

will be to discover the personality characteristics which make some doctors particularly vulnerable to desynchronisation of circadian performance rhythm after disruption of sleep.¹⁸

References

- 1 Wilkinson RT. Sleep deprivation. In: Edholm OG, Bacharach AL, eds. *The physiology of human survival*. London: Academic Press, 1965:399-430.
- 2 Horne JA, Anderson NR, Wilkinson RT. Effects of sleep deprivation on signal detection measures of vigilance: implications for sleep function. *Sleep* 1983;6:347-58.
- 3 Horne JA, Pettitt AN. High incentive effects on vigilance performance during 72 hours of total sleep deprivation. *Acta Psychol (Amst)* 1985;58:123-39.
- 4 Bonnet MH. Effect of sleep disruption on sleep, performance and mood. *Sleep* 1985;8:11-9.
- 5 Wilkinson RT, Tyler PD, Varey CA. Duty hours of young hospital doctors: effects on the quality of work. *Journal of Occupational Psychology* 1975;48:219-29.
- 6 Friedman RC, Bigger JT, Kornfeld DS. The intern and sleep loss. *N Engl J Med* 1971;285:201-3.
- 7 Friedman R, Kornfeld DS, Bigger JT. Psychological problems associated with sleep deprivation in interns. *J Med Educ* 1973;48:436-41.

- 8 Ford CV, Wentz DK. The internship year: a study of sleep, mood states and psychophysiological parameters. *South Med J* 1984;77:1435-41.
- 9 Poulton EC, Hunt GM, Carpenter A, Edwards RS. The performance of junior hospital doctors following reduced sleep and long hours of work. *Ergonomics* 1978;21:279-95.
- 10 Christie M, Venables PH. Mood changes in relation to age, EPI scores and time of day. *British Journal of Social and Clinical Psychology* 1973;12:61-72.
- 11 McKay CJ. The measurement of mood and psychophysiological activity using self-report techniques. In: Martin I, Venables PH, eds. *Techniques in psychophysiology*. Chichester: Wiley, 1980:501-64.
- 12 Wechsler D. *Manual for the Wechsler adult intelligence scale—revised (WAIS-R)*. New York: Psychological Corporation, 1981.
- 13 Wechsler D. *Manual for the Wechsler memory scale*. New York: Psychological Corporation, 1955.
- 14 Howell DC. *Statistical methods for psychology*. Boston: Duxbury, 1982.
- 15 Dunn OJ. Multiple comparisons among means. *Journal of the American Statistical Association* 1955;50:1096-121.
- 16 Smith JW, Denny WF, Witzke DB. Emotional impairment in internal medicine house staff. *JAMA* 1986;255:1155-8.
- 17 Firth-Cozens J. Emotional distress in junior house officers. *Br Med J* 1987;295:533-5.
- 18 Folkard S. Our diurnal nature. *Br Med J* 1986;293:1257-8.

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Respiratory effects of non-tobacco cigarettes

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Abstract

Data from the Tucson epidemiological study of airways obstructive disease on smoking of non-tobacco cigarettes such as marijuana were analysed to determine the effect of such smoking on respiratory symptoms and pulmonary function. Among adults aged under 40, 14% had smoked non-tobacco cigarettes at some time and 9% were current users. The prevalence of respiratory symptoms was increased in smokers of non-tobacco cigarettes. After tobacco smoking had been controlled for men who smoked non-tobacco cigarettes showed significant decreases in expiratory flow rates at low lung volumes and in the ratio of the forced expiratory volume in one second to the vital capacity. This effect on pulmonary function in male non-tobacco cigarette smokers was greater than the effect of tobacco cigarette smoking.

These data suggest that non-tobacco cigarette smoking may be an important risk factor in young adults with respiratory symptoms or evidence of airways obstruction.

Introduction

The adverse effects of tobacco cigarette smoking have been shown consistently in population studies.¹ The effects of non-tobacco cigarettes have not, however, been examined in a general population. Various illicit drugs are smoked as cigarettes, but by far the most widely used in the United States is marijuana.² Data from a

representative population sample would provide information on the effects of "usual" non-tobacco cigarette smoking.

Subjects participating in the Tucson epidemiological study of airways obstructive disease frequently inquired whether non-tobacco cigarette smoking (specifically marijuana) should be included in the responses to the smoking questions. For this reason, questions about non-tobacco cigarette smoking were included in this survey (1981-3). We report on the results of this survey as a cross sectional study of the effects of non-tobacco cigarettes on respiratory symptoms and pulmonary function.

Methods

The methods of selection for the study population have been described.³ In brief, the population is a random stratified cluster sample of households in Tucson, Arizona, enrolled in 1972-3. Details of the study questionnaire and spirometry methods have been reported.^{3,4} Questionnaire and spirometric data from the seventh survey (1981-3) were available for analysis on 2251 white non-Mexican-American subjects aged over 14 years. The survey questionnaire contained questions about the duration and intensity of non-tobacco cigarette smoking and the depth of inhalation. The questions referred to "non-tobacco cigarette" smoking because of the illegality of marijuana use.

Values for the forced expiratory volume in one second (FEV₁) and the forced vital capacity (FVC) were the best of at least three attempts.⁵ The flow rates at 50% (V̇max₅₀) and 75% (V̇max₇₅) of the expired forced vital capacity were derived from the best sum curve, FEV₁+FVC. Values were expressed as percentage of predicted. Predicted values were based on the subject's age, sex, and height using prediction equations derived from asymptomatic, non-diseased, non-smoking subjects in this population.⁴

Preliminary analyses showed that there were only two current and six ex-smokers of non-tobacco cigarettes aged over 40 years. Analyses were therefore confined to the 15-40 year age group. There were 990 subjects in this age range with questionnaire and spirometric data. Subjects were grouped according to their tobacco and non-tobacco cigarette smoking habits as current smokers, ex-smokers, and those who had never smoked. In some analyses current and ex-smokers of non-tobacco cigarettes were grouped together and referred to as "ever" smokers of non-tobacco cigarettes.

Data were processed on the DEC-10/Cyber 175 computer system of the University of Arizona. Statistical techniques included cross tabulation with χ^2 tests, analysis of variance (ANOVA), and logistic analysis using the statistical package for the social sciences routines.

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Results

Of the 990 subjects 136 (14%) reported that they had smoked non-tobacco cigarettes regularly at some time in their life (table I). There were 86 (9%) current and 50 (5%) ex-smokers of non-tobacco cigarettes. Those who had ever smoked non-tobacco cigarettes were younger than those who had never smoked them (table 1), and a higher proportion of those who had ever smoked were men (56%) than of those who had never smoked (48%). The intensity of non-tobacco cigarette smoking ranged from less than one to 23 non-tobacco cigarettes/week (mean 6.7). Non-tobacco cigarette years of smoking (number of non-tobacco cigarettes/week × years of smoking) ranged from 0.5 to 320 (mean 58.2 non-tobacco cigarette years). Men averaged significantly more non-tobacco cigarette years than women (68 v 45, $p < 0.05$).

TABLE I—Characteristics of non-tobacco cigarette smoking subjects

Non-tobacco cigarette smoking	No (%)	No (%) who had ever smoked tobacco cigarettes		Mean age	No (%) of men
		Ever*	Never		
Ever*	136 (14)	98 (72)	27.1	76 (56)	
Never	854 (86)	350 (41)	29.4	409 (48)	
Total	990 (100)				

*Ever=current smokers and ex-smokers.

The depth of inhalation of non-tobacco cigarettes differed significantly from that of tobacco cigarettes (table II). Sixty nine per cent of non-tobacco cigarette smokers inhaled non-tobacco cigarettes deeply and 26% moderately. In contrast, only 23% of tobacco cigarette smokers inhaled tobacco cigarettes deeply and 69% inhaled moderately. There was no significant difference in inhalation between men and women. Those subjects who smoked non-tobacco cigarettes but not tobacco cigarettes were less likely to inhale non-tobacco cigarettes "deeply" than those who smoked both types of cigarette. Subjects who had ever smoked non-tobacco cigarettes regularly were more likely to be current or ex-smokers of tobacco cigarettes (table III). Although non-tobacco cigarette smokers were more likely to have smoked tobacco cigarettes, the percentage of smokers of both non-tobacco cigarettes and tobacco cigarettes who had stopped smoking tobacco cigarettes (43%) was similar to that of tobacco only smokers who were ex-smokers (41%).

Among those who had ever smoked tobacco cigarettes we analysed the amount of tobacco cigarette smoking in relation to their non-tobacco cigarette smoking. Current and ex-smokers of non-tobacco cigarettes averaged significantly fewer pack years of tobacco cigarette smoking than those who had never smoked non-tobacco cigarettes. The mean values in these 15-40 year olds were 8.7 pack years of tobacco cigarettes for present non-tobacco cigarette smokers, 7.2 pack years for ex-smokers of non-

TABLE II—Reported depth of inhalation. Results are percentages

Depth of inhalation	Tobacco cigarette smoking			Non-tobacco cigarette smoking		
	Tobacco only (n=350)	Both tobacco and non-tobacco (n=98)	Total (n=448)	Non-tobacco only (n=37)	Both tobacco and non-tobacco (n=97)	Total (n=134)
Deeply	23	21	23	46	77	69
Moderate	68	72	69	46	19	26
Slight	8	6	8	3	4	4
Not at all	1	0	1	5	0	2

TABLE III—Distribution of tobacco and non-tobacco cigarette smoking. Results are numbers (and percentages of non-tobacco smoking groups)

Non-tobacco cigarette smoking	Tobacco cigarette smoking		
	Current	Ex-smoker	Never
Ever	56 (41)	42 (31)	38 (28)
Never	209 (24)	143 (17)	502 (59)

tobacco cigarettes, and 13.0 pack-years for those who had never smoked non-tobacco cigarettes ($p < 0.001$).

In current tobacco cigarette smokers we analysed the current intensity of tobacco cigarette smoking (cigarettes/day) in relation to non-tobacco cigarette smoking. There was no significant difference in current intensity of tobacco cigarette smoking among the non-tobacco cigarette smoking groups. Current non-tobacco cigarette smokers averaged 20.3 tobacco cigarettes/day, ex-smokers of non-tobacco cigarettes 16.8 tobacco cigarettes/day, and those who had never smoked non-tobacco cigarettes 21.2 tobacco cigarettes/day.

The prevalence of respiratory symptoms was related to non-tobacco cigarette smoking. To avoid the confounding effect of tobacco cigarette smoking we analysed data for present tobacco cigarette smokers and those who had never smoked tobacco cigarettes separately. Among both these groups we compared rates of cough, phlegm, wheeze, and attacks of shortness of breath with wheeze for those who had ever and those who had never smoked non-tobacco cigarettes (table IV). Ex-smokers of tobacco cigarettes were excluded from this analysis and the rates for both sexes were combined because there were no significant or consistent differences between sexes. For all symptoms and in both current tobacco smokers and those who had never smoked tobacco the rates were higher in those who had ever smoked non-tobacco cigarettes than in those who had never smoked non-tobacco cigarettes. The prevalence of phlegm and wheeze were significantly greater in those who had ever smoked non-tobacco cigarettes than in those who had never done so in both tobacco smoking groups.

TABLE IV—Prevalence of respiratory symptoms. Results are percentages

	Current tobacco cigarette smokers		Those who had never smoked tobacco cigarettes	
	Ever smokers of non-tobacco cigarettes (n=56)	Never smokers of non-tobacco cigarettes (n=209)	Ever smokers of non-tobacco cigarettes (n=38)	Never smokers of non-tobacco cigarettes (n=502)
Cough	68	54	32	23
Phlegm	63**	43	26*	13
Wheeze	61**	44	40**	23
Shortness of breath/wheeze	25	20	29	18

* $p < 0.05$, ** $p < 0.05$.

Logistic analysis in current tobacco cigarette smokers showed that either current intensity (non-tobacco cigarettes/week) or duration (non-tobacco cigarette years) of non-tobacco cigarette smoking was significantly related to cough ($p < 0.005$), phlegm ($p < 0.005$), and wheeze ($p < 0.005$). Among those who had never smoked tobacco cigarettes either current intensity or duration of non-tobacco cigarette smoking was significantly related to phlegm ($p = 0.025$), wheeze ($p = 0.01$), and attacks of shortness of breath with wheeze ($p < 0.01$).

Initial analysis of spirometric data (FEV_1 , \dot{V}_{max50} , \dot{V}_{max75} , and $FEV_1:FVC$ ratio) showed no significant effect of non-tobacco cigarette smoking on lung function with the sexes combined. Because men smoked significantly more non-tobacco cigarettes (duration and intensity) than women we then analysed them separately. There were differences in lung function for various smoking groups only for the men. Table V compares the percentage predicted values for FEV_1 , \dot{V}_{max50} , and \dot{V}_{max75} in men in the following groups: those who had never smoked either non-tobacco or tobacco cigarettes, current smokers of tobacco cigarettes only, current smokers of non-tobacco cigarettes only, and current smokers of both non-tobacco and tobacco cigarettes. (Ex-smokers of either non-tobacco or

TABLE V—Percentage predicted values for FEV_1 , \dot{V}_{max50} , \dot{V}_{max75} , and $FEV_1:FVC$ in men grouped according to smoking category

	Never smoked either tobacco or non-tobacco cigarettes	Current tobacco smoking	Current smokers of non-tobacco cigarettes	Current smokers of both
FEV_1	103.9	100.2	99.9	99.3
\dot{V}_{max50}	99.3	88.5**	84.9	81.0*
\dot{V}_{max75}	96.7	83.3**	75.1*	68.8**
$FEV_1:FVC$	98.4	95.2***	90.0*	91.1*

* $p < 0.05$, ** $p < 0.005$, *** $p < 0.001$.

tobacco cigarettes were excluded from these analyses.) For all three spirometric measures those who had never smoked had the best function followed, in order of decreasing function, by current tobacco cigarette smokers, current non-tobacco cigarette smokers, and current smokers of both tobacco and non-tobacco cigarettes. The V_{max75} for current non-tobacco cigarette smokers was significantly less than that for those who had never smoked either type of cigarette ($p < 0.05$). Non-tobacco cigarette smoking alone had a more profound effect than tobacco cigarette smoking alone for all flow indices. Furthermore, the effect of smoking both non-tobacco and tobacco cigarettes appeared to be additive since the group that smoked both non-tobacco and tobacco cigarettes had the lowest function. Table V also shows the percentage of predicted values for the $FEV_1:FVC$ ratio for men in the four smoking groups. Each of the three smoking categories showed significant decrements in the $FEV_1:FVC$ ratio. Again, the largest effects were seen in smokers of non-tobacco cigarettes alone or of both tobacco and non-tobacco cigarettes.

Discussion

This study shows not only a significant prevalence of non-tobacco cigarette smoking but also a striking effect on pulmonary symptoms and function. These findings in a general population sample suggest that non-tobacco cigarette smoking may be an important cause of pulmonary disease.

The survey questionnaire referred to non-tobacco cigarette smoking rather than specifically to marijuana or other illicit drugs, because questions concerning illegal acts might have jeopardised participation in the overall study. Nevertheless, in population studies concerned with illicit drug use, the only regular non-tobacco cigarette smoking of any important degree was marijuana smoking.² In fact the prevalence of marijuana smoking in the most recent large general population survey is almost identical to the prevalence of non-tobacco cigarette smoking in this study.² Thus, we believe that "non-tobacco cigarette smoking" in this survey reflects marijuana smoking.

Animal and in vitro studies have shown that marijuana smoke can injure the respiratory tract,⁶⁻¹⁰ but the results of clinical studies are conflicting.¹¹⁻¹⁹ This discrepancy may be explained by several factors, which include sampling biases and failure to control for the confounding effects of tobacco smoking. The subacute effects of heavy marijuana smoking on pulmonary function have been examined in "healthy" male volunteers by Tashkin *et al.*¹¹ In their prospective study smoking an average of five marijuana cigarettes per day over 47-59 days caused small but significant decreases in several indices of lung function. In subsequent studies from the same laboratory respiratory symptoms and lung function in volunteers who regularly smoked marijuana were compared with those of control subjects.^{12,13} The marijuana smokers had lower values for specific airways conductance and airways resistance, but no other differences were detected.

We found a significant excess of wheeze and sputum production in non-tobacco cigarette smokers of both sexes. We also showed pronounced decreases in expiratory flow rates and $FEV_1:FVC$ ratio in male but not female non-tobacco cigarette smokers. The lack of a demonstrable effect of non-tobacco cigarette smoking on pulmonary function in women is not surprising. There are important differences in tobacco cigarette smoking habits between the sexes.²⁰ Tobacco cigarette smoking has a smaller effect on pulmonary function in women than in men, especially in the

younger age groups.²¹ In this study the intensity and duration of non-tobacco cigarette smoking was greater in men, although the depth of inhalation did not differ between the sexes. In men smoking non-tobacco cigarettes had a more profound effect on pulmonary function than tobacco cigarette smoking. Of particular importance was the effect of non-tobacco cigarette smoking on the $FEV_1:FVC$ ratio. Decreases in the $FEV_1:FVC$ ratio have been shown to precede the development of frank obstructive airways disease.²²

Thus in a general population sample non-tobacco cigarette smoking has an important effect on respiratory symptoms and pulmonary function. The effect of non-tobacco cigarette smoking on pulmonary function in men was greater than the effect of tobacco cigarette smoking. These results suggest that non-tobacco cigarette smoking may be an important factor in a young adult with respiratory symptoms or evidence of obstructive airways disease.

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References

- 1 Surgeon General. *The health consequences of smoking: chronic obstructive lung disease*. Rockville, MD: US Department of Health and Human Services, Office on Smoking and Health, 1984.
- 2 Miller JD, Cisin IH, Gardner-Keaton H, *et al*. *National survey on drug abuse: main findings 1982*. Rockville, MD: National Institute on Drug Abuse, 1983. (DHSS Publication No (ADM) 83-1263.)
- 3 Lebowitz MD, Knudson RJ, Burrows B. The Tucson epidemiological study of obstructive lung disease. I. Methodology and prevalence of disease. *Am J Epidemiol* 1975;102:137-52.
- 4 Knudson RJ, Lebowitz MD, Holberg CJ, Burrows B. Changes in the maximum expiratory flow-volume curve with growth and aging. *Am Rev Respir Dis* 1983;127:725-34.
- 5 American Thoracic Society. Snowbird workshop on standardisation of spirometry. *Am Rev Respir Dis* 1979;119:831-8.
- 6 Leuchtenberger C, Leuchtenberger R. Cytological and cytochemical studies of the effects of fresh marijuana smoke on growth and DNA metabolism of animal and human lung cultures. In: Braude MC, Szara S, eds. *Pharmacology of marijuana*. New York: Raven Press, 1976:595-612.
- 7 Huber GL, Simmons GA, McCarthy CR, Cutting MB, Laguarda R, Pereira W. Depressant effect of marijuana smoke on antibacterial activity of pulmonary alveolar macrophages. *Chest* 1975;68:769-73.
- 8 Fleischman RW, Hayden DW, Braude MC, Rosenkrantz H. Chronic marijuana inhalation toxicity in rats. *Toxicol Appl Pharmacol* 1975;34:467-78.
- 9 Fleischman RW, Baker JR, Rosenkrantz H. Pulmonary pathologic changes in rats exposed to marijuana smoke for 1 year. *Toxicol Appl Pharmacol* 1979;47:557-66.
- 10 Roy PE, Maignan-LaPointe F, Huy ND, Boutet M. Chronic inhalation of marijuana and tobacco in dogs: pulmonary pathology. *Res Commun Chem Pathol Pharmacol* 1976;14:305-17.
- 11 Tashkin DP, Calvarese BM, Simmons MS, Shapiro BJ. Subacute effects of heavy marijuana smoking on pulmonary function in healthy men. *N Engl J Med* 1976;294:125-9.
- 12 Tashkin DP, Calvarese BM, Simmons MS, Shapiro BJ. Respiratory status of seventy-four habitual marijuana smokers. *Chest* 1980;78:699-706.
- 13 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;135:209-16.
- 14 Coggins WJ, Swenson EW, Dawson WW, *et al*. Health status of chronic heavy cannabis users. *Ann NY Acad Sci* 1976;282:148-61.
- 15 Cruickshank EK. Physical assessment of 30 chronic cannabis users and 30 matched controls. *Ann NY Acad Sci* 1976;282:162-7.
- 16 Rubin V, Comitas L. Respiratory function and hematology. In: *Ganja in Jamaica: a medical anthropological study of chronic marijuana use*. Paris: Mouton, 1975:88-102.
- 17 Boulougouris JC, Panayiotopoulos CP, Antypas E, Liakos A, Stefanis C. Effects of chronic hashish use on medical status in 44 users compared with 38 controls. *Ann NY Acad Sci* 1976;282:168-72.
- 18 Henderson RL, Tennant FS, Guerry R. Respiratory manifestations of hashish smoking. *Arch Otolaryngol* 1972;95:248-51.
- 19 Tennant FS, Jr. Histopathologic and clinical abnormalities of the respiratory system in chronic hashish smokers. *Subst Alcohol Actions Misuse* 1980;1:93-100.
- 20 Paoletti P, Camilli AE, Holberg CJ, Lebowitz MD. Respiratory effects in relation to estimated tar exposure from current and cumulative cigarette consumption. *Chest* 1985;88:849-55.
- 21 Camilli AE, Burrows B, Knudson RJ, Lyle SK, Lebowitz MD. Longitudinal changes in forced expiratory volume in one second in adults. *Am Rev Respir Dis* 1987;135:794-9.
- 22 Burrows B, Knudson RJ, Camilli AE, Lyle SK, Lebowitz MD. The "Horse-Racing Effect" and predicting decline in forced expiratory volume in one second from screening spirometry. *Am Rev Respir Dis* 1987;135:788-93.

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