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Evaluation of a low to middle tar/medium nicotine cigarette designed to maintain nicotine delivery to the smoker

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Abstract. A specific objective of this 6-week crossover study was to determine how 21 regular smokers of middle tar cigarettes changed their smoking behaviour and uptake of smoke constituents, when switching to either lower tar cigarettes capable of delivering amounts of nicotine similar to a conventional middle tar cigarette (maintained nicotine product), or to conventional low tar/low nicotine cigarettes. Subjects visited the laboratory every 2 weeks for detailed assessment of their smoking behaviour. Weekly per capita consumption was similar for all three cigarettes. They were smoked with variable intensities (low tar > maintained nicotine > middle tar), the tendency being for larger puff volumes, faster puffing and increased puff duration with the low tar cigarettes. The maintained nicotine cigarette was preferred to the middle tar cigarette, although acceptability ratings of the three cigarettes only differed marginally. The nicotine absorbed from the maintained nicotine and middle tar cigarettes was similar and significantly greater than the levels achieved from the low tar cigarettes. Intake of carbon monoxide into the mouth and absorption into the blood stream was lower for the maintained nicotine cigarette than for the middle tar cigarette, with the low tar cigarette occupying an intermediate position. Derived estimates of tar intake suggested reduced intake of tar into the respiratory tract (around 25%) from the maintained nicotine product relative to the middle tar product. The possible advantages of switching to maintained nicotine cigarettes is discussed.

Key words: Tar – Nicotine – Carbon monoxide – Tar: nicotine yield ratios – Smoking behaviour

For many years health education groups have sought to persuade cigarette smokers to smoke a product with low yields of tar and nicotine as a safer form of smoking. This advice may have been less beneficial than anticipated because low tar low nicotine cigarettes were generally smoked more intensively than the brand from which subjects had switched. Work by Russell et al. (1973) and Russell (1976, 1980) has consistently focussed attention on how smokers might reduce tar intake, considered by many to be associated with the risk of lung cancer and bronchitis, while still maintaining an adequate intake of nicotine to provide the pharmacological effects associated with tobacco smoking. This "maintained nicotine" approach was also mentioned in the 3rd report of the Independent Scientific Committee on Smoking and Health (1983) as being worthy of investigation. It required the development of a low tar medium nicotine cigarette, which until recently has not been commercially available. Over the last decade, it has become apparent that the intake of tar and nicotine by cigarette smokers is affected not only by the absolute yields of these constituents but also by the ratio of the yields (Stepney 1981; Woodman et al. 1987). This paper presents the findings of a study designed with the specific objective of establishing how a cigarette, with a low tar/nicotine (T/N) ratio of 8.0 and a relatively high nicotine yield, to maintain nicotine delivery, would be smoked in relation to more conventional middle tar (T/N 9.9) and low tar cigarettes (T/N 11.4). No direct measures of tar intake by human smokers have yet been established and such assessment can currently only be made by deduction. It was of particular interest to assess whether the intake of tar from the maintained nicotine cigarette was less than from the two reference cigarettes.

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Materials and methods

A randomised balanced design (double 3 × 3 Latin square, see Table 1) was used to compare the objective and subjective

Table 1. Study design

Group ↓ / Week →		Run-in		Crossover study					
		1	2	3	4	5	6	7	8
A	(3)	SP		MN		MT		LT	
B	(4)	SP		MN		LT		MT	
C	(4)	SP		MT		LT		MN	
D	(3)	SP		MT		MN		LT	
E	(3)	SP		LT		MN		MT	
F	(4)	SP		LT		MT		MN	
Experimental study days					↑ 1		↑ 2		↑ 3
Q = Questionnaire		Q Q QQ Q QQ Q QQ Q Q							

( ) = Number of subjects in each group during weeks 3–8; SP = standard product; MN = maintained nicotine, MT = middle tar, LT = low tar cigarette tive responses to the three cigarette products, designated maintained nicotine, middle tar and low tar. Some facets of smoking behaviour may change with time and so a crossover design was adopted to nullify any drift that might occur. The study was performed blind and all subjects were acclimatised to a standard cigarette (tar: 14.0 mg, nicotine: 1.3 mg) before the start of the 6-week crossover study, to eliminate any carryover effects from the preferred brands.

Subjects

Twenty-four male subjects (average age 26 years; range 19–45 years), all of whom normally smoked a minimum of ten filter tipped middle tar cigarettes per day (tar yield 15–17 mg) were chosen from the Hazleton Clinical Studies Volunteer Panel. They were made aware of the nature of the study and selection was based on willingness to participate according to the agreed timetable. Three subjects withdrew immediately prior to study day 1 and were not replaced.

Cigarettes

The tar, nicotine and carbon monoxide yields of the three cigarette products when smoked with a puff volume of 35 ml, a puff duration of 2 s and a puff frequency of 1/min on an analytical smoking machine, were as shown in Table 2.

Table 2. Tar nicotine and CO yields of three cigarette products

Cigarette	Tar yield (mg/cig)	Nicotine yield (mg/cig)	CO yield (mg/cig)	T/N ratio
Maintained nicotine (MN)	11.2	1.4	9.9	8.0
Middle tar (MT)	16.9	1.7	15.1	9.9
Low tar (LT)	9.1	0.8	8.5	11.4

The experimental cigarettes were all similar in general appearance and supplied to volunteers in plain white sealed packs (filter type: acetate; tip ventilation: maintained nicotine and low tar cigarettes; total cigarette length: 83.5–84.0 mm; filter length: 19.7–20.0 mm; diameter: 7.91–7.93 mm). Cigarettes were stored at a temperature of 21° C and a relative humidity of 60±2% prior to use. Weekly issues were made to participating subjects and the cigarettes used on each of 3 experimental study days were conditioned for 48 h before use in an airtight cabinet containing a saturated solution of potassium bromide.

Smoking and dietary restrictions

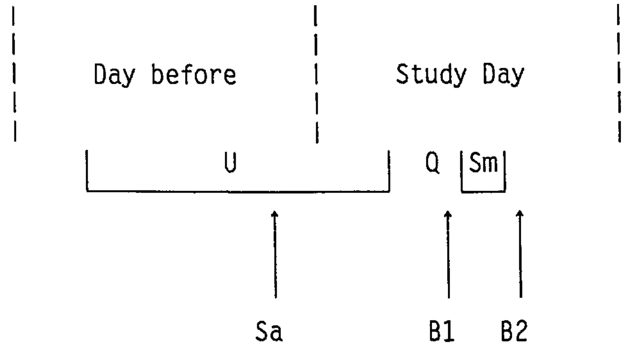
On each experimental study day subjects were asked not to smoke during the hour preceding their scheduled appointment in the study room. They were also asked not to smoke any other tobacco products during the course of the study. There were no dietary restrictions with the exception of alcohol, which was forbidden on each experimental study day.

Smoking regimen

At the start of the study, each subject was given a 2-week supply of the standard product. The number supplied was based on the stated weekly consumption of their own brand and allowed for any increase which tends to occur when free cigarettes are made available. Subjects were randomly allocated to six groups (A–F inclusive). They were then required to smoke their assigned cigarettes according to the schedule shown in Table 1. Each product was smoked exclusively for 2 weeks by each of the 21 subjects participating in this phase of the study. Subjects were unaware of which product they were smoking. Subjects were asked not to offer cigarettes to their friends during the course of the study and none reported on study days as having done so. The weekly consumption of study cigarettes was determined from the difference between those issued and those returned.

Experimental smoking and sampling schedule

Subjects were observed smoking a cigarette at the end of each 2-week period during the crossover phase of the study. Each experimental study day began at 1300 hours and lasted approximately 4 h. The sampling scheme for urine, saliva and blood, and the various analyses undertaken are shown in Fig. 1.



	Sample		*Analysed for*
U	24 hour urine sample (09.00–09.00 hours)	U	nicotine/cotinine/ nicotine-1′-N-oxide
Sa	pre-retiring saliva sample	Sa	cotinine
B1	pre-smoking blood sample	B1	nicotine/cotinine/ % COHb
Sm	test cigarette smoked		
B2	post-smoking blood sample (5 min after last puff)	B2	nicotine/% COHb
Q	questionnaire completed		

Fig. 1. Sampling scheme

Whenever possible, urine and saliva samples were refrigerated before bringing to the laboratory on the following day. Pending analysis, all samples were stored in the laboratory at −20° C.

On experimental study days, the smoking behaviour of each subject was monitored while he smoked one of his assigned cigarettes through a flow head/cigarette holder attached to a smoking analyser system. The latter measured puff intervals, puff durations, puff volumes, flow rates and pressure changes, the information being recorded on magnetic disc. The length of tobacco rod consumed was also recorded. Analytical duplicated slave smoking (Creighton et al. 1978) was subsequently undertaken to estimate the amount of tar, nicotine and carbon monoxide delivered to the mouth of each subject.

Product acceptance questionnaires

Subjective impressions of the three products were obtained by having each subject place a mark on a 10 cm analogue rating scale for seven sensory characteristics – effect on throat (too little/too much), strength (too mild/too strong), flavour (dislike/like), smoothness (too smooth/too rough, hotness (too hot/too cool), ease of puffing (too easy/too hard), general acceptability (dislike/like). Each question was scored as a whole number by measuring the relative position of each mark on a scale of 0–10. Flavour and acceptability were scored on a like/dislike scale; the other characteristics were scored on a bipolar intensity scale, for example, 10 too strong, 0 too mild.

Questionnaires were completed after the first 20 cigarettes of each weekly issue had been smoked and on the morning of each experimental study day after 2 weeks' exclusive smoking of the test product. In this way, the first impression of the first cigarette was measured and also the impression after a reasonable period of acclimatisation.

Analyses

% COHb in whole blood. % COHb was measured by the method of Brown (1980) using an IL 182 CO-oximeter (Instrumentation Lab Inc.)

Nicotine in plasma and urine; cotinine in plasma, saliva and urine. Modified versions of methods described by Feyerabend and Russell (1980a, b) were used.

Nicotine-1′-N-oxide in urine. A modified version of the method described by Beckett et al. (1971) was used.

Derived data

Increases in % COHb (CO boost) and plasma nicotine concentrations (nicotine boost) were calculated by subtracting the pre-smoke values from the 5 min post-smoking values. Nicotine concentrations have been shown in other experiments in these laboratories to be fluctuating less rapidly at this time, so that the measured boost, although not maximal, tends to be more consistent.

The masses of cotinine and nicotine-1′-N-oxide excreted in urine were converted to nicotine equivalents. These values together with the mass of nicotine excreted were summed to give the total urinary excretion expressed as mg equivalents of nicotine base.

The ratios of tar, nicotine and carbon monoxide deliveries (D) obtained under human smoking conditions, to the yields (Y) obtained under standard smoking conditions, were calculated and are referred to as D/Y ratios. The amounts of tar, nicotine and carbon monoxide appearing in the mainstream smoke depend critically on the way a cigarette is smoked, the four most important parameters being puff volume, puff duration, puff frequency and length of tobacco rod consumed (Armitage 1978). These four parameters collectively affect the number of puffs obtained from the cigarette and the time alight. It is well known that cigarette smokers do not smoke their cigarettes like analytical smoking machines and the ratio of D/Y therefore represents a measurement of smoke generation intensity relative to standardised analytical smoking. The D/Y ratio of the middle tar reference product was expressed relative to the ratio of the maintained nicotine product (=1.00). The mean of these values for the three constituents was calculated as a measure of smoke generation intensity (SGI).

For each subject the ratio of nicotine boost to nicotine simulated delivery and CO boost to CO simulated delivery was determined, from which a mean for the maintained nicotine and middle tar product was calculated. A relative uptake index (RUI) was then found by expressing the ratios of these means for the middle tar product relative to the maintained nicotine product (=1.00).

The projected tar intake from each product was calculated as simulated tar delivery × RUI. A relative tar intake index was then estimated by expressing these values relative to the maintained nicotine product (=1.00).

Statistics

Statistical analysis was performed using a general linear model for crossover designs. The model was fitted using the GLIM package, described by Baker and Nelder (1978), which takes account of imbalance caused by missing observations. Comparisons were performed between the maintained nicotine product and each of the two reference products using *t*-tests or trend statistics derived from the analysis of variance for the fitted model. Where necessary to justify the use of the model, data were logarithmically transformed prior to analysis. The tables of means presented in this paper use all available subjects for each computation; the direct comparison of means may be misleading for this reason because of missing data. The significance levels and differences between brands quoted in the text, however, make appropriate adjustment for this bias.

Results

The results are summarised in Table 3, which shows an almost complete set of data except for smoke component deliveries, particularly from low tar cigarettes in the smoking simulation experiment. There are several factors, not all of which are easy to control, that can compromise the validity of data obtained using smoking analysers and smoking duplicators. An experienced operator, however, can readily identify invalid data by application of appropriate calibrations and checks. It should be noted that satisfactory data were obtained from 17 subjects (81%) when smoking maintained nicotine and middle tar cigarettes but only 10 subjects (48%) when smoking low tar cigarettes. The reason for this low figure with the low tar cigarettes cannot be stated unequivocally but differences in ventilation under human and machine duplicated conditions is a likely contributory factor. These omissions did not compromise in any way the more important comparisons of the maintained nicotine and middle tar cigarettes.

CO uptake

The mean simulated CO delivery of the maintained nicotine product was significantly lower (30%) than that of the middle tar product ($P<0.001$), with the low tar product occupying an intermediate position. This trend was also reflected in the CO boost results ($P<0.05$), although the comparison between individual products did not achieve statistical significance.

Table 3. Mean smoke component uptake measures and smoking behaviour

	MN	(*n*)	MT	(*n*)	LT	(*n*)
Smoke dosimetry in laboratory						
Increase in % COHb	1.3 ±1.0	(21)	1.7 ±0.9	(21)	1.5 ±0.9	(21)
Increase in plasma nicotine level (ng ml^{-1})	13.1±3.7	(21)	13.8±5.1	(21)	7.8 ±3.5***	(20)
Smoke dosimetry outside laboratory						
Pre-smoke % COHb	5.3 ±1.7	(21)	5.6 ±2.1	(21)	5.8 ±2.0	(21)
Pre-smoke plasma cotinine level (ng ml^{-1})	317 ±119	(21)	313 ±93	(20)	268 ±105**	(21)
Pre-retiring saliva cotinine level (ng ml^{-1})	435 ±196	(21)	390 ±120	(19)	326 ±139***	(18)
Urinary excretion (mg nicotine equiv./24 h)	4.14±2.86	(20)	3.61±3.13	(19)	3.42±2.60*	(20)
Weekly cigarette consumption	204 ±61	(21)	203 ±56	(20)	202 ±56	(20)
Smoking behaviour in laboratory						
Total puff duration (s)	30.7±11.7	(21)	30.2±7.7	(20)	35.0±11.3*	(20)
Total puff volume (ml)	847 ±272	(21)	754±192**	(20)	938 ±236	(20)
Time alight (s)	326 ±73	(21)	342±80	(20)	285 ±70*	(20)
Number of puffs	15 ±4	(21)	15 ±3	(20)	14 ±4	(20)
Mean puff volume (ml)	58.8±12.8	(21)	52.5±12.6***	(20)	67.4±16.2***	(20)
Mean interval between puffs (s)	24.6±10.2	(21)	24.0±5.9	(20)	21.0±6.4	(20)
Mean length tobacco rod consumed (mm)	50.9±3.5	(17)	51.1±5.3	(17)	52.1±4.1	(10)
Simulated smoke deliveries (mg/cig) [a]						
Tar (T)	22.4±8.6	(17)	29.9±8.6**	(17)	22.4±9.1	(10)
Nicotine (N)	2.7 ±0.8	(17)	2.9 ±0.6	(17)	1.8 ±0.4***	(10)
Carbon monoxide (CO)	18.7±7.9	(17)	26.9±8.2***	(17)	20.7±6.9	(10)
T/N	8.2 ±1.4	(17)	10.1±0.9**	(17)	12.5±2.7***	(10)
Mean length tobacco rod consumed (mm)	52.8±3.8	(17)	53.9±4.8	(17)	53.3±3.6	(10)

MN = maintained nicotine, MT = middle tar, LT = low tar cigarette
All values are mean ± SD. *n* = number of observations on which the means were based

[a] Figures obtained by simulated analytical smoking using the study day smoking behaviour parameters
Significant differences were calculated relative to the MN cigarette. * $P<0.05$; ** $P<0.01$; *** $P<0.001$; where there is no symbol the means were not significantly different ($P>0.05$)

The relatively long plasma half-life of carbon monoxide of 2–4 h (Russell et al. 1973) allows the pre-smoke CO levels observed in the laboratory to be used as an indication of carbon monoxide absorption resulting from the previous 24 h smoking. These % COHb levels were 5.3, 5.6 and 5.8 for the maintained nicotine, middle tar and low tar products respectively, which did not differ significantly. The CO body burden achieved by smokers smoking the maintained nicotine cigarette was therefore no greater than when smoking either of the reference cigarettes.

Nicotine uptake

The mean nicotine mouth deliveries, assessed by simulated analytical smoking, and the nicotine boosts for the maintained nicotine and middle tar cigarettes did not differ significantly. Deliveries and boosts were significantly higher (in the range 55–64%) for the maintained nicotine cigarette than for the low tar cigarette ($P<0.001$).

Nicotine absorption assessed from smoking which took place away from the laboratory (plasma and salivary cotinine levels and urinary excretion of nicotine and metabolites) showed a similar pattern, with no significant differences being detected between the maintained nicotine and middle tar cigarettes but significant differences between the maintained nicotine and low tar cigarettes for all three parameters ($P<0.01$, $P<0.001$, $P<0.05$, respectively).

Smoking behaviour

The overall mean weekly cigarette consumption of the three products was almost identical, indicating that there was no tendency to smoke greater numbers of one cigarette than another. Mean weekly consumption of all products, however, increased consistently and significantly throughout the study ($P<0.001$) from 191 during weeks 3 and 4 to 213 during weeks 7 and 8.

The smoking behaviour on experimental study days provided the opportunity to compare exactly how the different cigarette products were smoked on three different occasions. The mean total puff volume of the middle tar cigarette was significantly less than that observed for the maintained nicotine cigarette ($P<0.01$); the latter did not differ significantly from the value of the low tar cigarette. The mean time alight of the low tar cigarettes was significantly less than the mean figure for the maintained nicotine cigarettes ($P<0.05$). A reverse relationship existed between puff durations for these same two cigarettes, with the duration of puff being significantly elevated for the low tar product ($P<0.05$). The mean length of tobacco rod consumed on the experimental study days was 50.9, 51.1 and 52.1 mm for the maintained nicotine, middle and low tar cigarettes, respectively, which did not differ significantly. In the simulated smoking experiment, the corresponding figures were 52.8, 53.9 and 53.3 mm, which also did not differ significantly.

Acceptability

Although the analogue scales used in this study do not provide quantitative indices with external validity, they do provide indications of differences in perception of the three products. After the first 20 cigarettes the mean scores for the seven characteristics measured were not significantly different between products. After 2 weeks' smoking, some differences were perceived between the maintained nicotine and middle tar cigarettes but not between the maintained nicotine and low tar cigarettes. The middle tar cigarettes had greater strength ($P<0.05$), stronger effect on the throat ($P<0.01$), gave a hotter smoke ($P<0.05$) and had a less likeable flavour ($P<0.05$). The butt length data, similar for all three products, suggests that there was no particular aversion to any product.

Smoke generation intensities

The results are shown in Table 4. The maintained nicotine cigarette was smoked slightly more intensely than the middle tar cigarette. There are some technical difficulties with the simulated analytical smoking of some low tar cigarettes, to which reference has already been made; the low tar cigarette used in this study was one such cigarette and so comparative values have been excluded from Table 4. The data that were obtained, however, indicate that the low tar cigarette was smoked most intensively of the three cigarettes, the increased intensity being a reflection of significantly longer puff duration, larger puff volume and more frequent puffs.

Relative smoke component uptake indices and tar intake estimates

The derived results are shown in Table 5. Again, it was not considered appropriate to make the equivalent calculations for the low tar cigarette in view of the limited data available. The relative nicotine and CO uptake measure were very similar for the maintained nicotine and middle tar cigarettes. The relative tar intake indices suggest a 23–28% decrease in tar intake by subjects smoking the maintained nicotine product compared with the intake when smoking the middle tar product.

Discussion

Approximately 38% of all cigarettes currently sold in the United Kingdom are classified as middle tar, which clearly represents a sizeable proportion of the smoking population. It was of particular interest in this study to find out how middle tar smokers would adapt to a lower tar cigarette, capable of delivering enough nicotine for the smoker to match, if he so wished, the blood levels attained from a middle tar cigarette, and how the resultant intake of carbon monoxide and tar might be concurrently affected. Nicotine deliveries and plasma level boosts were, indeed, found to be similar from the middle tar and maintained nicotine cigarettes. The general intensity with which the cigarettes were smoked was in the order low tar > maintained nicotine > middle tar. In spite of this more intense smoking, smaller amounts of carbon monoxide and tar were taken into the smoker's mouth from the maintained nicotine cigarette than from the middle tar cigarette and body uptake was also reduced as illustrated diagramatically in Fig. 2. The acceptability ratings of the maintained nicotine and low tar cigarettes were similar, as was tar intake to the mouth from these cigarettes, suggesting that smokers may adjust their smoking behaviour to achieve an acceptable tar level (Sutton et al. 1982), perhaps important for sensory gratification, as well as an acceptable nicotine level in the bloodstream.

The quantity of tar taken into the mouth is a less critical parameter of smoking behaviour than the quantity taken into the respiratory tract. Currently it is not possible to make such measurements directly. We have made estimates, however, using similar calculations to those of Russell et al. (1986) except that the derived calculations were based on a rise in blood levels of carbon monoxide or plasma levels of nicotine (5 min after last puff) rather than an absolute concentration (2 min after the last puff). It should be stressed, however, that these two tobacco smoke component markers can only provide a rough assessment of tar intake to the respiratory tract and that no exact equivalence between these three components is claimed. Russell et al. did not include a maintained nicotine cigarette in their study but they estimated a 25% reduction in tar intake when smoking the low tar cigarette relative to the middle tar cigarette. Some of our low tar data are unfortunately incomplete but the results in general do suggest that for the particular group of subjects used in the study, mouth delivery of smoke components (nicotine, CO, tar) may roughly reflect relative uptake (nicotine, CO) and relative intake

Table 4. Delivery/yield ratios (D/Y) and smoke generation intensity (refer to derived data in Materials and methods section)

	MN	MT
Tar D/Y	2.00	1.77
	(1.00)	(0.89)
Nicotine D/Y)	1.91	1.73
	(1.00)	(0.91)
Carbon monoxide D/Y	1.89	1.78
	(1.00)	(0.94)
Smoke generation intensity (SGI)	1.00	0.91

Table 5. Relative smoke component uptake indices and respiratory tract tar intake estimates (refer to derived data in Materials and methods section)

	MN	MT
Relative uptake measures		
Ratio of nicotine boost: simulated nicotine delivery	5.12	5.01
Relative nicotine uptake index (RUI)	1.00	0.98
Ratio of CO boost: simulated CO delivery[a]	0.61	0.63
Relative CO uptake index	1.00	1.04
Relative tar intake estimates		
Simulated tar delivery × $(RUI)_{nicotine}$	22.4	29.2
Simulated tar delivery × $(RUI)_{CO}$	22.4	31.1
Tar intake index based on nicotine uptake	1.00	1.30
Tar intake index based on CO uptake	1.00	1.38

[a] Number of subjects for this calculation was 16. The ratio for subject 5 was 6.3 x mean ratio for 17 subjects and was discounted as an atypical outlier

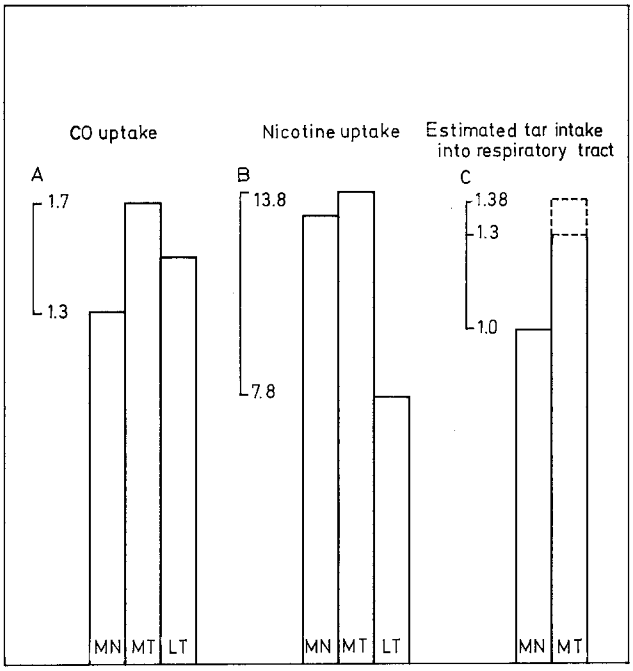


Fig. 2. Mean measured uptake of carbon monoxide and nicotine, calculated intake of tar when smoking a maintained nicotine (*MN*), middle tar (*MT*) and low tar (*LT*) cigarette. Data for the LT cigarette in column *C* are not shown for reasons given in text. Units: column *A* – increase in % COHb; column *B* – increase in plasma nicotine in ng ml^{-1}; column *C* – relative units, the *dotted* lines indicating the intake range based on calculations using CO and nicotine as smoke component markers

into the respiratory tract (tar). On this assumption, the tar intake index for the low tar cigarette might reasonably be expected to be closer to the maintained nicotine cigarette than to the middle tar cigarette, so that the present results are generally consistent with those of Russell et al. (1986).

It is also pertinent to compare our results with those of Stepney (1981) and Woodman et al (1987); all three studies have been concerned with evaluation of maintained nicotine cigarettes (tar yields in the range 10–11.2 mg and nicotine yields in the range 1.1–1.4 mg) in comparison with reference cigarettes. The specifications of the cigarettes used by the three groups were all different and it is therefore not surprising that findings and conclusions were not identical. Stepney compared the mouth deliveries of tar from three cigarettes whose tar yields were 19, 11 and 10 mg, whose nicotine yields were 1.55, 0.7 and 1.1 mg and whose T/N ratios were 12, 16 and 9, respectively. Delivery was reduced by 10–13% when smoking the maintained nicotine cigarette relative to delivery when smoking normal middle tar brands (17.7 to 15.5 mg in the laboratory under experimental conditions and 12.9 to 11.2 mg outside the laboratory). Stepney was not able to make any assessment of tar intake into the respiratory tract by his subjects.

Woodman et al. (1987) measured inhaled smoke volumes directly using a ^{81}Kr radiotracer technique. The values from the cigarette with maintained nicotine were 21% less than from a cigarette with the same standard tar yield but reduced nicotine. This figure agrees more closely with the 23–28% reduction in estimated tar intake reported in the present paper. The additional finding by Woodman and his colleagues that inhaled smoke volume from the maintained nicotine cigarette was 23% less than from a cigarette with the same nicotine yield but a higher tar yield was unexpected. It appears that both the absolute yields of tar and nicotine and the ratio of the yields may be critical for optimal acceptability of a cigarette product. So far as nicotine is concerned, Jarvis and Russell (1986) pointed out that British smokers are reluctant to smoke cigarettes with machine smoked yields below about 1.3 mg.

The results reported in this paper were obtained from a relatively small number of randomly selected middle tar smokers and therefore need to be interpreted with some caution, particularly as there is inevitably some uncertainty regarding the similarity of smoking under laboratory conditions to the smoking in a changeable environment throughout the day. Nevertheless, our data are consistent with the proposition that the middle tar smoking population at large might be exposed to lower concentrations of tar and carbon monoxide by smoking a product such as the one used in these experiments with a relatively high nicotine yield and low tar yield. The case cannot be proved or disproved until analytical methods have been established that allow particular deposition and retention to be measured directly and unequivocally. In addition, studies also need to be performed, not complicated by enforced brand switching, in subjects who regularly and voluntarily smoke maintained nicotine cigarettes.

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