

Absorption of nicotine and carbon monoxide from passive smoking under natural conditions of exposure

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ABSTRACT Seven non-smokers were exposed to tobacco smoke under natural conditions for two hours in a public house. Measures of nicotine and cotinine in plasma, saliva, and urine and expired air carbon monoxide all showed reliable increases. The concentrations of carbon monoxide and nicotine after exposure averaged 15.7% and 7.5% respectively of the values found in heavy smokers. Although the increase in expired air carbon monoxide of 5.9 ppm was similar to increases in smokers after a single cigarette, the amount of nicotine absorbed was between a tenth and a third of the amount taken in from one cigarette. Since this represented a relatively extreme acute natural exposure, any health risks of passive smoking probably depend less on quantitative factors than on qualitative differences between sidestream and mainstream smoke.

Passive smoking refers to the involuntary inhalation of tobacco smoke present in the air that people breathe. Some exposure is unavoidable in the present day lives of most non-smokers.^{1,2} Ten years ago it was shown that such exposure is associated with an increase in the incidence of bronchitis and pneumonia in young children, especially during their first year of life.^{3,4} Concern about its possible effects on the health of adult non-smokers has been heightened recently by reports that it may increase a non-smoker's risk of lung cancer⁵⁻⁷ and impair lung function.⁸ The issue has provoked intense debate⁹⁻¹² but many questions remain unanswered, not least in relation to the dosage received by exposed non-smokers.

Numerous reports exist of measured concentrations of various constituents of tobacco smoke in ambient air under both experimentally controlled and natural conditions.^{13,14} Absorption of carbon monoxide by non-smokers exposed to tobacco smoke under experimental conditions is well documented, the amount absorbed depending on the severity and duration of the exposure.¹³ Under extreme conditions in an unventilated, smoke filled room (38 ppm carbon monoxide) for just over an

hour we found that the carboxyhaemoglobin levels of non-smokers increased from an average of 1.6% to 2.6%, which is roughly equivalent to the increase produced by smoking one middle tar cigarette.¹⁵ This agrees well with the results of a similar study, in which it was estimated that about two hours' exposure to 20 ppm carbon monoxide was equivalent to actively smoking a single cigarette.¹⁶

To estimate the health risks to non-smokers it is more relevant to test absorption of tobacco products under natural conditions. Although easy to measure, carbon monoxide is not specific to tobacco smoke and concentrations in ambient air depend on many other factors, such as pollution from car exhausts, gas stoves and heaters. Nicotine, however, is specific to tobacco smoke. We have therefore studied the increases in nicotine and its metabolite cotinine in various body fluids of non-smokers after exposure to tobacco smoke under natural conditions.

Methods

Seven non-smoking employees of a large office in Liverpool, four women and three men, participated in the study. They provided baseline samples of blood, expired air, urine, and saliva at 11.30 am on a normal working day, and again at 7.45 pm in the evening after two hours' exposure to environmental tobacco smoke in a public house (pub). The day before had been a public holiday, and subjects had been instructed to avoid contact with tobacco smoke

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on that day. Exposure during working hours was not controlled.

In the public house subjects sat in a section of a single large bar. Electric ventilation was turned off, but there was natural ventilation as people entered and left the pub. The door to the lavatories was in the part of the bar where the subjects were sitting. Several smoking colleagues of the subjects were recruited to socialise with them and to provide a smoky atmosphere which, while subjectively at the extreme end of normally occurring environments, was nevertheless generally agreed to be not atypical of what may be encountered late in the evening in a busy pub or at a party. The ambient carbon monoxide outside and inside the pub at the start of the evening was 2 ppm. Later it reached a peak of 13 ppm inside the pub.

The concentration of nicotine and cotinine in plasma, saliva, and urine was determined by gas chromatography.^{17,18} Carbon monoxide in the ambient air and in end expired air after breath holding was measured with a portable carbon monoxide analyser incorporating an ethanol filter.¹⁹

Results

The mean values of each measure of smoke intake

Table 1 Average nicotine, cotinine, and carbon monoxide concentrations in seven non-smokers before and after passive exposure to cigarette smoke

Intake measures	Before	After	Significance	
			t	p
Nicotine (ng/ml)				
Plasma	0.76	2.49	5.5	<0.005
Saliva	1.90	43.63	7.2	<0.001
Urine	10.51	92.63	3.8	<0.01
Cotinine (ng/ml)				
Plasma	1.07	7.33	12.3	<0.001
Saliva	1.50	8.04	8.6	<0.001
Urine	4.80	12.94	3.1	<0.025
Expired air carbon monoxide (ppm)	4.71	10.57	9.9	<0.001

before and after exposure to environmental tobacco smoke are shown in table 1. The corresponding individual values are given in figures 1 and 2.

Despite their efforts to avoid tobacco smoke on the preceding day, by mid-morning of the study day all subjects had measurable concentrations of both nicotine and cotinine in all the body compartments surveyed. After exposure there were significant increases in all intake measures. Only in the case of one measure in one individual was an anomalous

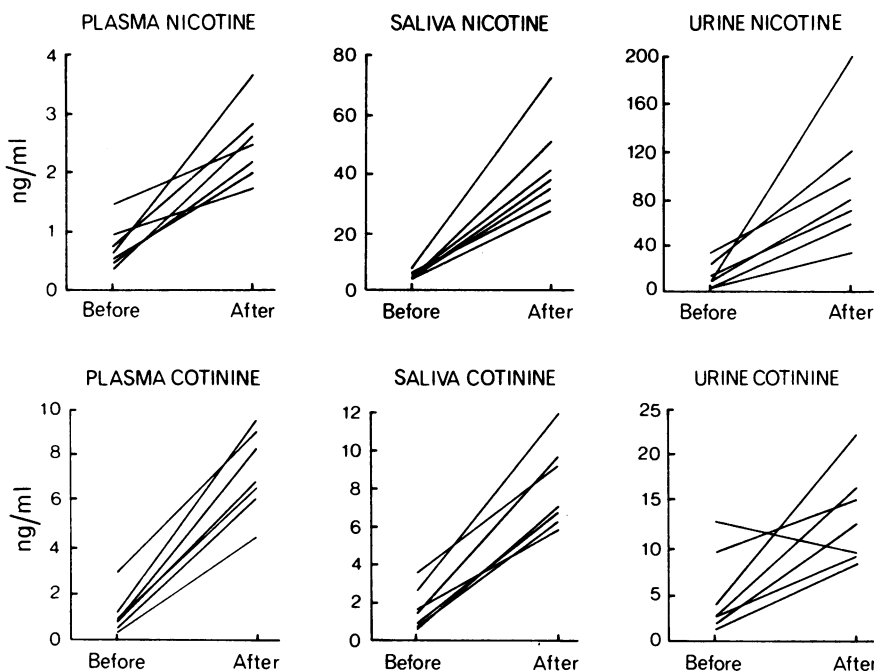


Fig 1 Individual concentrations in seven subjects of nicotine and cotinine in plasma, saliva, and urine before and after passive exposure to tobacco smoke in a public house.

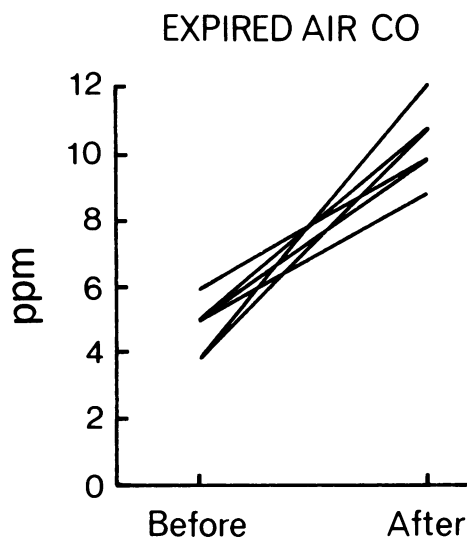


Fig 2 Individual concentrations in seven subjects of expired air carbon monoxide (CO) before and after passive exposure to tobacco smoke in a public house.

decline registered. In table 2 the data are compared with concentrations reported in cigarette smokers. On average, the levels in non-smokers after passive smoking, expressed as percentages of the levels found in smokers, were 15.7% for carbon monoxide, 7.5% for nicotine, and 1.8% for cotinine.

Discussion

The results show that when non-smokers keep away from smokers and try to avoid exposure to tobacco

smoke they still have small amounts of nicotine and its metabolite cotinine in their body fluids. This indicates that for a city dweller it is virtually impossible to avoid exposure completely. After a normal day at work in an office, followed by two hours socialising with smokers in a pub, all of the seven non-smokers showed increases in the concentrations of nicotine and cotinine in their body fluids and higher concentrations of carbon monoxide in their expired air. The findings are clear, unequivocal, and statistically significant.

Our results confirm and extend those of other studies in which acute exposure to environmental tobacco smoke has been manipulated, but exposure was more realistic in the present study than in other short term experiments.¹³ Experimental control is reduced under natural conditions, and as a result both the numbers of cigarettes smoked and the number of air changes during the two hours of exposure are unknown. Besides our subjects and their colleagues, the pub had its usual early evening clientèle, which built up as people came in for a drink after leaving work. There was a steady traffic of people entering and leaving, which certainly resulted in some degree of ventilation, although the electric ventilation was switched off. That the conditions were not outside the range normally encountered is supported by the measured ambient carbon monoxide, which at 13 ppm was similar to concentrations which have been reported in bars and night clubs.^{23 24} It is therefore reasonable to regard the conditions as being towards the extreme end of acute natural exposures.

Although the results have high statistical significance, what is the significance for health risks? One way to assess this is to compare the values with

Table 2 Comparison of intake measures after passive smoking with average values found in cigarette smokers who have been smoking in their usual way

Intake measure	Passive smoking	Normal smoking†		Passive smoking concentration as % of normal smoking concentration
	Mean (n=7)	No of subjects	Mean	
Expired air carbon monoxide (ppm)				
Uncorrected	10.6	360 ^a	42.3	25.1
*Corrected	5.9		37.6	15.7
Nicotine (ng/ml)				
Plasma	2.5	330 ^b	33.0	7.6
Saliva	43.6	82 ^c	568	7.7
Urine	92.6	100 ^d	1289	7.2
Cotinine (ng/ml)				
Plasma	7.3	136 ^e	335	2.2
Saliva	8.0	74 ^f	330	2.4
Urine	12.9	66 ^f	1448	0.9

*Corrected for non-tobacco sources by subtraction of baseline concentration found in non-smokers.

†Sources of data on samples of smokers: ^aVesey *et al*²⁰; ^bRussell *et al*²¹; ^cFeyerabend *et al*²; ^dFeyerabend *et al*² and Russell and Feyerabend¹; ^eRussell *et al*²²; ^fJarvis *et al* (unpublished). Samples b and e comprised heavy smokers attending a withdrawal clinic.

those of smokers. Expired air carbon monoxide concentrations were 15.7% of those in smokers. Nicotine and cotinine concentrations averaged 7.5% and 1.8% of those found in heavy smokers. The lack of correspondence between nicotine and cotinine in this respect (both being measures of nicotine intake) is attributable to two facts. Firstly, the most intense exposure of the non-smokers was recent, so there would not have been time for the cotinine levels to build up fully, especially in urine. Secondly, the longer plasma half life of cotinine (about 12 hours)²⁵ means that smokers' levels reflected intake over the past 2 to 3 days, whereas the non-smokers had been specifically instructed to avoid exposure the preceding day. The discrepancy between the 15.7% for expired air carbon monoxide and the 7.5% for nicotine probably reflects differences in their half lives in blood as well as differences between the behaviour of gaseous and particulate materials in the ambient air of enclosed spaces. Nicotine is contained mainly in the particulate material of tobacco smoke, which unlike gaseous products would tend to settle gradually. Data on half lives of various smoke components in room air with and without ventilation are not available. Another source of discrepancy is differences in sidestream:mainstream ratios, although in this respect carbon monoxide and nicotine are similar with ratios of 2.5 and 2.7.¹²

Passive smoking values of 15.7% (about 1/6) for carbon monoxide concentration and 7.5% (about 1/13) for nicotine concentration of the values found in heavy smokers might be a fair estimate of potential risks, but only if the passive exposure is maintained at this level and only so far as the risks attributable to these actual constituents are concerned. In realistic terms these figures probably represent an upper bound for the risk from passive smoking to non-smokers, since long term sustained exposure of this degree is likely to be rare. Furthermore, although tar and nicotine are both in the particulate phase of tobacco smoke, it would not be valid to extrapolate from nicotine to tar on the basis of these comparisons.

Although samples were not taken immediately before the subjects entered the pub, we may reasonably assume that most of the increase attributable to passive smoking occurred during this two hour exposure. The increase in expired air carbon monoxide concentration of 5.9 ppm is similar to increases in smokers after they have inhaled a single cigarette. In a recent study²⁶ we found a peak plasma nicotine concentration of 25.7 ng/ml after one cigarette, which declined to 7.0 ng/ml after one hour. The average plasma nicotine concentration of 2.5 ng/ml after two hours' passive smoking was therefore about one tenth of the peak and one third of the

value one hour after a cigarette. Without more measures it is impossible to compare areas under the concentration-time curves, but the data suggest that the amount of nicotine absorbed by these non-smokers was somewhere between a tenth and a third of the amount taken in by smokers from a single cigarette. The discrepancy between this and the carbon monoxide data is attributable to the gas-particulate differences mentioned above. Since it is also in the particulate phase, nicotine is probably a better guide than carbon monoxide to the amount of tar absorbed. As discussed above, however, direct extrapolation is difficult, since we cannot assume that the relation between tar and nicotine is maintained in particles suspended in ambient air.

The possible association of passive smoking with an increased incidence of lung cancer is based on studies in which the non-smoking wives of smoking and non-smoking men have been compared.⁵⁻⁷ How closely exposure in the home resembles that of the present study is not known. It seems unlikely that it could equate with the active smoking of more than one or two cigarettes a day in quantitative terms, unless the homes were unventilated and house-bound husbands smoked continuously. It is therefore difficult to explain the increased risk of lung cancer indicated by the epidemiological studies in purely quantitative terms. The risk, if it exists, must depend mainly on qualitative differences between sidestream and mainstream smoke. The sidestream:mainstream concentration ratios are particularly high (up to 10) in the case of various carcinogenic nitrosamines.¹² There remains an urgent need to establish the dose levels received via the whole range of passive exposures to smoke in daily life.

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