Measurement of self reported active exposure to cigarette smoke

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Abstract

Study objective—The number of cigarettes smoked per day is an imprecise indicator of exposure to cigarette smoke, and biochemical assessment of exposure is not always feasible. The aim of this study was to develop more accurate measures of self reported active exposure to cigarette smoke.

Design—Mail survey in 386 smokers, retest at one month in 94 participants (24%), analysis of saliva cotinine in 98 participants (25%), collection of empty cigarette packs in 214 participants (55%), collection of cigarette butts in 107 participants (28%). Ten questions and items intended to assess active exposure to cigarette smoke were tested and compared with saliva cotinine, the Fagerström test for nicotine dependence, and self rated dependence.

Setting—A population sample in Geneva, Switzerland, in 1999.

Participants—323 daily smokers and 63 occasional smokers.

Main results—Measures that were associated with saliva cotinine included the number of cigarettes smoked per day (r^2=0.36), smoking intensity (r^2=0.40), the type of cigarettes smoked (regular versus light) (r^2=0.04), smoking when ill (r^2=0.15) and a single item rating of the total quantity of smoke inhaled (r^2=0.27). A multivariate model combining the first four items explained the largest proportion of the variance in cotinine (r^2=0.63), substantially more than was explained by the number of cigarettes per day alone, by 75% in all smokers and by 110% in daily smokers.

Conclusions—The study identified measures of exposure to smoke that reflect saliva cotinine better than the number of cigarettes per day. These measures can be used in studies of the dose related risk of smoking and in smoking reduction studies.

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An accurate measurement of self reported exposure to cigarette smoke is useful for the assessment of the dose related risk of smoking and for the evaluation of the effectiveness of smoking reduction interventions.[1][2] The number of cigarettes smoked per day is the most frequently used indicator of exposure to cigarette smoke in epidemiological studies, but it may be inaccurate. For instance, saliva cotinine levels of smokers of 20 cigarettes per day may vary more than 10-fold,[3] and in regular smokers, the number of cigarettes smoked per day explains less than half of the variance in saliva cotinine.[3][4] The remaining variance is explained by variations in smoking (depth and duration of inhalation, number of puffs per cigarette, tapering of ventilation holes, etc),[5] by imprecise self report of the number of cigarettes smoked, by imprecise measurement of saliva cotinine or by variations in the metabolism of nicotine and cotinine.[4][6]

Exposure to cigarette smoke can be assessed by biochemical markers (nicotine, cotinine, thiocyanates, expired carbon monoxide, anatabine or anabasine),[7] but biochemical tests have limitations. Collecting and analysing blood or saliva samples is expensive and may not be feasible in large studies. Carbon monoxide, thiocyanates, nicotine and cotinine are not specific markers of tobacco smoke (nicotine can be obtained from patches or gums),[8][9] and assays of the most specific markers (anatabine and anabasine) are expensive.[7] In addition, many smokers may refuse to provide a sample of blood or saliva, which may create bias in biochemically validated data.[10][11] Little is known about the reliability of self reported information on other indicators of exposure to cigarette smoke, such as the number and length of cigarette butts, or the nicotine and tar yields written on cigarette packs.

The aim of this study was to develop and test the reliability and validity of several measures of self reported active exposure to cigarette smoke, and to test whether these measures were more accurate than the number of cigarettes per day in predicting saliva cotinine.

Methods

We conducted a cross sectional study to compare self reported data on exposure to cigarette smoke with objective indicators (saliva samples for cotinine analysis, cigarette butts and empty cigarette packs).

SETTING AND PARTICIPANTS

A random sample of 2000 people aged 18–70 was drawn from the official registry of Geneva residents. Potential participants received the survey by mail in March 1999. Non-respondents received a reminder postcard and two reminder questionnaires. The cover letter and the front page of the questionnaire indicated that participation was limited to current smokers and to ex-smokers who had quit smoking in the previous two years. Non-smokers and smokers who did not wish to participate were asked to transmit the questionnaire to someone else. Previous research has

shown that this procedure does not bias associations between smoking related variables.[12] We conducted a retest of the same questionnaire one month later, in volunteers only.

STUDY VARIABLES
Self reported data
We designed a series of questions intended to measure exposure to cigarette smoke. In particular, we hypothesised that asking smokers directly about their exposure would provide a useful assessment. The questionnaire was field tested in face to face interviews with seven smokers. It included the following questions about active exposure to cigarette smoke:

1 How many cigarettes do you smoke per day, on average? (Open-ended response).

2 On average, how many puffs do you take on each cigarette? (If you don't know, please count the number of puffs on your next cigarette). (Open-ended response).

3 Indicate, on a scale between 0 and 100, the intensity of your smoking. (Open-ended response).

4 In general, how much do you inhale the smoke of your cigarettes? *Response options:* I inhale no smoke at all; I inhale almost no smoke; I inhale smoke but not deeply; I inhale smoke rather deeply; I inhale smoke very deeply.

5 What is the total quantity of smoke that you inhale every day? (This quantity depends on the number of cigarettes you smoke, the depth of inhalation, the number of puffs, etc). (*Followed by a 0–10 scale with two anchors*: 0 = I inhale no smoke at all; 10 = I smoke so much that I could not inhale more smoke, even if I tried).

6 On this picture of a cigarette, please mark the length of the butts that you leave in the ashtray, on average. (*Followed by a picture exactly the size of a Marlboro cigarette*).

7 Indicate with a number between 0 and 10 the degree of coloration of the tip of the filters of your cigarettes, after you have smoked them. (*Followed by a 0–10 scale, with two anchors*: 0=When I put out my cigarettes, the tip of the filter is not coloured at all (white); 10=When I put out my cigarettes, the tip of the filter is extremely dark (dark brown).

8 and 9 What are the numbers of mg of tar and nicotine written on your cigarette pack? (Please look at the pack). (Open-ended responses).

10 In general the cigarettes you smoke are: normal (regular or full flavour); mild or medium; light; ultralight or superlight; hand rolled.

Participants also answered the Fagerström test for nicotine dependence,[13] they indicated their age and sex, and whether they smoked daily, occasionally or never.

Cigarette packs
Participants were asked to return one of their empty cigarette packs together with the baseline questionnaire. In Switzerland, indication of nicotine and tar yields on cigarette packs is mandatory; this information is provided by the manufacturers.

Cigarette butts
We asked participants whether they would collect their cigarette butts during one day. Those who agreed were sent a metal box upon receipt of their baseline questionnaire. When applicable, these participants indicated on the box the number of missing butts.

Saliva cotinine
Cotinine, a major metabolite of nicotine, has a half life of 20 hours in smokers,[4] and is stable in saliva when mailed or stored at room temperature during several days.[14] [15] Upon receipt of their baseline questionnaires, participants who agreed to provide a saliva sample were sent a plastic vial (Salivette, Sarstedt, Nümbrecht, Germany, article no 511534). The saliva samples were frozen at −20°C upon receipt and sent in dry ice for cotinine analysis to ABS Laboratories (London, Dr Feyerabend). Saliva cotinine level was determined by gas-liquid chromatography.[16] Participants who were currently using nicotine replacement therapy were excluded from cotinine analyses.

ANALYSES
Data were double entered to avoid errors. We assessed whether questionnaire items and scales produced variability, minimal floor and ceiling effects, and small proportions of missing answers, and we computed test-retest intraclass correlation coefficients.

To assess the accuracy of self reports, we compared the self reported yields of nicotine and tar with the nicotine and tar yields written on cigarette packs, the self reported number of cigarettes smoked per day with the number of cigarette butts in the boxes plus the number of missing butts indicated on the boxes, and the self reported length of cigarette butts with the actual length of butts in the boxes. We computed intraclass correlation coefficients and examined bias by matched pairs *t* tests.

To validate measures of exposure to cigarette smoke, we examined their associations with saliva cotinine. Firstly, we checked whether associations between intended measures of exposure to smoke and cotinine were linear throughout the range of exposure, using non-parametric regression (Lowess).[17] Then, we examined the same associations in univariate linear regression models, and used r^2 statistics to assess goodness of fit.

Finally, we sought to develop a multivariate model that best fitted cotinine data. We included only questionnaire data among predictor variables, because we intended to develop a questionnaire measure of exposure to cigarette smoke. Using a stepwise procedure, we included all variables that were associated with saliva cotinine in univariate analysis and retained only variables that remained statistically significant after adjustment. These analyses were conducted separately in all smokers and in daily smokers. Because exploratory analysis indicated that the association between cig/day and cotinine was not linear, we recoded

Table 1 Properties of self reported measures of exposure to cigarette smoke, in 386 daily and occasional smokers (Geneva, Switzerland, 1999)

	Test-retest†	Missing data (%)	Mean	SD
Cigarettes per day	0.94***	5.7	17.9	12.4
Cig/day, with values >25 set to 25	0.86***	5.7	15.6	7.8
Number of butts	—	72.3	14.5	9.0
Puffs per cigarette	0.54***	24.4	11.4	5.6
Intensity of smoking (0–100 rating)	0.77***	16.1	56.8	26.8
Self reported nicotine yield (mg)	0.85***	11.9	0.55	0.28
Nicotine yield observed on pack (mg)	—	53.1	0.56	0.27
Self reported tar yield (mg)	0.90***	11.9	6.37	3.67
Tar yield observed on pack (mg)	—	53.1	6.65	3.73
Type of cigarettes (regular + mild + hand rolled versus light + ultralight)	0.90***	6.2	—	—
Self reported length of butts (mm)	0.63***	10.9	35.5	7.3
Actual length of butts (mm)	—	72.3	35.3	6.3
Colour of the end of the filter (0–10 scale)	0.68***	11.1	5.6	2.1
Depth of inhalation (1–5 scale)	0.81***	5.4	3.6	0.8
Total quantity of smoke inhaled (0–10 scale)	0.80***	12.7	5.4	2.2
Fagerström test for nicotine dependence	0.81***	4.9	3.2	2.5
FTND items:				
1 Minutes to first cig (in four categories)	0.93***	10.4	1.3	1.0
1 Minutes to first cig (continuous)	0.96***	10.4	90.3	125.1
2 Difficult to refrain	0.65***	5.4	0.2	0.4
3 Cig hate most to give up	0.27**	8.3	0.4	0.5
4 Cig per day (in four categories)	0.85***	5.7	1.0	0.9
5 Morning smoking	0.75***	6.0	0.2	0.4
6 Smoke if ill	0.58***	6.2	0.2	0.4
Predicted value from four item model (see table 3)	0.85***	18.7	246.1	131.2

†Test-retest intraclass correlation coefficient, in 94 people who participated in the retest. ***$p \leqslant 0.001$.

Table 2 Univariate regression of saliva cotinine (dependent variable) on presumed measures of exposure to cigarette smoke (independent variables), among 98 smokers and 85 daily smokers who provided a saliva sample and were not currently using nicotine replacement products

	All smokers		Daily smokers	
Measures of exposure (independent variables)	Regression coefficient†	r^2‡	Regression coefficient†	r^2‡
Cigarettes per day	7.3***	0.359	5.7***	0.250
Cig/day, with values >25 set to 25	16.0***	0.527	14.7***	0.379
Number of butts	7.2***	0.326	5.5***	0.229
Puffs per cigarette	2.0 (NS)	0.004	2.5 (NS)	0.008
Intensity of smoking (0–100 rating)	3.9***	0.397	3.8***	0.356
Self reported nicotine yield (mg)	142.6*	0.058	144.5*	0.072
Nicotine yield on pack (mg)	147.6*	0.065	150.4*	0.080
Self reported tar yield (mg)	11.5**	0.067	12.1**	0.088
Tar yield on pack (mg)	11.4*	0.067	11.3*	0.066
Type of cigarettes (regular + mild + hand rolled versus light + ultralight)	73.5*	0.047	54.3 (NS)	0.031
Self reported length of butts (mm)	−1.5 (NS)	0.004	−3.7 (NS)	0.027
Actual length of butts (mm)	−4.0 (NS)	0.022	−4.1 (NS)	0.029
Colour, end of the filter (0–10 scale)	19.4*	0.054	12.6 (NS)	0.025
Inhalation (1–5 scale)	32.5 (NS)	0.030	12.6 (NS)	0.005
Quantity of smoke (0–10 scale)	41.5***	0.268	32.8***	0.160
Minutes to first cig in the morning	−0.7***	0.298	−0.8***	0.197
Fagerström dependence test (FTND)	41.1***	0.406	33.2***	0.302
FTND items:				
1 Minutes to first cig (in four categories)	94.2***	0.355	79.2***	0.282
2 Difficult to refrain	152.6***	0.121	113.9**	0.089
3 Cig hate most to give up	43.6 (NS)	0.016	38.3 (NS)	0.014
4 Cig per day (in four categories)	119.3***	0.407	95.7***	0.290
5 Morning smoking	130.9***	0.126	100.3**	0.092
6 Smoke if ill	157.8***	0.154	117.9**	0.112
Predicted value from four item model	1.0***	0.639	1.0	0.526

Statistical significance: *$p \leqslant 0.05$; **$p \leqslant 0.01$; ***$p \leqslant 0.001$. NS: not statistically significant. †Coefficients of linear regression indicate the change in cotinine (in ng/ml) for an increase of one unit in the independent variable. ‡r^2 statistics from linear regression models indicate the proportion of variance in saliva cotinine explained by independent variables.

the variable cig/day, attributing the value of 25 to all values above 25. For the multivariate model, we dichotomised the variables on the type of cigarette smoked (regular + mild + hand rolled versus light + ultralight) and on nicotine yield (>0.8 mg versus less).

To examine the degree of over-fitting of the multivariate model to the development sample, we performed a cross validation procedure. Firstly, the sample was split at random into 10 subsets. Then, the cotinine prediction model was estimated on nine tenths of the sample, and the resulting equation was applied to the remaining tenth. The latter predicted values were deemed cross validated, because these

observations did not contribute to model estimation. This procedure was repeated 10 times, rotating the validation subsample. Model over-fitting was assessed by a comparison of correlation coefficients of observed cotinine values with naive predicted values, and with cross validated predicted values.

Results

PARTICIPATION

We received 494 baseline questionnaires from smokers and ex-smokers (25% of 2000). We included only the 323 daily smokers and the 63 occasional (non-daily) smokers in this analysis (386 current smokers). These participants
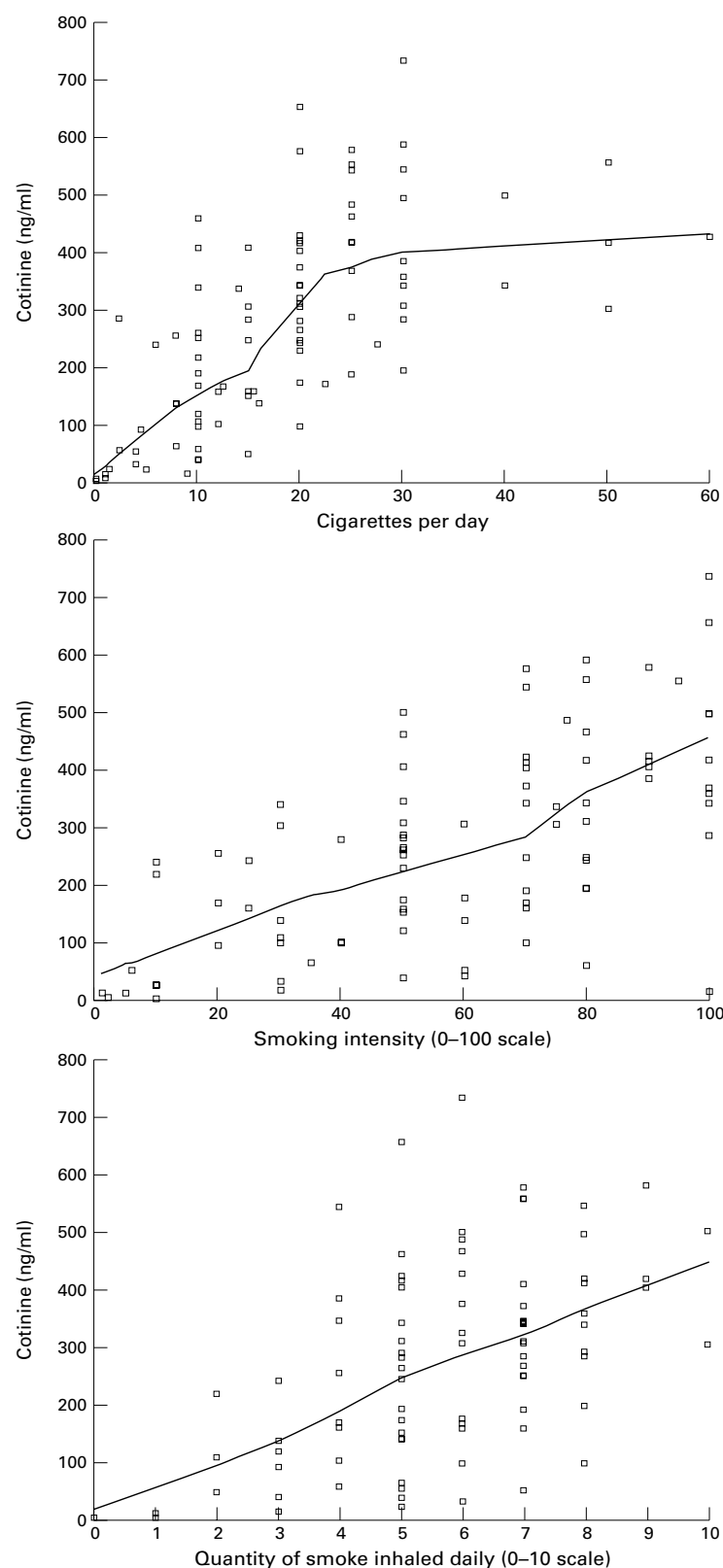
Figure 1   Association between cigarettes per day, intensity of smoking, quantity of smoke inhaled, and saliva cotinine levels in smokers. (Geneva, Switzerland, 1999).

KEY POINTS
- The number of cigarettes smoked per day is an imprecise indicator of exposure to cigarette smoke, and biochemical assessment of exposure is not always feasible.
- We identified self reported measures of exposure to smoke that reflect saliva cotinine better than the number of cigarettes smoked per day.
- These measures can be used in studies of the dose related risk of smoking and in the evaluation of smoking reduction interventions.

The retest questionnaire was returned by 94 people (24% of baseline smokers), on average 37 days after the baseline survey. Empty cigarette packs were returned by 214 people (55%), and boxes filled with cigarette butts by 107 people (28%). Saliva samples were returned by 107 smokers (28 %), but six vials did not contain enough saliva for analysis, and three smokers were currently using nicotine replacement products; the remaining 98 people were included in cotinine analyses (85 daily smokers and 13 occasional smokers).

MISSING DATA AND TEST-RETEST RELIABILITY
Among questionnaire items, the proportions of missing answers were highest for the number of puffs and intensity of smoking (table 1). Test-retest correlations were highest for the number of minutes before smoking the first cigarette in the morning and the number of cigarettes per day, lowest for the number of puffs per cigarette and the length of cigarette butts. Many participants in the face to face pre-test had difficulty indicating how many puffs they took per cigarette.

VALIDATION BY OBJECTIVE MEASUREMENTS
Nicotine and tar yields
For 186 persons (92% of 203 smokers who answered the question on nicotine yield and returned an empty cigarette pack), the number of mg of nicotine indicated in the questionnaire and on the pack were identical. The average difference was −0.01 mg (95% confidence intervals: −0.02, 0.003 mg), range −0.9 mg to +0.5 mg. The intraclass correlation coefficient between self report and nicotine yield written on the packs was 0.94 (95% confidence intervals: 0.92, 0.95).

For 185 persons (91% of those who answered the question on tar yield and returned an empty cigarette pack), the number of mg of tar indicated in the questionnaire and on the pack were identical. The average difference was −0.3 mg (95% confidence intervals: −0.57, −0.06), range −13.5 mg to +6 mg. The intraclass correlation coefficient between self report and tar yield written on the pack was 0.87 (95% confidence intervals: 0.84, 0.90).

Cigarette butts
The boxes that were returned to us contained on average 14.6 butts, and participants indicated that 2.3 butts were missing on average.

were on average 39 years old (SD = 13, range = 17 to 78 years), 182 (47%) were men, and they smoked on average 17.9 cigarettes per day (daily smokers: 20.1 cig/day, occasional smokers: 3.5 cig/day).

Table 3 Multivariate regression models of saliva cotinine measures of exposure to cigarette smoke on saliva cotinine, among 82 smokers who were not currently using nicotine replacement products

	Model 1		Model 2	
	β coefficients	*95% confidence intervals*	*β coefficients*	*95% confidence intervals*
Cigarettes per day (recoded, per cigarette between 0 and 25)	11.3	7.4, 15.3	10.9	6.8, 15.1
Smoking intensity (per unit on 0–100 scale)	1.1	0, 2.2	1.3	0.1, 2.4
Smoke if ill (yes=1, no=0)	65.2	10.3, 120.2	65.3	7.5, 123.0
Type of cigarettes (regular + mild + hand rolled versus light + ultralight)	77.7	32.7, 122.7	—	—
Nicotine yield of cigarettes (≥0.8 mg versus less)	—	—	76.2	24.2, 128.1

Missing butts were reported by 41 people (38% of 107 people who returned butts). Thus, on average, the number of butts (included + missing) was 16.9 (median = 15). Participants who returned butts declared in the questionnaire that they smoked on average 19.1 cigarettes per day (median = 20 cigarettes). The difference between the self reported number of cigarettes smoked per day and the number of butts (present + missing) was statistically significant (difference = 2.2, 95% confidence intervals: 1.0, 3.4); this difference was similar in men and women (between sex p = 0.65, from independent samples *t* test).

In all smokers, the self reported length of cigarette butts was 35.5 mm (SD=7.3, quartiles: 30, 35 and 40 mm). Among participants who returned cigarette butts, the self reported length of cigarette butts (35.3 mm) was similar to the actual average length of cigarette butts measured by us (35.3 mm). The difference ranged between −15 to +27 mm (95% confidence intervals on difference: −1.7, 0.6 mm). The intraclass correlation coefficient between self reported and observed length of butts was 0.64 (95% confidence intervals: 0.50, 0.74).

Saliva cotinine

Smokers who returned a saliva sample were 3.6 years younger than smokers who did not (p=0.02), but the proportion of men, the number of cigarettes smoked per day and the time to the first cigarette were similar in the two groups. Mean cotinine value was 236 ng/ml (SD = 173 ng/ml, range 3 to 733 ng/ml). In all smokers, the variance in saliva cotinine was best explained by the number of cigarettes per day (recoded with values above 25 set to 25), followed by the Fagerstöm test for nicotine dependence, the item rating the intensity of smoking, and by the total quantity of smoke inhaled (table 2). No other item explained more than 7% of the variance in cotinine.

The association between cig/day and cotinine was linear between 0 and 25 cig/day and then reached a plateau. Estimates of smoking intensity and of the total quantity of smoke were linearly associated with saliva cotinine (fig 1).

Neither self reported nor actual length of cigarette butts were significantly associated with saliva cotinine. The self reported number of puffs, colour of tip of cigarette filters, and depth of inhalation were not, or only weakly associated with saliva cotinine. The associations between saliva cotinine and yields of nicotine and tar were weak, and similar

whether self reported or actual yields were used (table 2).

The median self reported nicotine yields of regular, mild, light, ultralight and hand rolled cigarettes, were, 0.9, 0.7, 0.5, 0.3, and 0.9 mg, respectively, and the corresponding saliva cotinine levels were 342, 235, 253, 190, and 295 ng/ml. Cotinine levels were significantly higher in smokers of normal versus ultralight cigarettes (p=0.006), but differences between smokers of normal versus light cigarettes (p=0.058), normal versus mild cigarettes (p=0.10), and light versus ultralight cigarettes (p=0.15) failed to reach statistical significance. The cotinine level in smokers of hand rolled cigarettes was not significantly different from smokers of any other category. The difference between smokers of normal versus ultralight cigarettes remained statistically significant after adjustment for the number of cigarettes smoked per day. A test for linear trend, excluding smokers of hand rolled cigarettes, indicated that the type of cigarettes (normal, medium, light, ultralight) was linearly associated with saliva cotinine (p = 0.005).

Saliva cotinine levels were higher in men (313 ng/ml) than in women (240 ng/ml, p=0.04). This difference remained statistically significant, even after adjustment for the number of cigarettes per day and for the rating of smoking intensity.

MULTIVARIATE MODEL

Saliva cotinine was best predicted by a four item model that included cig/day recoded with values >25 set to 25, smoking intensity, smoking when ill (an item from the Fagerström test), and the type of cigarettes smoked (recoded in two categories) (table 3). The total quantity of smoke inhaled was no longer significant after adjustment for cig/day and smoking intensity. Eighty two people with complete data were included in this multivariate model. A very similar model was obtained when the type of cigarettes was replaced by the number of mg of nicotine written on the cigarette pack, dichotomised as ≥0.8 mg versus less (table 3).

The association between actual cotinine values and those predicted by the first model (including the type of cigarettes) was approximately linear (fig 2), and the corresponding Pearson correlation coefficient was 0.794. This coefficient decreased to 0.749 after cross validation. For the alternative model that included milligrams of nicotine written on the pack, the correlation coefficient decreased from 0.791 to 0.745.
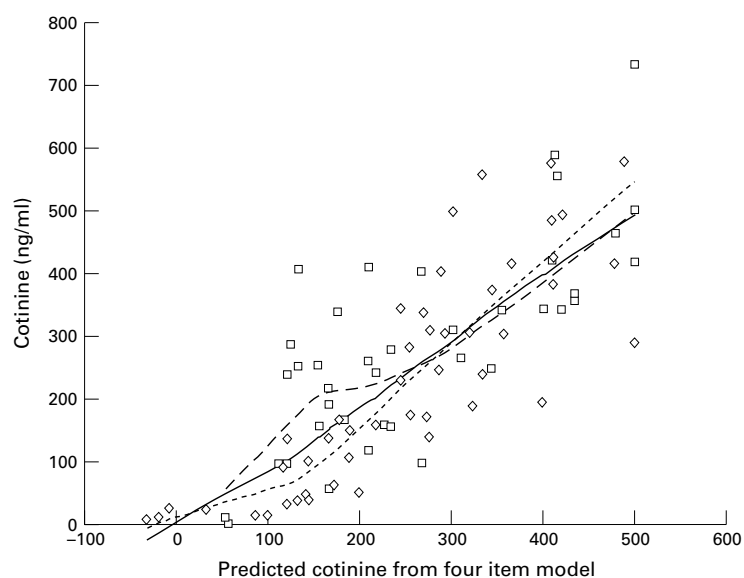
Figure 2   Association between predicted cotinine from a four item model of self reported exposure to cigarette smoke, and saliva cotinine, in all smokers (solid line), in men (dashed line, round symbols) and in women (dotted line, square symbols).

In all smokers, the first model explained a greater proportion of the variance in cotinine ($r^2 = 0.63$) than the number of cigarettes per day alone ($r^2 = 0.36$). This was also true in daily smokers ($r^2 = 0.53$ versus 0.25). The improvement in the variance explained was 75% in all smokers ($0.63/0.36 = 1.75$), and 110% in daily smokers ($0.53/0.25 = 2.10$). The four item model also explained a larger proportion of the variance in cotinine than the Fagerström test.

Discussion

In this study, we tested the reliability and validity of several measures of active exposure to cigarette smoke. Among single items, a rating of smoking intensity was more strongly associated with saliva cotinine than the raw number of cigarettes per day. This rating was linearly associated with saliva cotinine, whereas the association between cigarettes per day and cotinine presented a plateau above 25 cigarettes per day. The best prediction of saliva cotinine was obtained by a model that included the number of cigarettes smoked per day, the rating of smoking intensity, smoking when ill and the type of cigarettes smoked. In daily smokers, this model explained over twice as much of the variance in cotinine than the number of cigarettes per day. This model can be used as a measure of exposure to cigarette smoke in epidemiological studies or in smoking reduction studies.

This model was defined empirically. It excludes variables that are face valid but are not associated with saliva cotinine (for example, the number of puffs), and includes variables that do not only measure exposure to tobacco smoke (for example, smoking when ill). The validity of this model should be confirmed in other samples. Our data also showed that smokers report reliably the nicotine and tar yields of their cigarettes. These results are at odds with some previous studies, which showed that self reports of tar yields are

imprecise and that the majority of smokers do not know the tar yield of their cigarettes.[18–20] The discrepancy probably occurred because in many countries, tar yields are not written on all cigarette packs.

Many participants did not provide cigarette butts (72%), an empty cigarette pack (45%) or a saliva sample (72%). These high proportions of missing observations limit the use of these objective indicators. The difficulty in collecting these items emphasises the necessity of developing valid self reported measures of exposure to cigarette smoke.

Our results are congruent with published research on the accuracy of self reported butt length,[21] and on the absence of association between butt length and cotinine level.[22] The difference between the number of cigarette butts returned in the boxes and the self reported number of cigarettes smoked per day may be explained by a decrease in the number of cigarettes smoked during the day of butt collection, because collecting butts interfered with usual smoking habits.

The self reported number of puffs per cigarette and the colour of the tip of cigarette filters were not associated with saliva cotinine and therefore should not be used to measure exposure to cigarette smoke. Published research shows that when it is observed directly, the number of puffs is related to biochemical indicators of exposure to tobacco smoke,[5 23–25] but we know of no study on the validity of self reports of the number of puffs. In our data, the self assessment of the number of puffs may have been too imprecise to show an association with saliva cotinine.

Observed nicotine yields of ultralight cigarettes (mean=0.3 mg) were three times lower than yields of regular cigarettes (mean=0.9 mg), but cotinine levels in smokers of ultralight cigarettes (190 ng/ml) were 56% of cotinine levels in smokers of regular cigarettes (342 ng/ml). Either smokers of ultralight cigarettes did not compensate entirely for the lower nicotine yield of these cigarettes, or less addicted smokers had a preference for ultralight cigarettes. The latter hypothesis is supported by evidence that smokers of the lowest yield cigarettes have lower nicotine needs.[26] Our results confirm that only smokers of ultralow—but not low—yield cigarettes have lower levels of blood cotinine.[27]

The "light" or "ultralight" labels are determined according to marketing criteria. These criteria may not be similar for all brands, and they may vary over time and between countries. Values written on packs of light cigarettes returned by participants ranged from 0.2 to 0.8 mg for nicotine yields, and from 2 to 9 mg for tar yields. Therefore, self reports of the type of cigarettes should be considered with caution when used as an indicator of exposure to tobacco smoke.

As seen previously,[3] saliva cotinine levels were higher in men than in women, even after adjustment for self reported exposure to cigarette smoke. This suggests either that men under-report their exposure to cigarette smoke,

relative to women, or that the metabolism of cotinine is different in men and women.[28]

Saliva cotinine was our main criterion for assessing the validity of self reported exposure to cigarette smoke. However, cotinine level is influenced by factors independent of exposure to cigarette smoke, including metabolism, imprecision in laboratory measurement, and the hour of the day when saliva is collected.[29] Nicotine can be found in food, but at usual levels of food consumption, nicotine intake from food is trivial.[8] A single spot evaluation of cotinine level may not reflect its long term average,[30] which may attenuate associations with self reported measures of exposure to smoke. Finally, only a minority of participants provided a saliva sample, but smoking related variables were similar in those who provided and did not provide a saliva sample. Further studies of self reported exposure to cigarette smoke could use other indicators, such as expired carbon monoxide, or more specific markers such as anatabine or anabasine.[7]

Most studies on the dose related risk of smoking were based on the number of cigarettes smoked per day, which is an inaccurate indicator of exposure to tobacco smoke. This study identified more accurate single item and multi-item measures of self reported exposure to cigarette smoke. Because many smokers will not participate in biochemical assessments, valid self reported measures are essential to the validity of epidemiologic and clinical studies.

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