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Are population trends in high-risk alcohol consumption in smokers associated with trends in quit attempts and quit success? A time series analysis

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2019-034262
Article Type:	Original research
Date Submitted by the Author:	12-Sep-2019
Complete List of Authors:	Beard, Emma; UCL, Brown, Jamie; University College London, Psychology & Language Sciences West, Robert; UCL Michie, Susan; University College London, Centre for Outcomes Research and Effectiveness
Keywords:	time-series, tobacco, alcohol, high-risk drinking, quit attempts

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3 **Are population trends in high-risk alcohol consumption in smokers associated**
4 **with trends in quit attempts and quit success? A time series analysis**
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7 Version 1
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32 To submit to: BMJ OPEN
33

34 Short title: Population trends in high-risk alcohol consumption among smokers
35

36 Word count: 2,440
37
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41
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43 Key words: time-series, tobacco, alcohol, high-risk drinking, quit attempts
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Abstract

Objectives: Monthly changes in the prevalence of high-risk drinking and smoking in England appear to be positively correlated. This study aimed to assess how far monthly changes in high-risk drinking were specifically associated with attempts to stop smoking and success of quit attempts.

Design: Data were used from the Alcohol and Smoking Toolkit Studies between April 2014 and June 2018. These involve monthly household face-to-face surveys of representative samples of ~1800 adults.

Setting: England

Participants: Data were aggregated on 88,122 participants over the study period.

Primary and secondary outcome measures: ARIMAX modelling was used to assess the association over time between monthly prevalence of high-risk drinking among smokers and a) prevalence of attempts to quit smoking and b) prevalence of successful quit attempts in those attempting to quit. Bayes Factors (BF) were calculated to compare the null hypothesis with the hypothesis of an effect sufficiently large ($\beta=0.6$) to explain the established association between overall prevalence in smoking and high-risk drinking.

Results: No statistically significant associations were found between monthly changes in prevalence of high-risk drinking among smokers and attempts to quit smoking ($\beta=0.156$, 95%CI -0.079 to 0.391, $p=0.194$) or quit success ($\beta=0.066$, 95%CI -0.524 to 0.655, $p=0.827$). Bayes Factors (BF) indicated that the data were insensitive but suggested there is weak evidence for the null hypothesis in the case of both quit attempts (BF=0.80) and quit success (BF=0.53).

Conclusions: Monthly changes in prevalence of high-risk alcohol consumption in England are not clearly associated with changes in quit attempt or quit success rates.

Strengths and limitations of this study

- This is the first time series study to assess how far monthly changes in high-risk drinking are associated with attempts to stop smoking and success of quit attempts.

- This study uses a large representative sample of the population in England.
- In countries with weaker tobacco control different effects may be observed.
- Data are observational and so strong conclusions regarding cause and effect cannot be made.

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Background

In England, around 15% of the population are smokers and 20% drink alcohol at high-risk levels, i.e. levels which are likely to cause harm (1, 2). Both are associated with a number of preventable conditions and appear to have an accumulative effect on the risk of mortality(3). The association between high-risk drinking and smoking has been well established at an individual level. High-risk drinkers are substantially more likely to smoke (4-8) and smokers who report starting a quit attempt also report lower alcohol consumption (9, 10). Attempts to quit smoking are also less successful among those with an alcohol use disorder(11-13). Such associations may arise by a number of mechanisms. For example, smokers drinking at high-risk levels may follow advice that it is important to restrict alcohol consumption when they quit(9, 14-16), alcohol and smoking appear to provide cues to lapses for the other and there may be pharmacological interactions between nicotine and alcohol (17-19). This is contrary to the popular notion of self-medication and reward seeking with people deprived of cigarettes compensating by increasing their use of alcohol (20).

It is important to identify whether similar patterns exist at a population level. An association in either direction could mean that policies that reduce smoking prevalence may have the added benefit of reducing high-risk drinking or vice versa. In England, since 2014 monthly data have been gathered on high-risk drinking, smoking status, attempts to quit smoking and quit success (21). Recently, we used these data to examine population-level associations over time between smoking and high-risk drinking and showed that monthly changes in prevalence of smoking in England were associated positively with prevalence of high-risk drinking. However, there were no significant associations between motivation to stop and motivation to reduce alcohol consumption, or attempts to quit smoking and attempts to reduce alcohol consumption(22). We found the combination of results surprising and suggested that the association with overall prevalence may be related to an unmeasured variable that accounted for the change in both smoking and high-risk drinking. Alternatively, the failure to find an overall association between motivation and attempts for each

behaviour may be an issue of power when focussing on the global association between subsamples that represented only a fifth of the overall sample.

This study attempted to resolve this apparent contradiction and extend these findings by relying on the assessment of specific trends expected to be more strongly related, if the association between the prevalence of smoking and high-drinking is causal. Specifically, we will assess whether changes in trends of excessive alcohol consumption *among smokers* are associated with trends in attempts to quit smoking and quit success. If no association is found, this would support the conclusion of a third unmeasured variable associated with both smoking and high-risk drinking.

This study addressed the following research questions:

1. Is there an association in England between increases or decreases in monthly prevalence of high-risk drinking among smokers and attempts to quit smoking?
2. Is there an association in England between increases or decreases in monthly prevalence of high-risk drinking among smokers and quit success rates?

Methods

Study design

Data were used from the Smoking and Alcohol Toolkit Studies (STS and ATS) collected between April 2014 and June 2018. The STS and ATS are ongoing studies that involve a series of monthly cross-sectional household, face-to-face, computer assisted surveys of representative samples of ~1800 adults in England aged 16+. Thus, the same participants take part in both surveys. The respondents are recruited using a type of random location sampling, which is a hybrid between random probability and simple quota sampling. England is first split into over 170000 'Output Areas', comprising of approximately 300 households. These areas are then stratified according to

1
2 ACORN characteristics and geographic region (<http://www.caci.co.uk/acorn/>) and are randomly
3
4 allocated to interviewers. Interviewers visit households within their allocated locality starting at a
5
6 random point in the area. One member per household is interviewed until interviewers achieve local
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8 quotas designed to minimise differences in the probability of participation. Participants appear to be
9
10 representative of the population in England, having similar socio-demographic composition and
11
12 smoking characteristics to large national surveys based on probability samples such as the Health
13
14 Survey for England (23), while drinking characteristics also appear similar at a regional level to
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16 other national surveys (24). For further details see: www.smokinginengland.info and
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18 www.alcoholinengland.info and the published protocol (21, 23).
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25 *Participants*

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27 Data were collected on 88,122 participants over the study period. Of these, 19.94% (95%CI 19.67
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29 to 20.20 n=17,560) reported that they had smoked in the past year. Data from these participants
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31 were aggregated monthly and this forms the basis of the sample in this paper.
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36 *Measures*

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38 Participants were asked whether they smoked or had smoked cigarettes (including hand-rolled)
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40 daily or non-daily in the past year and to complete the Alcohol Use Disorders Identification Test
41
42 (AUDIT) (25). The AUDIT identifies people who could be classed as dependent, harmful or
43
44 hazardous drinkers and has demonstrated validity, high internal consistency and good test-retest
45
46 reliability across gender, age and cultures (26-29). Those scoring 8 or more were classed as high-
47
48 risk drinkers. This is a common threshold for high-risk drinkers (27, 30-32). The prevalence of
49
50 high-risk alcohol consumption among smokers in each month was obtained by counting the number
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52 smokers reporting an AUDIT score greater than or equal to 8.
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59 Past year smokers were then asked:
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- 1
2 1. “How many serious attempts to stop smoking have you made in the last 12 months? By
3 serious attempt I mean you decided that you would try to make sure you never smoked
4 again. Please include any attempt that you are currently making and please include any
5 successful attempt made within the last year”.
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11 2. “How long did your most recent serious quit attempt last before you went back to
12 smoking?”
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18 The prevalence of quit attempts in monthly were calculated as the number of respondents who
19 reported having made one or more quit attempts in the past 12 months divided by the number of
20 past year smokers. The success rate in each quarter was calculated as the number of respondents
21 reporting that they were still not smoking divided by the number reporting having made a quit
22 attempt.
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32 *Analysis*

33 The analysis plan, data and syntax were preregistered on the Open Science Framework
34 (<https://osf.io/384gx/>). Cases with missing data on either smoking or drinking variables were
35 classified as missing in calculating the prevalence figures: smoking status (n=55; %=0.06), high-
36 risk drinking status among smokers (n=202; %=1.17) and quit attempts among smokers (n=562;
37 %=3.24). All data were analysed in R studio.
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48 Data were weighted (see (23) for further details) to match the population in England and analysed
49 using Autoregressive Integrated Moving Average with Exogeneous Input (ARIMAX) modelling to
50 assess the association between prevalence of high risk drinking among smokers and 1) prevalence
51 of attempts to quit smoking and 2) prevalence of successful attempts to quit smoking among those
52 having made a quit attempt. ARIMAX is an extension of autoregressive integrated moving average
53 analysis (ARIMA), which produces forecasts based upon prior values in the time series
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1
2 (Autoregressive terms; AR) and the errors made by previous predictions (Moving Average terms;
3
4 MA). We followed a standard ARIMAX modelling approach (33).
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9 The ARIMAX assumption of weak exogeneity was met: past prevalence of quit attempts ($p=0.747$)
10
11 and quit success ($p=0.999$) did not statistically predict future prevalence of high-risk drinking
12
13 among smokers. No outliers were identified in any of the series using an approach based on that
14
15 described by Chen and Liu(34, 35). To stabilise the variance the series were log-transformed. The
16
17 Augmented Dickey-Fuller test and visual inspection of the plots indicated that first order
18
19 differencing was required for both time series. First order differencing involves calculating the
20
21 change between one observation and the next. No additional seasonal differencing was required
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24
25 (36).
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29
30 The autocorrelation and partial autocorrelation functions were examined to determine the non-
31
32 seasonal MA and AR terms. These suggested an ARIMAX(0,1,1) model for the time series
33
34 predicting both prevalence of quit attempts and prevalence of quit success. This was confirmed by
35
36 comparing models with different specifications using the AIC. To identify the most appropriate
37
38 transfer function for the continuous explanatory variables the sample cross-correlation function was
39
40 checked and models with varying distributed lags compared using the Akaike Information
41
42 Criterion. This suggested a lag of 0 when predicting the prevalence of quit attempts and predicting
43
44 the prevalence of quit success, thus only current values and not lagged (past period) values of the
45
46 input series were used to predict current values of the output series. In our previous study,
47
48 prevalence of smoking was found to be associated with high-risk drinking with a distributed lag of 2
49
50 (22). Thus, additional sensitivity analyses were run with the output series lagged by an order of 2
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55 i.e. the time base was shifted back by 2 months.
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2 The Ljung-Box test for white noise showed that the residuals for both fitted models were free of
3 serial correlation. A number of additional model checks were also made. First, the autocorrelation
4 terms included in the model were checked for their statistical significance. Secondly, it was
5 determined whether the model residuals were normally distributed, random and independent.
6
7 Finally, that the inclusion of the MA term conformed to the bounds of invertibility i.e. its value was
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9 <1 (33, 34).
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18 Bayes factors (BFs) were derived for non-significant findings using an online calculator to
19 disentangle whether there is evidence for the null hypothesis of no effect ($BF < 1/3rd$) or the data are
20 insensitive (BF between $1/3rd$ and 3) (37, 38). A half-normal distribution was assumed with a
21 percentage change in the outcomes of interest for every percentage increase in the input series of
22 0.6%. This is on the basis of a previous study showing that smokers who had made a quit attempt
23 were around 40% less likely to report that they were high risk drinkers (9). Strengthening the
24 Reporting of Observational Studies in Epidemiology (STROBE) guidelines for the reporting of
25 observational studies were followed throughout (39).
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39 **Patient involvement**

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41 No patients were involved in setting the research question or the outcome measures, nor were they
42 involved in developing plans for recruitment, design, or implementation of the study. No patients
43 were asked to advise on interpretation or writing up of results. There are no plans to disseminate the
44 results of the research directly to study participants or any specific patient community.
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52 **Results**

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54 Figure 1 shows the raw time series data from 2014 to 2018. Prevalence of high-risk drinking among
55 smokers declined from 26.9% (95% CI 22.34 to 32.03) in 2014 to 23.7% (95% CI 19.26 to 28.87)
56
57 in June 2018. Attempts to quit smoking also declined from 38.1% (95%CI 32.86 to 43.66) to 28.5%
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1
2 (95%CI 23.60 to 33.90) and quit success from 19.6% (95%CI 13.22 to 27.87) to 9.4% (95%CI 4.51
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4 to 17.95) in June 2018.
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9 Tables 1 shows the results of the ARIMAX models assessing the association between prevalence of
10
11 high-risk drinking among smokers and (1) quit attempts and (2) quit success. The findings were
12
13 inconclusive as to whether any associations were present. BFs suggested that there is anecdotal
14
15 evidence for the null hypothesis that prevalence of high-risk drinking among smokers is not
16
17 associated with prevalence of quit attempts and prevalence of quit success. Findings were similar
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19 when a 2 month back shifted lag was used for prevalence of quit attempts and quit success.
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25 **Discussion**

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27 To our knowledge, this is the first empirical study to estimate the population association between
28
29 high-risk drinking among smokers and attempts to quit smoking and the success of those attempts.
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31 There was weak evidence that there was no substantial association between changes in the
32
33 prevalence of high-risk drinking and quit attempts and quit success.
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38 These findings appear to be at odds with individual level studies which suggest that smokers with
39
40 an alcohol use disorder are less likely to attempt and succeed in stopping smoking (12, 13). Alcohol
41
42 consumption during attempts at smoking cessation is also associated with a greater risk of relapse
43
44 (14). As a result, smokers are often advised to lower their alcohol consumption when they attempt
45
46 to quit smoking(9). Of course, it remains plausible that high-risk drinking among smokers may still
47
48 be associated with a small effect on mean population prevalence of quit attempts and their success,
49
50 but it was not possible to detect this in the current study. An association may also be masked by
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52 factors impacting at a population level which were not accounted for in the current study. Although
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54 we are unaware of any major population-level interventions or other events during the study period
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56 which may have affected the associations under investigation, we cannot rule out residual
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58 confounding. There may also be some statistical bias due to the loss of power and sensitivity that
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1
2 comes with aggregating data. Prevalence of high-risk drinking among smokers will also be
3
4 somewhat noisier than if prevalence was also assessed among non-smokers, given the smaller
5
6 sample size involved in estimation.
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10 These findings suggest that the previously identified positive association between prevalence of
11
12 smoking and prevalence of high-risk drinking is unlikely to be causal, whereby smokers attempting
13
14 to quit, and those succeeding, also reduce their alcohol intake (22). Although it remains possible
15
16 that use of alcohol by smokers impacts on other key indices including longer term abstinence, the
17
18 small proportion of smokers who relapse long term (i.e. after a year) could not account for the size
19
20 of association noted. It may instead be that overall prevalence is related to an unmeasured variable,
21
22 perhaps economic factors and sociocultural events, that account for the change in both smoking and
23
24 high-risk drinking. For example, in recent years taxation on cigarettes and alcohol have increased
25
26 linearly, driving down sales of both (40, 41). There have also been substantial fluctuations in
27
28 average household income since 2013, which have been shown to independently affect smoking and
29
30 alcohol consumption (42-44). Sporting events such as the Olympics may also concurrently increase
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32 alcohol and tobacco intake as they are celebratory occasions.
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39 A strength of this study is the use of a large representative sample of the population in England.
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41 Several limitations need to be considered. First, the ATS required participants to recall their alcohol
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43 consumption and attempts to quit smoking which is likely to have been somewhat inaccurate due to
44
45 recall bias and social desirability. For example, it has been found that a large proportion of
46
47 unsuccessful quit attempts fail to be reported, particularly if they only last a short time or occurred
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49 longer ago(45). However, social pressure in population surveys tends to be low and so it is
50
51 generally considered acceptable to rely on self-report data(46). Second, these findings may not
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53 generalise to other countries. England has a strong tobacco-control climate. In countries with
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55 weaker tobacco control or different alcohol control policies, different effects may be observed.
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Conclusion

These findings suggest that the previously identified positive association between prevalence of smoking and prevalence of high-risk drinking is unlikely to be causal, whereby smokers attempting to quit, and those succeeding, also reduce their alcohol intake. Instead, it may be that overall prevalence is related to an unmeasured third variable such as economic factors and sociocultural events.

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List of abbreviations

ARIMAX - autoregressive integrated moving average with exogenous input

BF – Bayes Factor

ATS – Alcohol Toolkit Study

STS – Smoking Toolkit Study

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Table 1: Estimated percentage point changes in proportion of quit attempts and proportion of quitters who met criteria for quit success during the study period, based on autoregressive integrated moving average with exogenous input (ARIMAX) models

		Output series					
		Quit attempts ¹			Quit success ²		
Input series		Percentage change per 1% change in the exposure	95%CI	p	Percentage change per 1% change in the exposure	95%CI	p
	Model 1: High-risk drinking among smokers (no backward lag of the output series)	0.156	-0.079 to 0.391	0.194	0.066	-0.524 to 0.655	0.827
	Model 2: High-risk drinking among smokers (two month backward lag of the output series)	0.065	-0.183 to 0.313	0.608	0.134	-0.469 to 0.736	0.663
	Bayes Factor						
	Model 1	0.80			0.53		
	Model 2	0.33			0.64		

Declarations

Ethical approval and consent to participate

Ethics approval for the Smoking Toolkit Survey (STS) was originally granted by the UCL Ethics Committee (ID 0498/001) and approval for the ATS was granted by the same committee as an extension of the STS (ID 2808/005). In accordance with our ethical approval, all respondents were given a written information sheet about the study, and provided informed verbal consent

Availability of data and material

The analysis plan, data and syntax were preregistered on the Open Science Framework (<https://osf.io/384gx/>).

Funding

The Smoking Toolkit Study is currently primarily funded by Cancer Research UK (C1417/A14135; C36048/A11654; C44576/A19501) and has previously also been funded by Pfizer, GSK, and the Department of Health. The ATS is currently funded by the NIHR School for Public Health Research (SPHR) (SPHR-SWP-ALC-WP5). SPHR is a partnership between the Universities of Sheffield; Bristol; Cambridge; Exeter; UCL; The London School for Hygiene and Tropical Medicine; the LiLaC collaboration between the Universities of Liverpool and Lancaster and Fuse; The Centre for Translational Research in Public Health, a collaboration between Newcastle, Durham, Northumbria, Sunderland and Teesside Universities. The views expressed are those of the authors(s) and not necessarily those of the NHS, NIHR, or Department of Health. No funders had any involvement in the design of the study, the analysis or interpretation of the data, the writing of the report, or the decision to submit the paper for publication. JB's post is funded CRUK (C1417/A14135). RW is funded by Cancer Research UK (C1417/A14135). EB is funded by the NIHR SPHR (SPHR-SWP-ALC-WP5) and CRUK also provide support (C1417/A14135).

Competing interests

RW undertakes consultancy and research for and receives travel funds and hospitality from manufacturers of smoking cessation medications. RW salary is funded by Cancer Research UK. SM receives support from Cancer Research UK and the National Institute for Health Research (NIHR)'s School for Public Health Research (SPHR). EB and JB have received unrestricted research funding from Pfizer. PM's research is funded by a variety of governmental funding agencies including UKRI and NIHR.

Authors' contributions

EB, JB, SM and RW wrote the first draft of the manuscript and conducted the analysis. All other authors commented on this draft and contributed to the final version. All authors read and approved the final manuscript.

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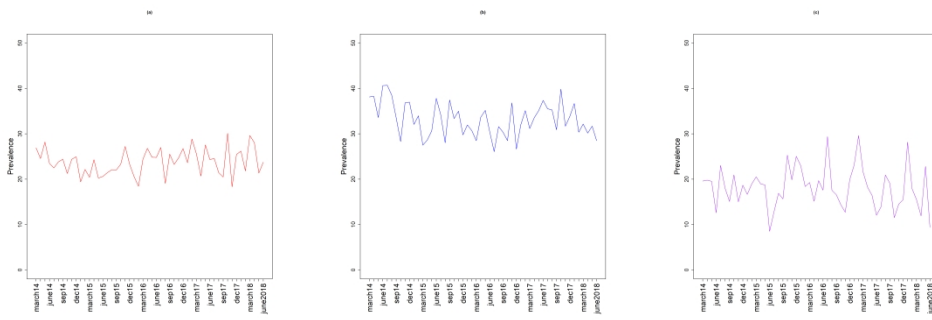
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Figure 1: Time series showing the prevalence of a) high risk drinking; b) attempts to quit smoking among smokers and c) successful quit attempts among smokers having made a quit attempt



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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of cross-sectional studies

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	6-7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	6-7
		(b) Describe any methods used to examine subgroups and interactions	6-8
		(c) Explain how missing data were addressed	6-8
		(d) If applicable, describe analytical methods taking account of sampling strategy	6-8
		(e) Describe any sensitivity analyses	6-8
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	N/a
		(c) Consider use of a flow diagram	N/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	
		(b) Indicate number of participants with missing data for each variable of interest	N/a
Outcome data	15*	Report numbers of outcome events or summary measures	9-10
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9-10
		(b) Report category boundaries when continuous variables were categorized	9-10
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9-10
Discussion			
Key results	18	Summarise key results with reference to study objectives	10-11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10-11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10-11
Generalisability	21	Discuss the generalisability (external validity) of the study results	10-11
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Are population trends in high-risk alcohol consumption in smokers associated with trends in quit attempts and quit success? A time series analysis

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2019-034262.R1
Article Type:	Original research
Date Submitted by the Author:	06-Jan-2020
Complete List of Authors:	Beard, Emma; UCL, Brown, Jamie; University College London, Psychology & Language Sciences West, Robert; UCL Michie, Susan; University College London, Centre for Outcomes Research and Effectiveness
Primary Subject Heading:	Addiction
Secondary Subject Heading:	Addiction, Epidemiology, Public health, Smoking and tobacco, Global health
Keywords:	time-series, tobacco, alcohol, high-risk drinking, quit attempts

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3 **Are population trends in high-risk alcohol consumption in smokers associated**
4 **with trends in quit attempts and quit success? A time series analysis**
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7 Version 1
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32 To submit to: BMJ OPEN
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34 Short title: Population trends in high-risk alcohol consumption among smokers
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36 Word count: 2,440
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43 Key words: time-series, tobacco, alcohol, high-risk drinking, quit attempts
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Abstract

Objectives: Monthly changes in the prevalence of high-risk drinking and smoking in England appear to be positively correlated. This study aimed to assess how far monthly changes in high-risk drinking were specifically associated with attempts to stop smoking and success of quit attempts.

Design: Data were used from the Alcohol and Smoking Toolkit Studies between April 2014 and June 2018. These involve monthly household face-to-face surveys of representative samples of ~1800 adults.

Setting: England

Participants: Data were aggregated on 17,560 past year smokers over the study period.

Primary and secondary outcome measures: ARIMAX modelling was used to assess the association over time between monthly prevalence of high-risk drinking among smokers and a) prevalence of attempts to quit smoking and b) prevalence of successful quit attempts in those attempting to quit. Bayes Factors (BF) were calculated to compare the null hypothesis with the hypothesis of an effect sufficiently large ($\beta=0.6$) to explain the established association between overall prevalence in smoking and high-risk drinking.

Results: No statistically significant associations were found between monthly changes in prevalence of high-risk drinking among smokers and attempts to quit smoking ($\beta=0.156$, 95%CI -0.079 to 0.391, $p=0.194$) or quit success ($\beta=0.066$, 95%CI -0.524 to 0.655, $p=0.827$). Bayes Factors (BF) indicated that the data were insensitive but suggested there is weak evidence for the null hypothesis in the case of both quit attempts (BF=0.80) and quit success (BF=0.53).

Conclusions: Monthly changes in prevalence of high-risk alcohol consumption in England are not clearly associated with changes in quit attempt or quit success rates.

Strengths and limitations of this study

- This is the first time series study to assess how far monthly changes in high-risk drinking are associated with attempts to stop smoking and success of quit attempts.

- This study uses a large representative sample of the population in England.
- In countries with weaker tobacco control different effects may be observed.
- Data are observational and so strong conclusions regarding cause and effect cannot be made.

For peer review only

Background

In England, around 15% of the population are smokers and 20% drink alcohol at high-risk levels, i.e. levels which are likely to cause harm (1, 2). Both are associated with a number of preventable conditions and appear to have an accumulative effect on the risk of mortality(3). The association between high-risk drinking and smoking has been well established at an individual level. High-risk drinkers are substantially more likely to smoke (4-8) and smokers who report starting a quit attempt also report lower alcohol consumption (9, 10). Attempts to quit smoking are also less successful among those with an alcohol use disorder (11-13). Such associations may arise by a number of mechanisms. For example, smokers drinking at high-risk levels may follow advice that it is important to restrict alcohol consumption when they quit(9, 14-16), alcohol and smoking appear to provide cues to lapses for the other and there may be pharmacological interactions between nicotine and alcohol (17-19). This is contrary to the popular notion of self-medication and reward seeking with people deprived of cigarettes compensating by increasing their use of alcohol (20).

It is important to identify whether similar patterns exist at a population level. An association in either direction could mean that policies that reduce smoking prevalence may have the added benefit of reducing high-risk drinking or vice versa. In England, since 2014 monthly data have been gathered on high-risk drinking, smoking status, attempts to quit smoking and quit success (21). Recently, we used these data to examine population-level associations over time between smoking and high-risk drinking and showed that monthly changes in prevalence of smoking in England were associated positively with prevalence of high-risk drinking. However, there were no significant associations between motivation to stop and motivation to reduce alcohol consumption, or attempts to quit smoking and attempts to reduce alcohol consumption (22). We found the combination of results surprising and suggested that the association with overall prevalence may be related to an unmeasured variable that accounted for the change in both smoking and high-risk drinking. Alternatively, the failure to find an overall association between motivation and attempts for each

behaviour may be an issue of power when focussing on the global association between subsamples that represented only a fifth of the overall sample.

This study attempted to resolve this apparent contradiction and explore the previously identified positive association between prevalence of smoking and prevalence of high-risk drinking. We relied on the assessment of trends between more specific outcomes expected to be more strongly related, if the identified association between the changes in the overall prevalence of smoking and high-risk drinking was causal. Specifically, we will assess whether changes in trends of excessive alcohol consumption among smokers are associated with trends in attempts to quit smoking and quit success.. If no association is found, this would support the conclusion of a third unmeasured variable associated with both smoking and high-risk drinking.

This study addressed the following research questions:

1. Is there an association in England between increases or decreases in monthly prevalence of high-risk drinking among smokers and attempts to quit smoking?
2. Is there an association in England between increases or decreases in monthly prevalence of high-risk drinking among smokers and quit success rates?

Methods

Study design

Data were used from the Smoking and Alcohol Toolkit Studies (STS and ATS) collected between April 2014 and June 2018. The STS and ATS are ongoing studies that involve a series of monthly cross-sectional household, face-to-face, computer assisted surveys of representative samples of ~1800 adults in England aged 16+. Thus, the same participants take part in both surveys. The respondents are recruited using a type of random location sampling, which is a hybrid between

1
2 random probability and simple quota sampling. England is first split into over 170000 ‘Output
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4 Areas’, comprising of approximately 300 households. These areas are then stratified according to
5
6 ACORN characteristics and geographic region (<http://www.caci.co.uk/acorn/>) and are randomly
7
8 allocated to interviewers. Interviewers visit households within their allocated locality starting at a
9
10 random point in the area. One member per household, chosen based on who the interviewer judge
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12 would best fulfil their quota requirements, is interviewed until interviewers achieve local quotas
13
14 designed to minimise differences in the probability of participation. Participants appear to be
15
16 representative of the population in England, having similar socio-demographic composition and
17
18 smoking characteristics to large national surveys based on probability samples such as the Health
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20 Survey for England (23), while drinking characteristics also appear similar at a regional level to
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22 other national surveys (24). For further details see: www.smokinginengland.info and
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24 www.alcoholinengland.info and the published protocol (21, 23).
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32 *Participants*

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34 Data were collected on 88,122 participants over the study period. Of these, 19.94% (95%CI 19.67
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36 to 20.20 n=17,560) reported that they had smoked in the past year. Forty-seven percent of past year
37
38 smokers (n=8097) were male, 18.9% (n=3272) were aged 16-24, 19.7% (n=3416) were aged 25 to
39
40 34, 16.2% (n=2804) were aged 35 to 44, 17.0% (n=2946) were aged 45 to 54, 14.6% (n=2521) were
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42 aged 55 to 64 and 13.7% (n=2371) were aged 65+. Finally, 59.4% (n=10286) were in manual
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44 occupations. Data from these participants were aggregated monthly and this forms the basis of the
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46 sample in this paper.
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52 *Measures*

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54 Participants were asked whether they smoked or had smoked cigarettes (including hand-rolled)
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56 daily or non-daily in the past year and to complete the Alcohol Use Disorders Identification Test
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58 (AUDIT) (25). The AUDIT identifies people who could be classed as dependent, harmful or
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1
2 hazardous drinkers and has demonstrated validity, high internal consistency and good test-retest
3 reliability across gender, age and cultures (26-29). Those scoring 8 or more were classed as high-
4 risk drinkers. This is a common threshold for high-risk drinkers (27, 30-32). The prevalence of
5 high-risk alcohol consumption among smokers in each month was obtained by counting the number
6 smokers reporting an AUDIT score greater than or equal to 8.
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16 Past year smokers were then asked:

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18 1. “How many serious attempts to stop smoking have you made in the last 12 months? By
19 serious attempt I mean you decided that you would try to make sure you never smoked
20 again. Please include any attempt that you are currently making and please include any
21 successful attempt made within the last year”.
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27 2. “How long did your most recent serious quit attempt last before you went back to
28 smoking?”
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34 The prevalence of quit attempts in monthly were calculated as the number of respondents who
35 reported having made one or more quit attempts in the past 12 months divided by the number of
36 past year smokers. The success rate in each quarter was calculated as the number of respondents
37 reporting that they were still not smoking divided by the number reporting having made a quit
38 attempt.
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48 *Analysis*

49 The analysis plan, data and syntax were preregistered on the Open Science Framework
50 (<https://osf.io/384gx/>). Cases with missing data on either smoking or drinking variables were
51 classified as missing in calculating the prevalence figures: smoking status (n=55; %=0.06), high-
52 risk drinking status among smokers (n=202; %=1.17) and quit attempts among smokers (n=562;
53 %=3.24). All data were analysed in R studio.
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4 Data were weighted (see (23) for further details) to match the population in England and analysed
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6 using Autoregressive Integrated Moving Average with Exogeneous Input (ARIMAX) modelling to
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8 assess the association between prevalence of high risk drinking among smokers and 1) prevalence
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10 of attempts to quit smoking and 2) prevalence of successful attempts to quit smoking among those
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12 having made a quit attempt. ARIMAX is an extension of autoregressive integrated moving average
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14 analysis (ARIMA), which produces forecasts based upon prior values in the time series
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16 (Autoregressive terms; AR) and the errors made by previous predictions (Moving Average terms;
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18 MA). We followed a standard ARIMAX modelling approach (33).
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25 The ARIMAX assumption of weak exogeneity was met: past prevalence of quit attempts ($p=0.747$)
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27 and quit success ($p=0.999$) did not statistically predict future prevalence of high-risk drinking
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29 among smokers. No outliers were identified in any of the series using an approach based on that
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31 described by Chen and Liu(34, 35). To stabilise the variance the series were log-transformed. The
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33 Augmented Dickey-Fuller test and visual inspection of the plots indicated that first order
34
35 differencing was required for both time series. First order differencing involves calculating the
36
37 change between one observation and the next. No additional seasonal differencing was required
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41 (36).
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45 The autocorrelation and partial autocorrelation functions were examined to determine the non-
46
47 seasonal MA and AR terms. These suggested an ARIMAX(0,1,1) model for the time series
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49 predicting both prevalence of quit attempts and prevalence of quit success. This was confirmed by
50
51 comparing models with different specifications using the AIC. To identify the most appropriate
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53 transfer function for the continuous explanatory variables the sample cross-correlation function was
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55 checked and models with varying distributed lags compared using the Akaike Information
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57 Criterion. This suggested a lag of 0 when predicting the prevalence of quit attempts and predicting
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1
2 the prevalence of quit success, thus only current values and not lagged (past period) values of the
3
4 input series were used to predict current values of the output series. In our previous study,
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6 prevalence of smoking was found to be associated with high-risk drinking with a distributed lag of 2
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8 (22). Thus, additional sensitivity analyses were run with the output series lagged by an order of 2
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10 i.e. the time base was shifted back by 2 months.
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16 The Ljung-Box test for white noise showed that the residuals for both fitted models were free of
17
18 serial correlation. A number of additional model checks were also made. First, the autocorrelation
19
20 terms included in the model were checked for their statistical significance. Secondly, it was
21
22 determined whether the model residuals were normally distributed, random and independent.
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24 Finally, that the inclusion of the MA term conformed to the bounds of invertibility i.e. its value was
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26 <1 (33, 34).
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32 Bayes factors (BFs) were derived for non-significant findings using an online calculator to
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34 disentangle whether there is evidence for the null hypothesis of no effect ($BF < 1/3rd$) or the data are
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36 insensitive (BF between $1/3rd$ and 3) (37, 38). A half-normal distribution was assumed with a
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38 percentage change in the outcomes of interest for every percentage increase in the input series of
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40 0.6%. This is on the basis of a previous study showing that smokers who had made a quit attempt
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42 were around 40% less likely to report that they were high risk drinkers (9). Strengthening the
43
44 Reporting of Observational Studies in Epidemiology (STROBE) guidelines for the reporting of
45
46 observational studies were followed throughout (39).
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51 52 **Patient involvement**

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54 No patients were involved in setting the research question or the outcome measures, nor were they
55
56 involved in developing plans for recruitment, design, or implementation of the study. No patients
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1
2 were asked to advise on interpretation or writing up of results. There are no plans to disseminate the
3
4 results of the research directly to study participants or any specific patient community.
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8 9 **Results**

10
11 Figure 1 shows the raw time series data from 2014 to 2018. Prevalence of high-risk drinking among
12
13 smokers declined from 26.9% (95% CI 22.34 to 32.03) in 2014 to 23.7% (95% CI 19.26 to 28.87)
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15 in June 2018. Attempts to quit smoking also declined from 38.1% (95%CI 32.86 to 43.66) to 28.5%
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17 (95%CI 23.60 to 33.90) and quit success from 19.6% (95%CI 13.22 to 27.87) to 9.4% (95%CI 4.51
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19 to 17.95) in June 2018.
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25
26 Tables 1 shows the results of the ARIMAX models assessing the association between prevalence of
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28 high-risk drinking among smokers and (1) quit attempts and (2) quit success. The findings were
29
30 inconclusive as to whether any associations were present. BFs suggested that there is anecdotal
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32 evidence for the null hypothesis that prevalence of high-risk drinking among smokers is not
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34 associated with prevalence of quit attempts and prevalence of quit success. Findings were similar
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36 when a 2 month back shifted lag was used for prevalence of quit attempts and quit success.
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41 **Discussion**

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43 To our knowledge, this is the first empirical study to estimate the population association between
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45 high-risk drinking among smokers and attempts to quit smoking and the success of those attempts.
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47 There was weak evidence that there was no substantial association between changes in the
48
49 prevalence of high-risk drinking and quit attempts and quit success.
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54 These findings appear to be at odds with individual level studies which suggest that smokers with
55
56 an alcohol use disorder are less likely to attempt and succeed in stopping smoking (12, 13). Alcohol
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58 consumption during attempts at smoking cessation is also associated with a greater risk of relapse
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60 (14). As a result, smokers are often advised to lower their alcohol consumption when they attempt

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2 to quit smoking(9). Of course, it remains plausible that high-risk drinking among smokers may still
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4 be associated with a small effect on mean population prevalence of quit attempts and their success,
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6 but it was not possible to detect this in the current study. An association may also be masked by
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8 factors impacting at a population level which were not accounted for in the current study. Although
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10 we are unaware of any major population-level interventions or other events during the study period
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12 which may have affected the associations under investigation, we cannot rule out residual
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14 confounding. There may also be some statistical bias due to the loss of power and sensitivity that
15
16 comes with aggregating data. Prevalence of high-risk drinking among smokers will also be
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18 somewhat noisier than if prevalence was also assessed among non-smokers, given the smaller
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20 sample size involved in estimation.
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26 These findings suggest that the previously identified positive association between prevalence of
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28 smoking and prevalence of high-risk drinking is unlikely to be causal, whereby smokers attempting
29
30 to quit, and those succeeding, also reduce their alcohol intake (22). Although it remains possible
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32 that use of alcohol by smokers impacts on other key indices including longer term abstinence, the
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34 small proportion of smokers who relapse long term (i.e. after a year) could not account for the size
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36 of association noted. It may instead be that overall prevalence is related to an unmeasured variable,
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38 perhaps economic factors and sociocultural events, that account for the change in both smoking and
39
40 high-risk drinking. For example, in recent years taxation on cigarettes and alcohol have increased
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42 linearly, driving down sales of both (40, 41). There have also been substantial fluctuations in
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44 average household income since 2013, which have been shown to independently affect smoking and
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46 alcohol consumption (42-44). Sporting events such as the Olympics may also concurrently increase
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48 alcohol and tobacco intake as they are celebratory occasions. Mass media campaigns may also play
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50 role, simultaneously promoting attempts to quit smoking and the adoption of a healthier lifestyle by
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52 reducing alcohol intake (45).
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2 A strength of this study is the use of a large representative sample of the population in England.
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4 Several limitations need to be considered. First, the ATS required participants to recall their alcohol
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6 consumption and attempts to quit smoking which is likely to have been somewhat inaccurate due to
7
8 recall bias and social desirability. For example, it has been found that a large proportion of
9
10 unsuccessful quit attempts fail to be reported, particularly if they only last a short time or occurred
11
12 longer ago(46). However, social pressure in population surveys tends to be low and so it is
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14 generally considered acceptable to rely on self-report data(47). Second, these findings may not
15
16 generalise to other countries. England has a strong tobacco-control climate. In countries with
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18 weaker tobacco control or different alcohol control policies, different effects may be observed.
19
20 Thirdly, this paper did not consider the impact of changes in excessive alcohol consumption
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22 prevalence on the length of quit success, being defined as having made a quit in attempt in the last
23
24 12 months and still reporting not smoking. This will be an important area for future research as
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26 more data are accumulated to provide adequate power. Finally, although there can be no individual-
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28 level confounding in population trend data there is a possibility of population-level confounding,
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30 such as introduction of policies that may affect quitting rates. However, we were unable to identify
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32 any such population policies occurring during the study period that may have confounded the
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34 results.
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43 **Conclusion**

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45 These findings suggest that the previously identified positive association between prevalence of
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47 smoking and prevalence of high-risk drinking is unlikely to be causal, whereby smokers attempting
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49 to quit, and those succeeding, also reduce their alcohol intake. Instead, it may be that overall
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51 prevalence is related to an unmeasured third variable such as economic factors and sociocultural
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53 events.
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For peer review only

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3 **List of abbreviations**

4 ARIMAX - autoregressive integrated moving average with exogenous input

5 BF – Bayes Factor

6 ATS – Alcohol Toolkit Study

7 STS – Smoking Toolkit Study

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Table 1: Estimated percentage point changes in proportion of quit attempts and proportion of quitters who met criteria for quit success during the study period, based on autoregressive integrated moving average with exogenous input (ARIMAX) models

		Output series					
		Quit attempts ¹			Quit success ²		
		Percentage change per 1% change in the exposure	95%CI	p	Percentage change per 1% change in the exposure	95%CI	p
Input series	Model 1: High-risk drinking among smokers (no backward lag of the output series)	0.156	-0.079 to 0.391	0.194	0.066	-0.524 to 0.655	0.827
	Model 2: High-risk drinking among smokers (two month backward lag of the output series)	0.065	-0.183 to 0.313	0.608	0.134	-0.469 to 0.736	0.663
	Bayes Factor						
	Model 1	0.80			0.53		
	Model 2	0.33			0.64		

Figure 1: Prevalence of a) high-risk drinking; b) attempts to quit smoking and c) quit success

Declarations

Ethical approval and consent to participate

Ethics approval for the Smoking Toolkit Survey (STS) was originally granted by the UCL Ethics Committee (ID 0498/001) and approval for the ATS was granted by the same committee as an extension of the STS (ID 2808/005). In accordance with our ethical approval, all respondents were given a written information sheet about the study, and provided informed verbal consent

Availability of data and material

The analysis plan, data and syntax were preregistered on the Open Science Framework (<https://osf.io/384gx/>).

Funding

The Smoking Toolkit Study is currently primarily funded by Cancer Research UK (C1417/A14135; C36048/A11654; C44576/A19501) and has previously also been funded by Pfizer, GSK, and the Department of Health. The ATS is currently funded by the NIHR School for Public Health Research (SPHR) (SPHR-SWP-ALC-WP5). SPHR is a partnership between the Universities of Sheffield; Bristol; Cambridge; Exeter; UCL; The London School for Hygiene and Tropical Medicine; the LiLaC collaboration between the Universities of Liverpool and Lancaster and Fuse; The Centre for Translational Research in Public Health, a collaboration between Newcastle, Durham, Northumbria, Sunderland and Teesside Universities. The views expressed are those of the author(s) and not necessarily those of the NHS, NIHR, or Department of Health. No funders had any involvement in the design of the study, the analysis or interpretation of the data, the writing of the report, or the decision to submit the paper for publication. JB's post is funded CRUK

1
2 (C1417/A14135). RW is funded by Cancer Research UK (C1417/A14135). EB is funded by the
3 NIHR SPHR (SPHR-SWP-ALC-WP5) and CRUK also provide support (C1417/A14135).
4

5
6 ***Competing interests***

7 RW undertakes consultancy and research for and receives travel funds and hospitality from
8 manufacturers of smoking cessation medications. RW salary is funded by Cancer Research UK. SM
9 receives support from Cancer Research UK and the National Institute for Health Research (NIHR)'s
10 School for Public Health Research (SPHR). EB and JB have received unrestricted research funding
11 from Pfizer. PM's research is funded by a variety of governmental funding agencies including
12 UKRI and NIHR.
13

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15 **Authors' contributions**

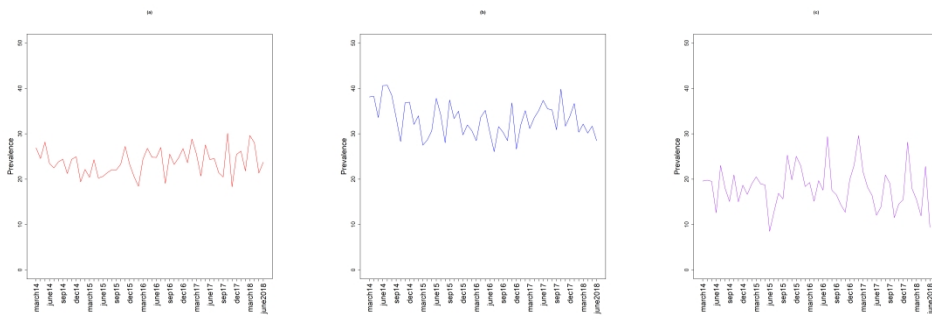
16 EB, JB, SM and RW wrote the first draft of the manuscript and conducted the analysis. All other
17 authors commented on this draft and contributed to the final version. All authors read and approved
18 the final manuscript.
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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of cross-sectional studies

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	6-7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	6-7
		(b) Describe any methods used to examine subgroups and interactions	6-8
		(c) Explain how missing data were addressed	6-8
		(d) If applicable, describe analytical methods taking account of sampling strategy	6-8
		(e) Describe any sensitivity analyses	6-8
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	N/a
		(c) Consider use of a flow diagram	N/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	
		(b) Indicate number of participants with missing data for each variable of interest	N/a
Outcome data	15*	Report numbers of outcome events or summary measures	9-10
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9-10
		(b) Report category boundaries when continuous variables were categorized	9-10
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9-10
Discussion			
Key results	18	Summarise key results with reference to study objectives	10-11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10-11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10-11
Generalisability	21	Discuss the generalisability (external validity) of the study results	10-11
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Are population trends in high-risk alcohol consumption in smokers associated with trends in quit attempts and quit success? A time series analysis

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2019-034262.R2
Article Type:	Original research
Date Submitted by the Author:	18-Feb-2020
Complete List of Authors:	Beard, Emma; UCL, Brown, Jamie; University College London, Psychology & Language Sciences West, Robert; UCL Michie, Susan; University College London, Centre for Outcomes Research and Effectiveness
Primary Subject Heading:	Addiction
Secondary Subject Heading:	Addiction, Epidemiology, Public health, Smoking and tobacco, Global health
Keywords:	time-series, tobacco, alcohol, high-risk drinking, quit attempts

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3 **Are population trends in high-risk alcohol consumption in smokers associated**
4 **with trends in quit attempts and quit success? A time series analysis**
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7 Version 1
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32 To submit to: BMJ OPEN
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34 Short title: Population trends in high-risk alcohol consumption among smokers
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36 Word count: 2,440
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43 Key words: time-series, tobacco, alcohol, high-risk drinking, quit attempts
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Abstract

Objectives: Monthly changes in the prevalence of high-risk drinking and smoking in England appear to be positively correlated. This study aimed to assess how far monthly changes in high-risk drinking were specifically associated with attempts to stop smoking and success of quit attempts.

Design: Data were used from the Alcohol and Smoking Toolkit Studies between April 2014 and June 2018. These involve monthly household face-to-face surveys of representative samples of ~1800 adults.

Setting: England

Participants: Data were aggregated on 17,560 past year smokers over the study period.

Primary and secondary outcome measures: ARIMAX modelling was used to assess the association over time between monthly prevalence of high-risk drinking among smokers and a) prevalence of attempts to quit smoking and b) prevalence of successful quit attempts in those attempting to quit. Bayes Factors (BF) were calculated to compare the null hypothesis with the hypothesis of an effect sufficiently large ($\beta=0.6$) to explain the established association between overall prevalence in smoking and high-risk drinking.

Results: No statistically significant associations were found between monthly changes in prevalence of high-risk drinking among smokers and attempts to quit smoking ($\beta=0.156$, 95%CI -0.079 to 0.391, $p=0.194$) or quit success ($\beta=0.066$, 95%CI -0.524 to 0.655, $p=0.827$). Bayes Factors (BF) indicated that the data were insensitive but suggested there is weak evidence for the null hypothesis in the case of both quit attempts (BF=0.80) and quit success (BF=0.53).

Conclusions: Monthly changes in prevalence of high-risk alcohol consumption in England are not clearly associated with changes in quit attempt or quit success rates.

Strengths and limitations of this study

- This is the first time series study to assess how far monthly changes in high-risk drinking are associated with attempts to stop smoking and success of quit attempts.

- This study uses a large representative sample of the population in England.
- In countries with weaker tobacco control different effects may be observed.
- Data are observational and so strong conclusions regarding cause and effect cannot be made.

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Background

In England, around 15% of the population are smokers and 20% drink alcohol at high-risk levels, i.e. levels which are likely to cause harm (1, 2). Both are associated with a number of preventable conditions and appear to have an accumulative effect on the risk of mortality(3). The association between high-risk drinking and smoking has been well established at an individual level. High-risk drinkers are substantially more likely to smoke (4-8) and smokers who report starting a quit attempt also report lower alcohol consumption (9, 10). Attempts to quit smoking are also less successful among those with an alcohol use disorder (11-13). Such associations may arise by a number of mechanisms. For example, smokers drinking at high-risk levels may follow advice that it is important to restrict alcohol consumption when they quit(9, 14-16), alcohol and smoking appear to provide cues to lapses for the other and there may be pharmacological interactions between nicotine and alcohol (17-19). This is contrary to the popular notion of self-medication and reward seeking with people deprived of cigarettes compensating by increasing their use of alcohol (20).

It is important to identify whether similar patterns exist at a population level. An association in either direction could mean that policies that reduce smoking prevalence may have the added benefit of reducing high-risk drinking or vice versa. In England, since 2014 monthly data have been gathered on high-risk drinking, smoking status, attempts to quit smoking and quit success (21). Recently, we used these data to examine population-level associations over time between smoking and high-risk drinking and showed that monthly changes in prevalence of smoking in England were associated positively with prevalence of high-risk drinking. However, there were no significant associations between motivation to stop and motivation to reduce alcohol consumption, or attempts to quit smoking and attempts to reduce alcohol consumption (22). We found the combination of results surprising and suggested that the association with overall prevalence may be related to an unmeasured variable that accounted for the change in both smoking and high-risk drinking. Alternatively, the failure to find an overall association between motivation and attempts for each

behaviour may be an issue of power when focussing on the global association between subsamples that represented only a fifth of the overall sample.

This study attempted to resolve this apparent contradiction and explore the previously identified positive association between prevalence of smoking and prevalence of high-risk drinking. We relied on the assessment of trends between more specific outcomes expected to be more strongly related, if the identified association between the changes in the overall prevalence of smoking and high-risk drinking was causal. Specifically, we will assess whether changes in trends of excessive alcohol consumption among smokers are associated with trends in attempts to quit smoking and quit success.. If no association is found, this would support the conclusion of a third unmeasured variable associated with both smoking and high-risk drinking.

This study addressed the following research questions:

1. Is there an association in England between increases or decreases in monthly prevalence of high-risk drinking among smokers and attempts to quit smoking?
2. Is there an association in England between increases or decreases in monthly prevalence of high-risk drinking among smokers and quit success rates?

Methods

Study design

Data were used from the Smoking and Alcohol Toolkit Studies (STS and ATS) collected between April 2014 and June 2018. The STS and ATS are ongoing studies that involve a series of monthly cross-sectional household, face-to-face, computer assisted surveys of representative samples of ~1800 adults in England aged 16+. Thus, the same participants take part in both surveys. The respondents are recruited using a type of random location sampling, which is a hybrid between

1
2 random probability and simple quota sampling. England is first split into over 170000 ‘Output
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4 Areas’, comprising of approximately 300 households. These areas are then stratified according to
5
6 ACORN characteristics and geographic region (<http://www.caci.co.uk/acorn/>) and are randomly
7
8 allocated to interviewers. Interviewers visit households within their allocated locality starting at a
9
10 random point in the area. One member per household, chosen based on who the interviewer judge
11
12 would best fulfil their quota requirements, is interviewed until interviewers achieve local quotas
13
14 designed to minimise differences in the probability of participation. Participants appear to be
15
16 representative of the population in England, having similar socio-demographic composition and
17
18 smoking characteristics to large national surveys based on probability samples such as the Health
19
20 Survey for England (23), while drinking characteristics also appear similar at a regional level to
21
22 other national surveys (24). For further details see: www.smokinginengland.info and
23
24 www.alcoholinengland.info and the published protocol (21, 23).
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32 *Participants*

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34 Data were collected on 88,122 participants over the study period. Of these, 19.94% (95%CI 19.67
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36 to 20.20 n=17,560) reported that they had smoked in the past year. Forty-seven percent of past year
37
38 smokers (n=8097) were male, 18.9% (n=3272) were aged 16-24, 19.7% (n=3416) were aged 25 to
39
40 34, 16.2% (n=2804) were aged 35 to 44, 17.0% (n=2946) were aged 45 to 54, 14.6% (n=2521) were
41
42 aged 55 to 64 and 13.7% (n=2371) were aged 65+. Finally, 59.4% (n=10286) were in manual
43
44 occupations. Data from these participants were aggregated monthly and this forms the basis of the
45
46 sample in this paper.
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52 *Measures*

53 *Input series*

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55 Participants were asked whether they smoked or had smoked cigarettes (including hand-rolled)
56
57 daily or non-daily in the past year and to complete the Alcohol Use Disorders Identification Test
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1
2 (AUDIT) (25). The AUDIT identifies people who could be classed as dependent, harmful or
3
4 hazardous drinkers and has demonstrated validity, high internal consistency and good test-retest
5
6 reliability across gender, age and cultures (26-29). Those scoring 8 or more were classed as high-
7
8 risk drinkers. This is a common threshold for high-risk drinkers (27, 30-32). The prevalence of
9
10 high-risk alcohol consumption among smokers in each month was obtained by counting the number
11
12 smokers reporting an AUDIT score greater than or equal to 8.
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18 *Output series*

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20 Past year smokers were then asked:

- 21
22 1. “How many serious attempts to stop smoking have you made in the last 12 months? By
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24 serious attempt I mean you decided that you would try to make sure you never smoked
25
26 again. Please include any attempt that you are currently making and please include any
27
28 successful attempt made within the last year”.
- 29
30 2. “How long did your most recent serious quit attempt last before you went back to
31
32 smoking?”
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39 The prevalence of quit attempts in monthly were calculated as the number of respondents who
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41 reported having made one or more quit attempts in the past 12 months divided by the number of
42
43 past year smokers. The success rate in each quarter was calculated as the number of respondents
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45 reporting that they were still not smoking divided by the number reporting having made a quit
46
47 attempt.
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52 *Covariates*

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54 Past-year smokers’ socio-economic status was assessed by social grade measured using the British
55
56 National Readership Survey (NRS) Social Grade Classification Tool (27): AB (higher managerial,
57
58 administrative or professional), C1 (supervisory or clerical and junior managerial, administrative or
59
60

1 professional), C2 (skilled manual workers), D (semi-skilled and unskilled manual workers) and E
2 (casual or lowest grade workers, pensioners, and others who depend on the welfare state for their
3 income). The prevalence of smokers in lower social grades in each quarter was calculated as the
4 proportion of past-year smokers who reported being in C2, D and E. Past-year smokers were also
5 asked their age, with a mean estimated each month.
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13 *Analysis*

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16 The analysis plan, data and syntax were preregistered on the Open Science Framework
17 (<https://osf.io/384gx/>). An amendment was made to the analysis plan following reviewer comments
18 to also adjust for socio-demographic variables. Variables can only be included in ARIMAX models
19 at the aggregated level and must vary sufficiently over the study period (33)). There was insufficient
20 variation in gender and ethnicity over the period but there was sufficient variation in mean age and
21 the proportion of those in lower social-grades, which were included. Studies have shown an
22 increase in the age of smokers over time (34) and socio-economic status is a strong predictor of
23 quitting activity (35, 36).
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39 Cases with missing data on either smoking or drinking variables were classified as missing in
40 calculating the prevalence figures: smoking status (n=55; %=0.06), high-risk drinking status among
41 smokers (n=202; %=1.17) and quit attempts among smokers (n=562; %=3.24). All data were
42 analysed in R studio.
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50 Data were weighted (see (23) for further details) to match the population in England and analysed
51 using Autoregressive Integrated Moving Average with Exogeneous Input (ARIMAX) modelling to
52 assess the association between prevalence of high risk drinking among smokers and 1) prevalence
53 of attempts to quit smoking and 2) prevalence of successful attempts to quit smoking among those
54 having made a quit attempt. ARIMAX is an extension of autoregressive integrated moving average
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1
2 analysis (ARIMA), which produces forecasts based upon prior values in the time series
3
4 (Autoregressive terms; AR) and the errors made by previous predictions (Moving Average terms;
5
6 MA). We followed a standard ARIMAX modelling approach (37).
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8
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10
11 The ARIMAX assumption of weak exogeneity was met: past prevalence of quit attempts ($p=0.747$)
12
13 and quit success ($p=0.999$) did not statistically predict future prevalence of high-risk drinking
14
15 among smokers. No outliers were identified in any of the series using an approach based on that
16
17 described by Chen and Liu(38, 39). To stabilise the variance the series were log-transformed. The
18
19 Augmented Dickey-Fuller test and visual inspection of the plots indicated that first order
20
21 differencing was required for both time series. First order differencing involves calculating the
22
23 change between one observation and the next. No additional seasonal differencing was required
24
25
26
27 (40).
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30
31

32 The autocorrelation and partial autocorrelation functions were examined to determine the non-
33
34 seasonal MA and AR terms. These suggested an ARIMAX(0,1,1) model for the time series
35
36 predicting both prevalence of quit attempts and prevalence of quit success. This was confirmed by
37
38 comparing models with different specifications using the AIC. To identify the most appropriate
39
40 transfer function for the continuous explanatory variables the sample cross-correlation function was
41
42 checked and models with varying distributed lags compared using the Akaike Information
43
44 Criterion. This suggested a lag of 0 when predicting the prevalence of quit attempts and predicting
45
46 the prevalence of quit success, thus only current values and not lagged (past period) values of the
47
48 input series were used to predict current values of the output series. In our previous study,
49
50 prevalence of smoking was found to be associated with high-risk drinking with a distributed lag of 2
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52 (22). Thus, additional sensitivity analyses were run with the output series lagged by an order of 2
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57 i.e. the time base was shifted back by 2 months.
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2 The Ljung-Box test for white noise showed that the residuals for both fitted models were free of
3
4 serial correlation. A number of additional model checks were also made. First, the autocorrelation
5
6 terms included in the model were checked for their statistical significance. Secondly, it was
7
8 determined whether the model residuals were normally distributed, random and independent.
9
10 Finally, that the inclusion of the MA term conformed to the bounds of invertibility i.e. its value was
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12 <1 (37, 38).
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18 Bayes factors (BFs) were derived for non-significant findings using an online calculator to
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20 disentangle whether there is evidence for the null hypothesis of no effect ($BF < 1/3rd$) or the data are
21
22 insensitive (BF between $1/3rd$ and 3)(41, 42). A half-normal distribution was assumed with a
23
24 percentage change in the outcomes of interest for every percentage increase in the input series of
25
26 0.6%. This is on the basis of a previous study showing that smokers who had made a quit attempt
27
28 were around 40% less likely to report that they were high risk drinkers (9). Strengthening the
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30 Reporting of Observational Studies in Epidemiology (STROBE) guidelines for the reporting of
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32 observational studies were followed throughout (43).
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39 **Patient involvement**

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41 No patients were involved in setting the research question or the outcome measures, nor were they
42
43 involved in developing plans for recruitment, design, or implementation of the study. No patients
44
45 were asked to advise on interpretation or writing up of results. There are no plans to disseminate the
46
47 results of the research directly to study participants or any specific patient community.
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52 **Results**

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54 Figure 1 shows the raw time series data from 2014 to 2018. Prevalence of high-risk drinking among
55
56 smokers declined from 26.9% (95% CI 22.34 to 32.03) in 2014 to 23.7% (95% CI 19.26 to 28.87)
57
58 in June 2018. Attempts to quit smoking also declined from 38.1% (95%CI 32.86 to 43.66) to 28.5%
59
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1
2 (95%CI 23.60 to 33.90) and quit success from 19.6% (95%CI 13.22 to 27.87) to 9.4% (95%CI 4.51
3
4 to 17.95) in June 2018.
5
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7

8
9 Tables 1 shows the results of the ARIMAX models assessing the association between prevalence of
10
11 high-risk drinking among smokers and (1) quit attempts and (2) quit success. The findings were
12
13 inconclusive as to whether any associations were present. BFs suggested that there is anecdotal
14
15 evidence for the null hypothesis that prevalence of high-risk drinking among smokers is not
16
17 associated with prevalence of quit attempts and prevalence of quit success. Findings were similar
18
19 when a 2 month back shifted lag was used for prevalence of quit attempts and quit success.
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21 Adjusting for age and social-grade did not change the findings (see Table 2).
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26

27 **Discussion**

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29 To our knowledge, this is the first empirical study to estimate the population association between
30
31 high-risk drinking among smokers and attempts to quit smoking and the success of those attempts.
32
33 There was weak evidence that there was no substantial association between changes in the
34
35 prevalence of high-risk drinking and quit attempts and quit success.
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40 These findings appear to be at odds with individual level studies which suggest that smokers with
41
42 an alcohol use disorder are less likely to attempt and succeed in stopping smoking (12, 13). Alcohol
43
44 consumption during attempts at smoking cessation is also associated with a greater risk of relapse
45
46 (14). As a result, smokers are often advised to lower their alcohol consumption when they attempt
47
48 to quit smoking(9). Of course, it remains plausible that high-risk drinking among smokers may still
49
50 be associated with a small effect on mean population prevalence of quit attempts and their success,
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52 but it was not possible to detect this in the current study. An association may also be masked by
53
54 factors impacting at a population level which were not accounted for in the current study. Although
55
56 we are unaware of any major population-level interventions or other events during the study period
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58 which may have affected the associations under investigation, we cannot rule out residual
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60

1
2 confounding. There may also be some statistical bias due to the loss of power and sensitivity that
3
4 comes with aggregating data. Prevalence of high-risk drinking among smokers will also be
5
6 somewhat noisier than if prevalence was also assessed among non-smokers, given the smaller
7
8 sample size involved in estimation.
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10
11
12 These findings suggest that the previously identified positive association between prevalence of
13
14 smoking and prevalence of high-risk drinking is unlikely to be causal, whereby smokers attempting
15
16 to quit, and those succeeding, also reduce their alcohol intake (22). Although it remains possible
17
18 that use of alcohol by smokers impacts on other key indices including longer term abstinence, the
19
20 small proportion of smokers who relapse long term (i.e. after a year) could not account for the size
21
22 of association noted. It may instead be that overall prevalence is related to an unmeasured variable,
23
24 perhaps economic factors and sociocultural events, that account for the change in both smoking and
25
26 high-risk drinking. For example, in recent years taxation on cigarettes and alcohol have increased
27
28 linearly, driving down sales of both (44, 45). There have also been substantial fluctuations in
29
30 average household income since 2013, which have been shown to independently affect smoking and
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32 alcohol consumption (46-48). Sporting events such as the Olympics may also concurrently increase
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34 alcohol and tobacco intake as they are celebratory occasions. Mass media campaigns may also play
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36 role, simultaneously promoting attempts to quit smoking and the adoption of a healthier lifestyle by
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38 reducing alcohol intake (49).
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A strength of this study is the use of a large representative sample of the population in England.
Several limitations need to be considered. First, the ATS required participants to recall their alcohol
consumption and attempts to quit smoking which is likely to have been somewhat inaccurate due to
recall bias and social desirability. For example, it has been found that a large proportion of
unsuccessful quit attempts fail to be reported, particularly if they only last a short time or occurred
longer ago(50). However, social pressure in population surveys tends to be low and so it is
generally considered acceptable to rely on self-report data(51). Second, these findings may not

1
2 generalise to other countries. England has a strong tobacco-control climate. In countries with
3
4 weaker tobacco control or different alcohol control policies, different effects may be observed.
5
6 Thirdly, this paper did not consider the impact of changes in excessive alcohol consumption
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8 prevalence on the length of quit success, being defined as having made a quit in attempt in the last
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10 12 months and still reporting not smoking. This will be an important area for future research as
11
12 more data are accumulated to provide adequate power. Finally, although there can be no individual-
13
14 level confounding in population trend data there is a possibility of population-level confounding,
15
16 such as introduction of policies that may affect quitting rates. However, we were unable to identify
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18 any such population policies occurring during the study period that may have confounded the
19
20 results.
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27 **Conclusion**

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29 These findings suggest that the previously identified positive association between prevalence of
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31 smoking and prevalence of high-risk drinking is unlikely to be causal, whereby smokers attempting
32
33 to quit, and those succeeding, also reduce their alcohol intake. Instead, it may be that overall
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35 prevalence is related to an unmeasured third variable such as economic factors and sociocultural
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37 events.
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List of abbreviations

ARIMAX - autoregressive integrated moving average with exogenous input

BF – Bayes Factor

ATS – Alcohol Toolkit Study

STS – Smoking Toolkit Study

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Table 1: Estimated percentage point changes in proportion of quit attempts and proportion of quitters who met criteria for quit success during the study period, based on autoregressive integrated moving average with exogenous input (ARIMAX) models

		Output series					
		Quit attempts ¹			Quit success ²		
		Percentage change per 1% change in the exposure	95%CI	p	Percentage change per 1% change in the exposure	95%CI	p
Input series	Model 1: High-risk drinking among smokers (no backward lag of the output series)	0.156	-0.079 to 0.391	0.194	0.066	-0.524 to 0.655	0.827
	Model 2: High-risk drinking among smokers (two month backward lag of the output series)	0.065	-0.183 to 0.313	0.608	0.134	-0.469 to 0.736	0.663
	Bayes Factor						
	Model 1	0.80			0.53		
	Model 2	0.33			0.64		

Table 2: Estimated percentage point changes in proportion of quit attempts and proportion of quitters who met criteria for quit success during the study period, based on autoregressive integrated moving average with exogenous input (ARIMAX) models – adjusted age and social-economic status

		Output series					
		Quit attempts ¹			Quit success ²		
		Percentage change per 1% change in the exposure	95%CI	p	Percentage change per 1% change in the exposure	95%CI	p
Input series	Model 1: High-risk drinking among smokers (no backward lag of the output series)	0.040	-0.214 to 0.294	0.758	0.168	-0.489 to 0.825	0.616
	Model 2: High-risk drinking among smokers (two month backward lag of the output series)	0.030	-0.229 to 0.289	0.822	0.132	-0.549 to 0.814	0.703

Figure 1: Prevalence of a) high-risk drinking; b) attempts to quit smoking and c) quit success

Declarations

Ethical approval and consent to participate

1
2 Ethics approval for the Smoking Toolkit Survey (STS) was originally granted by the UCL Ethics
3 Committee (ID 0498/001) and approval for the ATS was granted by the same committee as an
4 extension of the STS (ID 2808/005). In accordance with our ethical approval, all respondents were
5 given a written information sheet about the study, and provided informed verbal consent
6

7 ***Availability of data and material***

8 The analysis plan, data and syntax were preregistered on the Open Science Framework
9 (<https://osf.io/384gx/>).
10
11

12 ***Funding***

13 The Smoking Toolkit Study is currently primarily funded by Cancer Research UK (C1417/A14135;
14 C36048/A11654; C44576/A19501) and has previously also been funded by Pfizer, GSK, and the
15 Department of Health. The ATS is currently funded by the NIHR School for Public Health
16 Research (SPHR) (SPHR-SWP-ALC-WP5). SPHR is a partnership between the Universities of
17 Sheffield; Bristol; Cambridge; Exeter; UCL; The London School for Hygiene and Tropical
18 Medicine; the LiLaC collaboration between the Universities of Liverpool and Lancaster and Fuse;
19 The Centre for Translational Research in Public Health, a collaboration between Newcastle,
20 Durham, Northumbria, Sunderland and Teesside Universities. The views expressed are those of the
21 authors(s) and not necessarily those of the NHS, NIHR, or Department of Health. No funders had
22 any involvement in the design of the study, the analysis or interpretation of the data, the writing of
23 the report, or the decision to submit the paper for publication. JB's post is funded CRUK
24 (C1417/A14135). RW is funded by Cancer Research UK (C1417/A14135). EB is funded by the
25 NIHR SPHR (SPHR-SWP-ALC-WP5) and CRUK also provide support (C1417/A14135).
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29

30 ***Competing interests***

31 RW undertakes consultancy and research for and receives travel funds and hospitality from
32 manufacturers of smoking cessation medications. RW salary is funded by Cancer Research UK. SM
33 receives support from Cancer Research UK and the National Institute for Health Research (NIHR)'s
34 School for Public Health Research (SPHR). EB and JB have received unrestricted research funding
35 from Pfizer. PM's research is funded by a variety of governmental funding agencies including
36 UKRI and NIHR.
37
38

39 ***Authors' contributions***

40 EB, JB, SM and RW wrote the first draft of the manuscript and conducted the analysis. All other
41 authors commented on this draft and contributed to the final version. All authors read and approved
42 the final manuscript.
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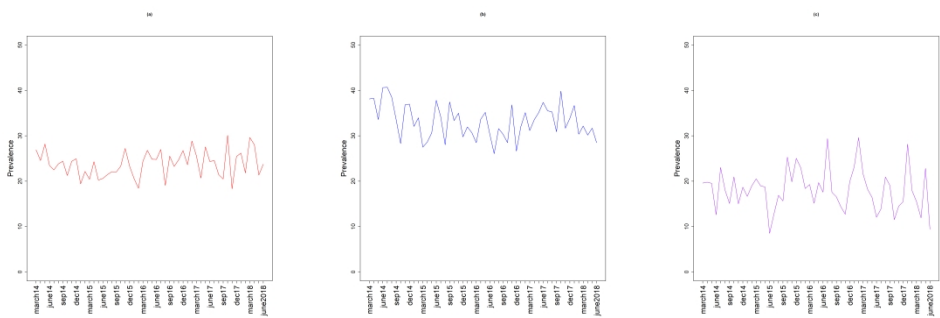
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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of cross-sectional studies

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	6-7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	6-7
		(b) Describe any methods used to examine subgroups and interactions	6-8
		(c) Explain how missing data were addressed	6-8
		(d) If applicable, describe analytical methods taking account of sampling strategy	6-8
		(e) Describe any sensitivity analyses	6-8
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	N/a
		(c) Consider use of a flow diagram	N/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	
		(b) Indicate number of participants with missing data for each variable of interest	N/a
Outcome data	15*	Report numbers of outcome events or summary measures	9-10
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9-10
		(b) Report category boundaries when continuous variables were categorized	9-10
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9-10
Discussion			
Key results	18	Summarise key results with reference to study objectives	10-11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10-11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10-11
Generalisability	21	Discuss the generalisability (external validity) of the study results	10-11
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.