John Macleod, Roy Robertson, Lorraine Copeland, James McKenzie, Rob Elton and Peter Reid

Cannabis, tobacco smoking, and lung function:

a cross-sectional observational study in a general practice population

Abstract

Background
Health concerns around cannabis use have focused on the potential relationship with psychosis but the effect of cannabis smoking on respiratory health has received less attention.

Aim
To investigate the association between tobacco-only smoking compared with tobacco plus cannabis smoking and adverse outcomes in respiratory health and lung function.

Design and setting
The design was cross-sectional with two groups recruited: cigarette smokers with tobacco pack-years; cannabis smokers with cannabis joint-years. Recruitment occurred in a general practice in Scotland with 12 500 patients.

Method
Exposures measured were tobacco smoking (pack-years) and cannabis smoking (joint-years). Cannabis type (resin, herbal, or both) was recorded by self-report. Respiratory symptoms were recorded using NHANES and MRC questionnaires. Lung function was measured by spirometry (FEV1/FVC ratio).

Results
Participants consisted of 500 individuals (242 males). Mean age of tobacco-only smokers was 45 years; median tobacco exposure was 25 pack-years. Mean age of cannabis and tobacco smokers was 37 years; median tobacco exposure was 19 pack-years, rising to 22.5 when tobacco smoked with cannabis. Although tobacco and cannabis use were associated with increased reporting of respiratory symptoms, this was higher among those who also smoked cannabis. Both tobacco and cannabis users had evidence of impaired lung function but, in fully adjusted analyses, each additional joint-year of cannabis use was associated with a 0.3% (95% confidence interval = 0.0 to 0.5) increase in prevalence of chronic obstructive pulmonary disease.

Conclusion
In adults who predominantly smoked resin cannabis mixed with tobacco, additional adverse effects were observed on respiratory health relating to cannabis use.

Keywords
cannabis; general practice; lung function tests; signs and symptoms, respiratory.

INTRODUCTION

An estimated 3 million individuals in the UK suffer from chronic obstructive pulmonary disease (COPD) for which tobacco smoking remains the most important risk factor.[1] Tobacco use in the UK appears to be in decline. This contrasts with an increase in the smoking of cannabis, particularly among younger people.[2] Health concerns around cannabis use have typically focused on the potential relationship with psychosis.[3] The effect of cannabis use on respiratory health has received less attention. Current evidence from North America and New Zealand is mixed providing no definitive conclusion on the respiratory effects of cannabis. Although cannabis use does appear to be associated with greater reported respiratory symptoms, no strong evidence has emerged of deleterious effects on objective measures of respiratory function.[4–13] The populations studied in this regard have been relatively young and have almost exclusively used herbal (grass or weed made from the dried leaves and flowering part of the female plant and resembling dried herbs) cannabis. In countries such as the UK, resin cannabis (known as 'hash'), smoked in a cigarette prepared with tobacco, known colloquially as a 'joint' and elsewhere as a spliff or reefer, appears to be the most common form of consumption.[14] In some cases a smoking device is used to inhale cannabis vapour (known as a 'bong'). When estimating respiratory effects of such use it is important to consider effects of this additional tobacco use. Cannabis use may become established and extend at least into middle adulthood, leading to high cumulative exposure. Effects of such exposure can only be studied in older established cannabis users. This study was an investigation of the influence of cannabis use and tobacco use, including tobacco smoked with cannabis, on reports of respiratory symptoms and measures of lung function among established cannabis and tobacco users in a general practice-based sample in Scotland, where cannabis resin was the most common form of the drug consumed.

METHOD

Recruitment, classification of cannabis, and tobacco use

Participants were recruited from consecutive patients attending for care at Muirhouse Medical Group between May 2010 and September 2011. Individuals who were aged ≥18 years with a record of past or current smoking in their medical notes were identified in appointment lists and approached by a researcher, who explained the study and determined eligibility. Individuals were eligible for recruitment if they reported significant tobacco or cannabis use (20 cigarettes per day for at

J Macleod, MSc, PhD, MRCGP, professor of clinical epidemiology and primary care, School of Social and Community Medicine, University of Bristol, Bristol. **R Robertson**, FRCP, FRCGP, GP, professor of addiction medicine; **L Copeland**, MA, MSc, researcher; **J McKenzie**, RMN, RGN, BSc, researcher, Muirhouse Medical Group, Edinburgh. **R Elton**, PhD, statistician, University of Edinburgh, Centre for Population Health Sciences, Edinburgh. **P Reid**, FRCP, MD, consultant respiratory physician, Respiratory Unit, Western General Hospital, Edinburgh.

Address for correspondence
Roy Robertson, University of Edinburgh, Centre for Population Health Sciences, Medical School, Teviot Place, Edinburgh, EH8 9AG.
E-mail: roy.robertson@ed.ac.uk

Submitted: 1 April 2014; **Editor's response:** 27 May 2014; **final acceptance:** 26 June 2014.

DOI: 10.3399/bjgp15X683521

How this fits in

Cannabis smoking is associated with increased respiratory symptoms, but evidence of adverse effects on lung function is sparse. This study provides the first UK data on the impact of cannabis smoking on the prevalence of respiratory symptoms and chronic obstructive pulmonary disease in a general practice population. Although many adverse effects appeared attributable to tobacco, evidence of some additional adverse effects of cannabis was found.

least 5 years or one cannabis joint per day for at least 1 year). Individuals were invited to complete a questionnaire covering demographic details, health, tobacco and cannabis use, and self-reported respiratory symptoms. Recruited individuals also underwent a standard respiratory assessment at the practice. Quota sampling with a target of 250 tobacco-only smokers and 250 cannabis smokers who may also have smoked tobacco was used. Patients whose notes indicated recent bereavement or receipt of palliative care were not approached by the researcher. Of the patients approached, nine (2%) refused.

Questionnaire measures

Responders were asked to report all periods of regular smoking during their lifetime and daily cigarettes smoked during these periods. Cumulative tobacco exposure was calculated using pack-years (1 pack-year being equivalent to smoking 20 cigarettes per day for 1 year). For participants who rolled-their-own tobacco cigarettes, established conventions were adopted suggesting that one cigarette is considered equivalent to 1 g of tobacco and 1 oz tobacco/week equivalent to 4 g/day.[15] To estimate cannabis use, the questionnaire developed for use in the Avon Longitudinal Study of Parents and Children was employed.[16] Responders reported periods of regular cannabis use, the main type of cannabis used during these periods, the mode of use, the terms of number of joints smoked, and the frequency of this use. This allowed derivation of cannabis 'joint-year' as a measure of cumulative exposure with 1 joint-year being exposure to one joint or equivalent per day or 365 in 1 year. Participants who shared joints were asked to estimate the proportion of the joint they smoked themselves, and these proportions were incorporated into calculations. The respiratory section of the third National Health Nutrition Examination Survey (NHANES III) and the Medical Research Council breathlessness questionnaire were employed to record reported respiratory symptoms.[17,18] Questionnaires were given as face-to-face interviews by one investigator in a standardised manner. Participants reported their home postcode, which was used to assign Scottish Index of Multiple Deprivation (SIMD). The SIMD ranks small areas (called datazones) from most deprived (ranked 1) to least deprived (ranked 6505). People using the SIMD will often focus on the datazones below a certain rank, for example, the 5%, 10%, 15%, or 20% most deprived datazones in Scotland.[19]

Exclusion criteria

Participants were excluded with known bronchiectasis, asthma, cystic fibrosis, and tuberculosis, and persons with significant occupational exposure known to be hazardous to the lungs. Patients with asthma were excluded as they are likely to have an unpredictable response to lung function testing dependent on variable factors.

Lung function tests

Participants underwent pulmonary function testing using Vitalograph Alpha (Vitalograph UK). Tests performed included forced expiratory volume in 1 second (FEV1), forced vital capacity (FVC), maximum mid-expiratory flow (MMEF), and slow vital capacity (SVC). Lung function tests were carried out before and 20 minutes after giving 400 µg inhaled salbutamol via a spacer device. Reference equations were derived by the European Community for Coal and Steel. These equations were used to calculate FEV1 and FVC as a percentage of the age and sex predicted value. The lung function tests were conducted in accordance with American Thoracic Society and European Respiratory Society guidelines and equipment was calibrated daily.[20,21] COPD was defined as the presence of a post-bronchodilator per cent predicted FEV1/FVC < 0.70.

Power

It was aimed to recruit 250 tobacco-only and 250 cannabis smokers, giving 80% power to detect as significant at the 5% level a 13% difference in the prevalence of respiratory symptoms between groups for prevalences in the range 30–70%.

Statistical analysis

Unadjusted group comparisons were made by χ^2 tests with Yates' correction. Multiple linear, logistic, or ordinal logistic

Table 1. Characteristics of study participants

Median (range)	Tobacco-only males (*n* = 93)	Tobacco-only females (*n* = 155)	Cannabis and tobacco males (*n* = 150)	Cannabis and tobacco females (*n* = 102)
Age, years	47 (24–73)	43 (17–68)	38 (18–63)	36.5 (22–63)
BMI, kg/m^2	24.9 (17–47.8)	26.4 (16.9–55)	23.1 (15.2–47.4)	23.7 (15.2–48.2)
Age of first smoking tobacco	15 (7–31)	15 (8–39)	14 (5–25)	14 (8–36)
Tobacco pack-years[a]	30 (5–116)	24 (5–70)	23.5 (2.4–113.3)	20.4 (3.6–88.5)
Age of first smoking cannabis	n/a	n/a	15 (7–40)	16 (11–45)
Cannabis joint-years	n/a	n/a	104.5 (1.0–1050)	53.2 (1.0–325)
SIMD deprivation	1.0 (0.1–6.1)	0.6 (0–1–6.1)	0.6 (0.1–5.7)	0.6 (0.1–6.4)

[a]*Includes additional tobacco used to make a joint. BMI = body mass index. SIMD = Scottish Index of Multiple Deprivation (the Scottish Government official tool for identifying those places in Scotland suffering from deprivation).*

regression was used to estimate the effect of cannabis use on quantitative, binary, or ordinal outcomes, respectively, after adjusting for the effects of other factors. Estimates and confidence limits (95% CI) for odds ratios derived from these regressions were expressed as percentage changes by subtracting one and multiplying by 100. The demographic factors chosen for the logistic regression were all those that had been collected, which were based on plausibility as possible confounders and ease of collection. There was no stepwise selection on grounds of significance.

RESULTS

Participants

Five-hundred participants were recruited of whom 242 were male (Table 1): 248 participants (92 males) reported use of tobacco only, whereas 252 participants (150 males) reported use of both cannabis and tobacco. Participants who used cannabis and tobacco were younger and had lower body mass index than users of tobacco only (Table 1).

Tobacco use

Lifetime tobacco exposure was higher among tobacco-only smokers even when the additional tobacco used with cannabis was taken into account (Table 1).

Cannabis use

Most participants (77%, 95% CI = 72 to 82) smoked resin cannabis with a smaller group smoking herbal cannabis (16%, 95% CI = 12 to 21). A small number reported smoking both forms (6%, 95% CI = 4 to 10). Cannabis was most commonly smoked in the form of joints (88%, 95% CI = 83 to 91), with the remainder employing a pipe or a bong (6%, 95% CI = 4 to 10), some using joints and pipes/bongs (4%, 95% CI = 2 to 7). Cannabis was almost always smoked with tobacco (93%, 95% CI = 89 to 96). Cannabis smokers used similar amounts of cannabis whether or not they also smoked tobacco. Tobacco smokers, who also smoked cannabis, smoked fewer cigarettes than those who smoked tobacco alone, with a difference of 6.2 pack-years (95% CI = 3.2 to 9.2). Male participants were slightly older than female participants and had greater exposure to tobacco and cannabis.

Respiratory symptoms and lung function

Self-reported respiratory symptoms in tobacco-only smokers compared with tobacco and cannabis smokers are presented in Table 2. In general, cannabis smokers reported more respiratory symptoms than tobacco smokers and this was most apparent when asked about expectoration of sputum and wheeze. Four-hundred and forty lung function tests met Global Initiative for Chronic Obstructive Lung Disease criteria for analysis (210 tobacco-only users and 230 cannabis and tobacco users). The prevalence of spirometric COPD among tobacco-only smokers was 24.3% (51 out of 210). Among tobacco and cannabis smokers this proportion was 25.2% (58 out of 230).

Table 3 shows the effect of cannabis use on respiratory symptoms and lung function adjusted for covariant cigarette use (all cannabis users also smoked cigarettes) and for additional tobacco smoked with cannabis. Most estimates are substantially attenuated by this second adjustment; however, relatively strong and substantial effects are still apparent in relation to

Table 2. NHANES III respiratory symptoms in tobacco and cannabis users

	Tobacco-only, *n* (%)	Cannabis and tobacco, *n* (%)	*P*-value
Has a doctor ever told you that you have chronic bronchitis?	36 (14.5)	37 (14.7)	0.92
Do you usually cough on most days for 3 consecutive months or more during the year?	74 (29.8)	102 (40.5)	0.024
Do you bring up phlegm on most days for 3 consecutive months or more during the year?	58 (23.4)	97 (38.5)	0.001
Are you troubled by shortness of breath when hurrying on level ground or walking up a slight hill?	110 (44.4)	120 (47.6)	0.63
Have you had wheezing or whistling in your chest at any time during the past 12 months?	126 (50.8)	167 (66.3)	<0.001
Apart from when you have a cold does your chest ever sound wheezy or whistling?	106 (42.7)	146 (57.9)	0.002
During the past 12 months have you had pneumonia?	12 (4.8)	9 (3.6)	0.60

Table 3. Additional influence of tobacco smoked in 'joints' on NHANES III respiratory symptoms and lung function in those who use cannabis

	Tobacco pack-years from cigarettes % change (95% CI)	*P*-value	Tobacco pack-years from cigarettes plus cannabis joints % change (95% CI)	*P*-value
MRC dyspnoea score	0.4 (0.2 to 0.6)	<0.001	0.2 (0.0 to 0.4)	0.022
Do you usually cough on most days for 3 consecutive months or more during the year?	0.4 (0.2 to 0.7)	0.001	0.3 (0.0 to 0.5)	0.026
Do you bring up phlegm on most days for 3 consecutive months or more during the year?	0.5 (0.2 to 0.7)	<0.001	0.4 (0.1 to 0.6)	0.006
Are you troubled by shortness of breath when hurrying on level ground or walking up a slight hill?	0.2 (0.0 to 0.5)	0.037	0.1 (–0.1 to 0.4)	0.290
Have you had wheezing or whistling in your chest at any time during the past 12 months?	0.3 (0.0 to 0.7)	0.022	0.2 (–0.1 to 0.4)	0.240
Apart from when you have a cold does your chest ever sound wheezy or whistling?	0.3 (0.1 to 0.6)	0.014	0.2 (–0.1 to 0.4)	0.180
During the past 12 months have you had pneumonia?	0.2 (–0.1 to 0.7)	0.180	0.2 (–0.2 to 0.6)	0.280
Number of NHANES questions (answered 'Yes')	0.4 (0.2 to 0.6)	<0.001	0.3 (0.1 to 0.5)	0.010
More than three NHANES questions (answered 'Yes')	0.4 (0.1 to 0.7)	0.001	0.3 (0.0 to 0.5)	0.041
Lung function				
FEV1/FVC<0.7	0.4 (0.0 to 0.7)	0.013	0.3 (0.0 to 0.5)	0.024

Estimated effect of cannabis on respiratory symptoms and lung function in ordinal logistic regression analyses adjusted for age, sex, deprivation, and tobacco pack-years from cigarettes only or tobacco pack-years from cigarettes plus cannabis joints. Figures shown are estimates for per cent change in positive response or increase of one category per joint-year of cannabis.

several symptoms and prevalence of COPD. In fully adjusted analyses each additional joint-year of cannabis use was associated with a 0.3% (95% CI = 0.0 to 0.5) increase in prevalence of COPD. Table 4 shows unadjusted estimates of lung function by age group among tobacco and cannabis users. COPD is generally apparent at a younger age among tobacco and cannabis smokers compared with tobacco-only smokers. For example, in the age range 25–34 years, 6% of tobacco-only users compared with 14% of tobacco and cannabis users met COPD criteria; in the 35–44 years age range, these proportions rose to 16% and 29%, respectively. Because of the small numbers these differences are imprecisely estimated, and further adjustment for the additional tobacco smoked in joints (not shown) among tobacco and cannabis users attenuated them further.

DISCUSSION

Summary

In a general practice-based sample of established adult tobacco and cannabis users, cannabis use (which was predominantly use of resin cannabis smoked with tobacco) was associated with greater reporting of respiratory symptoms. In particular, the slightly increased presence of cough, wheeze, and sputum production are more likely in cannabis smokers. In addition, it was also associated with objective evidence of COPD. Part of the adverse effect of cannabis is likely to be attributable to the tobacco included in the cannabis joint; however, even after this additional tobacco smoked with cannabis was taken into account, the effects of cannabis on increased respiratory symptoms and increased prevalence of spirometric COPD were still apparent. This evidence of increased COPD was also apparent at younger ages among cannabis smokers. There is clear evidence that

Table 4. Lung function by age group among tobacco and cannabis users

	Tobacco-only users				Tobacco and cannabis users				
Age band, years	*n*	FEV1 Mean (SD)	FVC Mean (SD)	FEV1/FVC<0.7 % (95% CI)	*n*	FEV1 Mean (SD)	FVC Mean (SD)	FEV1/FVC<0.7 % (95% CI)	*P*-value [a]
15–24	11	107.1 (12.3)	109.4 (16.8)	9.1 (1.6 to 37.7)	12	104.6 (9.7)	112.2 (11.0)	8.3 (1.5 to 35.4)	0.95
25–34	34	96.2 (12.4)	103.7 (15.8)	5.9 (1.6 to 19.1)	79	98.6 (14.2)	107.3 (15.3)	13.9 (8.0 to 23.2)	0.36
35–44	64	96.1 (15.1)	109.2 (15.6)	15.6 (8.7 to 26.4)	89	95.8 (15.7)	109.3 (17.1)	29.2 (20.8 to 39.4)	0.08
45–54	68	92.6 (21.3)	107.5 (16.5)	27.9 (18.7 to 39.6)	41	93.4 (17.0)	108.1 (14.0)	36.6 (23.6 to 51.9)	0.46
55–64	28	89.1 (17.7)	106.0 (23.3)	53.5 (35.8 to 70.5)	9	83.3 (41.1)	113.8 (19.6)	55.6 (26.7 to 81.1)	0.78
65–74	5	72.0 (22.1)	96.5 (20.6)	80.0 (37.6 to 96.4)	0	–	–	–	–
All ages	210	93.8 (18.1)	107.0 (17.4)	24.3 (19.0 to 30.5)	230	96.4 (17.0)	108.7 (15.8)	25.2 (20.0 to 31.2)	0.90

Figures for FEV1 and FVC are percentages of the predicted values from the reference equations by age and sex. [a]P-value for difference in FEV1/FVC% tobacco only users compared with tobacco and cannabis users. FVC = forced vital capacity. FEV1 = forced expiratory volume in 1 second.

among individuals whose cannabis use is established beyond adolescence, and who predominantly use the resin type, cannabis has non-trivial effects on respiratory health that are additional to the effects of the tobacco it is smoked with.

The study sample was obtained from a community practice with a previously noted high prevalence of illegal drug use.[14] Although this may not represent experience in the many UK general practice populations, it is by no means untypical of poorer socioeconomic communities in larger cities.

Recruitment in this study was very successful, only nine individuals declined to participate. This was the result of a combination of clinical experience and research skills in a small team with a series of recent successful studies on overlapping topics and a cooperative clinical practice with good relations to the caseload.

In a general practice-based sample of established adult tobacco and cannabis users, cannabis use (which was predominantly use of resin cannabis smoked with tobacco) was associated with greater reporting of respiratory symptoms. Current clinical guidelines emphasise the importance of considering a diagnosis of COPD in symptomatic patients aged ≥35 years.[1] These results suggest that active case finding of COPD should be considered in younger patients, particularly those who smoke cannabis. Public health messages around the possible harms of cannabis use should highlight evidence for its adverse effects on respiratory health.

Strengths and limitations

The main strengths of the present study were that it was a general practice-based sample composed of adults with established tobacco and cannabis use. Most were users of resin cannabis (a previously understudied group in this regard). The study also included detailed measures of tobacco and cannabis use and detailed measures of respiratory symptoms collected, using validated instruments along with objective, clinically meaningful measures of lung function assessed using standard procedures.

The main limitations were that the study was cross-sectional, which constrained inference of causality. For reasons of efficiency, only smokers were sampled, resulting in the absence of a non-smoking group from this population for comparison.

For convenience, the sampling strategy was based on individuals attending a general practice. Although most people in the UK attend general practices relatively regularly, it is possible that unwell individuals were oversampled and that this may have introduced bias. To minimise participant burden and because of concerns that more detailed questions about illicit drug use other than cannabis might deter participation, no detailed questions were asked regarding other drug use. It is possible that individuals in this population who use cannabis also use other illicit drugs to a greater extent than those who do not use cannabis. Tobacco and cannabis use were self-reported and neither was corroborated biochemically such as using urine toxicology. Several studies have used biochemical corroboration of tobacco use alongside self-report and have concluded that the latter is valid.[22,23] No extant studies of effects of cannabis on respiratory outcomes have used biochemical corroboration of cannabis exposure, partly reflecting limitations in available assays. Misreporting of cannabis use may have occurred in the present study, with the most likely consequence being a dilution of ability of the researchers to detect effects of cannabis. There remains, however, a possible effect of tobacco-only smokers failing to reveal their cannabis use.

Comparison with existing literature

Most, although not all, researchers have described increased reporting of respiratory symptoms among cannabis smokers similar to those described here.[4–13] These studies have predominantly involved smokers of herbal cannabis. Evidence from the present study suggests that these effects are also seen with resin cannabis. In contrast, previous studies have not always found strong or consistent evidence that cannabis smoking has adverse effects on objective measures of COPD such as the FEV1/FVC ratio.[24,25] The present study did find evidence of such effects, over and above those that appeared attributable to the tobacco use of cannabis smokers. It has been suggested that discrepancies in the evidence partly relate to the extent that cannabis use is associated with increased FVC (which may result from repeated pulmonary hyperinflation related to the way cannabis is smoked.[25] FVC was notably higher among cannabis users in the present study. Some studies have reported apparent increases in FEV1 associated with cannabis smokers compared with non-smokers.

The present study found no such evidence, although FEV1 among cannabis and tobacco smokers was higher than that among tobacco-only smokers in the study population, both were considerably less

Funding

This research study was funded by a Chief Scientist Office project grant (CZH 4 566).

Ethical approval

Ethical approval for the study was granted by South East Scotland Research Ethics Committee 01 (ref: 09/S1101/71).

Provenance

Freely submitted; externally peer reviewed.

Competing interests

The authors have declared no competing interests.

Acknowledgements

We gratefully acknowledge the cooperation received from the study participants who were all patients of Muirhouse Medical Group. In addition, we thank the partners and staff of Muirhouse Medical Group for the daily support and accommodation given to our study.

Discuss this article

Contribute and read comments about this article: **bjgp.org/letters**

than 100% of the predicted value in non-smokers. Some of the discrepancy between the present findings and those of previous studies may be attributable to a particular adverse effect of resin cannabis smoking (the predominant form of cannabis use in the present study population on these outcomes) or to the relatively high levels of cumulative exposure seen in the present study population. Previous studies have included fewer participants with these exposure levels, and have, therefore, lacked power to estimate their effects.[13]

Implications for research and practice

This study is the first study from the UK providing data on the potential impact of cannabis resin smoking on the prevalence of respiratory symptoms and COPD in a general practice population. The study findings indicate that there are some adverse respiratory effects from smoking cannabis and this should possibly be included in future health education messages, in a similar way to those for tobacco smoking.

REFERENCES

1. National Institute for Health and Clinical Excellence. *Chronic obstructive pulmonary disease: Management of chronic obstructive pulmonary disease in adults in primary and secondary care (partial update)*. NICE guidelines [CG101]. https://www.nice.org.uk/guidance/cg101 (accessed 9 Dec 2014).
2. United Nations Office on Drugs and Crime. *World Drug Report 2010*. http://www.unodc.org/unodc/data-and-analysis/WDR-2010.html (accessed 25 Nov 2014).
3. Kuepper R, van Os J, Lieb R, *et al*. Continued cannabis use and risk of incidence and persistence of psychotic symptoms: 10 year follow-up cohort study. *BMJ* 2011; **342:** d738.
4. Tashkin DP, Coulson AH, Clark VA, *et al*. Respiratory symptoms and lung function in habitual heavy smokers of marijuana alone, smokers of marijuana and tobacco, smokers of tobacco alone, and nonsmokers. *Am Rev Respir Dis* 1987; **135:** 209–216.
5. Bloom JW, Kaltenborn WT, Paoletti P, *et al*. Respiratory effects of non-tobacco cigarettes. *BMJ* 1987; **295:** 1516–1518.
6. Tashkin DP, Shapiro BJ, Lee YE, Harper CE. Subacute effects of heavy marihuana smoking on pulmonary function in healthy men. *N Engl J Med* 1976; **294:** 125–129.
7. Sherrill DL, Krzyzanowski M, Bloom JW, Lebowitz D. Respiratory effects of non-tobacco cigarettes: a longitudinal study in general population. *Int J Epidemiol* 1991; **20(1):** 132–137.
8. Taylor D, Poulton R, Moffitt TE, *et al*. The respiratory effects of cannabis dependence in young adults. *Addiction* 2000; **95:** 1169–1677.
9. Taylor DR, Fergusson DM, Milne BJ, *et al*. A longitudinal study of the effects of tobacco and cannabis exposure on lung function in young adults. *Addiction* 2002; **97:** 1055–1061.
10. Moore BA, Auguston EM, Moser RP, Budney AJ. Respiratory effects of marijuana and tobacco use in a US sample. *J Gen Int Med* 2004; **20:** 33–37.
11. Aldington S, Williams M, Nowitz M, *et al*. Effects of cannabis on pulmonary structure, function and symptoms. *Thorax* 2007; **62:** 1058–1063.
12. Tan WC, Lo C, Jong A, *et al*. Marijuana and chronic obstructive lung disease: a population-based study. *CMAJ* 2009: **180(8):** 814–820.
13. Pletcher MJ, Vittinghoff E, Kalhan R, *et al*. Association between marijuana exposure and pulmonary function over 20 years. *JAMA* 2012; **307:** 173–181.
14. Robertson R, Miller P, Anderson R. Cannabis use in the community. *Br J Gen Pract* 1996; **46:** 671–674.
15. Doll R, Bradford Hill A. The mortality of doctors in relation to their smoking habits. *BMJ* 1954; **1(4877):** 1451–1455.
16. University of Bristol. *The Avon Longitudinal Study of Parents and Children*. http://www.bristol.ac.uk/alspac/ (accessed 9 Dec 2014).
17. Centers for Disease Control and Prevention. *National Health and Nutrition Examination Survey*. http://www.cdc.gov/nchs/about/major/nhanes/questexam.html (accessed 25 Nov 2014).
18. Fletcher CM (Chairman). Standardised questionnaire on respiratory symptoms: a statement prepared and approved by the MRC Committee on the Aetiology of Chronic Bronchitis (MRC breathlessness score). *BMJ* 1960; **2:** 1665.
19. SIMD. Scottish Index of Multiple Deprivation. http://simd.scotland.gov.uk/publication-2012/ (accessed 9 Dec 2014).
20. Quanjer P, Dalhuisen A, van Zomeren B. Standardisation of lung function tests. Report of the Working Party for Standardisation of Lung Function Tests. European Community for Coal and Steel. *Bull Eur Physiopathol Respir* 1983; **19:** 45–51.
21. American Thoracic Society. Standardisation of spirometry: 1994 update. *Am J Respir Crit Care Med* 1994; **152:** 1107–1136.
22. Martin GW, Wilkinson DA, Kapur BM. Validation of self-reported cannabis use by urine analysis. *Addict Behav* 1988; **13:** 147–150.
23. Akinci IH, Tarter RE, Kirisci L. Concordance between verbal report and urine screen of recent marijuana use in adolescents. *Addict Behav* 2001; **26:** 613–619.
24. Tashkin DP. Does cannabis use predispose to chronic airflow obstruction? *Eur Respir J* 2010; **35:** 3–5.
25. Lee MH, Hancox RJ. Effects of smoking cannabis on lung function. *Expert Rev Respir Med* 2011; **4:** 537–546.