic characteristics						
Age						
16-24	25.5	20.3	0.001	3.2	20.5	<0.001
25-34	31.4	23.2	-	17.3	23.3	-
35-44	20.1	20.2	-	28.2	20.1	-
45-54	12.7	15.9	-	21.2	15.8	-
55-64	7.8	11.7	-	17.9	11.6	-
65+	2.5	8.8	-	12.2	8.7	-
Female	47.1	52.1	0.155	56.4	52.0	0.269
Social grade C2DE	46.1	63.1	<0.001	46.8	63.0	<0.001
Smoking characteristics						
Strength of urges to smoke, mean (SD)	1.92 (1.18)	1.95 (1.18)	0.719	2.06 (1.32)	1.95 (1.18)	0.232
Time since the quit attempt started						
≤1-26 weeks	61.8	62.9	0.748	47.4	63.0	<0.001
26-52 weeks	38.2	37.1	-	52.6	37.0	-
Number of prior quit attempts in the past year						
1	55.4	65.4	0.016	63.5	65.3	0.958
2	26.0	21.2	-	21.8	21.2	-
3	8.8	7.4	-	8.3	7.4	-
4 or more	9.8	6.1	-	6.4	6.1	-
Planned attempt	61.3	46.8	<0.001	53.8	46.9	0.083
Abrupt attempt (no cutting down first)	37.3	55.5	<0.001	69.9	55.2	<0.001

Figures are presented as percentages, unless stated otherwise. Strength of urges to smoke: 0 (no urges) to 5 (extremely strong urges).

NRT = nicotine replacement therapy; SD = standard deviation.

Table 3 Interactions between use of smoking cessation aids and cigarette addiction and social grade

	Cigarette addiction OR [95% CI]	Social grade OR [95% CI]	Age OR [95% CI]	Sex OR [95% CI]
Prescription NRT	1.10 [0.94-1.29]	0.95 [0.67-1.34]	1.51 [1.08-2.11]*	0.96 [0.69-1.35]
NRT bought over the counter	1.05 [0.94-1.16]	0.95 [0.76-1.18]	1.13 [0.91-1.39]	0.91 [0.73-1.12]
Varenicline	0.95 [0.80-1.13]	0.94 [0.64-1.37]	1.05 [0.73-1.52]	1.02 [0.70-1.48]
Bupropion	1.27 [0.87-1.84]	1.53 [0.66-3.57]	0.70 [0.32-1.54]	1.09 [0.50-2.40]
E-cigarettes	1.12 [1.00-1.26]	1.13 [0.88-1.45]	0.93 [0.73-1.20]	0.78 [0.61-1.00]
Face-to-face behavioural support	1.13 [0.92-1.38]	1.32 [0.84-2.07]	1.24 [0.80-1.93]	1.18 [0.75-1.86]
Telephone support	1.64 [1.03-2.61]*	0.30 [0.09-0.99]*	1.99 [0.61-6.45]	0.58 [0.18-1.87]
Written self-help materials	0.57 [0.37-0.90]*	1.02 [0.48-2.13]	1.00 [0.47-2.14]	1.55 [0.72-3.35]
Websites	1.68 [1.16-2.43]**	2.79 [1.19-6.54]*	0.37 [0.13-1.09]	1.92 [0.81-4.54]
Hypnotherapy	0.61 [0.34-1.09]	1.73 [0.62-4.88]	1.32 [0.47-3.70]	1.86 [0.63-5.49]

OR = odds ratio; CI = confidence interval; NRT = nicotine replacement therapy.

Each OR and 95% CI is for the interaction between using the smoking cessation aid and degree of cigarette addiction or social grade. Higher ORs indicate greater effectiveness (and lower ORs indicate lower effectiveness) of the smoking cessation aid among those with a higher level of cigarette addiction (per point increase), lower social grade, older age, or women.

All values are adjusted for use of all other smoking cessation aids, age, sex, social grade, strength of urges to smoke, time since the quit attempt started, number of prior quit attempts in the past year, whether the quit attempt was planned, whether the respondent quit abruptly versus gradually, and month and year of the survey.

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 4 Associations between use of smoking cessation aids and abstinence

	Unadjusted abstinence (%)	Model 1 OR [95% CI]	Model 2 OR [95% CI]	Model 3 OR [95% CI]
No aid	16.8	-	0.75 [0.69-0.83]***	-
Prescription NRT ¹	14.1	0.88 [0.76-1.02]	1.28 [1.08-1.52]**	1.34 [1.12-1.59]**
Age 16-44 years	11.9	0.69 [0.55-0.87]***	1.05 [0.82-1.36]	1.09 [0.85-1.42]
Age ≥45 years	16.5	1.04 [0.85-1.28]	1.50 [1.19-1.88]**	1.58 [1.25-2.00]***
NRT bought over the counter	11.6	0.68 [0.61-0.75]***	0.88 [0.79-0.99]*	0.98 [0.87-1.09]
Varenicline	20.4	1.31 [1.11-1.54]**	1.67 [1.38-2.01]***	1.82 [1.51-2.21]***
Bupropion	11.7	0.74 [0.52-1.05]	1.23 [0.83-1.81]	1.27 [0.86-1.89]
E-cigarettes ²	21.2	1.49 [1.34-1.67]***	1.86 [1.62-2.13]***	1.95 [1.69-2.24]***
Men	24.3	1.76 [1.51-2.04]***	2.15 [1.78-2.60]***	2.26 [1.87-2.74]***
Women	18.1	1.25 [1.06-1.47]**	1.58 [1.29-1.94]***	1.66 [1.35-2.04]***
Face-to-face behavioural support	15.4	1.02 [0.84-1.24]	1.24 [1.00-1.55]	1.20 [0.95-1.50]
Telephone support ^{3,4}	11.1	0.66 [0.39-1.12]	0.83 [0.47-1.47]	0.75 [0.42-1.35]
Low cigarette addiction	10.3	0.57 [0.30-1.07]	0.60 [0.29-1.21]	0.51 [0.25-1.06]
High cigarette addiction	12.3	1.48 [0.58-3.77]	1.62 [0.63-4.14]	1.67 [0.64-4.37]
Social grade ABC1	17.7	1.01 [0.51-2.00]	1.52 [0.70-3.32]	1.57 [0.70-3.49]
Social grade C2DE	7.0	0.44 [0.19-1.00]	1.07 [0.89-1.28]	0.40 [0.16-0.99]*
Written self-help materials ³	16.8	0.91 [0.66-1.26]	0.92 [0.64-1.32]	0.91 [0.63-1.32]
Low cigarette addiction	22.5	1.05 [0.74-1.47]	1.06 [0.71-1.57]	1.07 [0.71-1.60]
High cigarette addiction	3.3	0.15 [0.02-1.11]	0.17 [0.02-1.22]	0.16 [0.02-1.15]
Websites ^{3,4,5}	18.6	1.07 [0.73-1.57]	1.19 [0.78-1.83]	1.25 [0.81-1.92]
Age 16-44 years	18.5	1.23 [0.80-1.88]	1.42 [0.88-2.28]	1.54 [0.95-2.49]

Age ≥45 years	19.1	0.74 [0.31-1.76]	0.62 [0.24-1.62]	0.56 [0.21-1.49]
Low cigarette addiction	21.6	0.94 [0.62-1.43]	1.08 [0.66-1.77]	1.15 [0.70-1.87]
High cigarette addiction	9.8	1.97 [0.76-5.09]	2.15 [0.82-5.60]	2.51 [0.93-6.75]
Social grade ABC1	20.0	0.73 [0.40-1.38]	0.73 [0.40-1.35]	0.74 [0.40-1.38]
Social grade C2DE	17.0	1.46 [0.86-2.49]	2.14 [1.18-3.87]*	2.20 [1.22-3.98]**
Hypnotherapy ⁶	17.3	0.92 [0.58-1.44]	0.81 [0.48-1.35]	0.84 [0.50-1.40]
Low cigarette addiction	24.3	1.06 [0.66-1.72]	0.85 [0.48-1.51]	0.92 [0.52-1.63]
High cigarette addiction	2.0	0.34 [0.05-2.49]	0.30 [0.04-2.22]	0.31 [0.04-2.31]

OR = odds ratio; CI = confidence interval; NRT = nicotine replacement therapy. Low cigarette addiction = score of 0-2 on strength of urges to stop scale; high cigarette addiction = score of 3-5 on strength of urges to stop scale.

Model 1 = multivariable model including all smoking cessation aid variables, but no covariates.

Model 2 = multivariable model including all covariates (age, sex, social grade, strength of urges to smoke, time since the quit attempt started, number of prior quit attempts in the past year, whether the quit attempt was planned, whether the respondent quit abruptly versus gradually, and month and year of the survey), but no other smoking cessation aid variables.

Model 3 = fully adjusted multivariable model including all covariates and all smoking cessation aid variables..

Each OR and 95% CI is for using the smoking cessation aid in question relative to not using that smoking cessation aid.

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

¹ Interactions showed effectiveness differed significantly by age (Table 4).

² Bayes factor indicated that the data provided moderate evidence of differing effectiveness by sex (Supplementary Table 1) despite the interaction not reaching statistical significance (Table 4).

³ Effectiveness differed significantly by level of cigarette addiction (Table 4).

³ Effectiveness differed significantly by social grade (Table 4).

⁵ Bayes factor indicated that the data provided strong evidence of differing effectiveness by sex (Supplementary Table 1) despite the interaction not reaching statistical significance (Table 4).

⁶ Bayes factor indicated that the data provided moderate evidence of differing effectiveness by level of cigarette addiction (Supplementary Table 1) despite the interaction not reaching statistical significance (Table 4).

