they could reduce the effect of falls on the older adult population. □

Acknowledgments

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Carcinogens in Tobacco Smoke: Benzo[a]pyrene from Canadian Cigarettes and Cigarette Tobacco

Murray J. Kaiserman, PhD, and William S. Rickert, PhD

ABSTRACT

We evaluated the benzo[a]pyrene (BaP) content in the smoke from 35 brands of Canadian cigarettes and 5 brands of Canadian tobaccos for roll-your-own cigarettes. For the cigarettes, mean values of BaP ranged from 3.36 ng to 28.39 ng per cigarette, roughly in proportion with declared tar values. The relationship between declared tar and yields of BaP, however, does not allow accurate prediction of one from the other. For the tobaccos, mean BaP values ranged from 22.92 ng to 26.27 ng (average, 24.7 ng) per cigarette. The implications of these findings are discussed with respect to overall exposure. (*Am J Public Health.* 1992;82:1023–1026)

Introduction

The particulate fraction of tobacco smoke ("tar") is composed of a complex mixture of constituents,[1,2] some of which are regulated under environmental legislation.[3–6] One constituent is benzo[a]pyrene (BaP), a polynuclear aromatic hydrocarbon formed during the incomplete combustion of organic matter such as gasoline, garbage, and plants. BaP has been identified by the International Agency for Research on Cancer as an animal carcinogen and a probable human carcinogen (Class 2A)[7] with inhalation, oral ingestion, and dermal absorption as the important routes of entry.

Human data are unavailable, but oral ingestion of about 7 to 9 mg of BaP per kilogram has produced cancers in laboratory animals.[8] With respect to tobacco smoke, BaP has been detected in concentrations ranging from 20 to 40 ng per cigarette in mainstream cigarette smoke[1] to 40 to 79 ng per cigarette in sidestream smoke[1] and 96 to 292 ng per cigar in mainstream cigar smoke.[9]

On January 1, 1989, the Tobacco Products Control Act came into force in Canada. One of the purposes of this legislation is to "enhance public awareness of the hazards of tobacco use by ensuring the effective communication of pertinent information to consumers of tobacco products."[10] To achieve this goal, the Health Protection Branch of Health and Welfare Canada has undertaken a series of studies to develop and validate analytical test methods for toxic constituents.

In this paper we report on the BaP delivery of 35 brands of commercially available Canadian cigarettes and 5 brands

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TABLE 1—Mean Benzo[a]pyrene (BaP) and Declared Tar, Nicotine, and Carbon Monoxide (CO) Concentrations per Cigarette in 35 Brands of Canadian Cigarettes

Brand	Tar, mg	Nicotine, mg	CO, mg	BaP, ng
Accord Ultra Mild KS	3	0.3	3	5.63
Black Cat Light RS FT	14	1.2	14	23.36
Black Cat RS FT	16	1.3	16	21.87
B&H 100's Light FT	10	1	10	16.85
Cameo Menthol KS FT	18	1.4	19	23.03
Craven A KS FT	13	1.2	13	22.53
Craven A Ultra Light KS FT	1	0.1	1	3.36
Du Maurier Extra Light RS FT	10	0.9	11	17.08
Du Maurier KS FT	16	1.3	17	22.92
Du Maurier Light KS FT	13	1.1	12	21.17
Du Maurier RS FT	15	1.2	16	23.06
Du Maurier Special KS FT	12	1	13	19.29
Export A Extra Light RS FT	8	0.9	9	17.66
Export A Light RS	12	1.3	12	17.85
Export A Medium RS FT	13	1.2	14	19.04
Export A RS FT	15	1.3	16	25.86
Gitanes FT RS	12.9	0.89	16	12.40
Mark Ten FT KS	16	1.2	16	28.39
Mark Ten FT RS	17	1.3	17	24.02
Matinee Extra Mild KS FT	4	0.4	5	6.85
Matinee KS FT	13	1.1	12	13.16
Matinee Slims Extra Mild KS FT	3	0.4	3	8.21
Medallion KS FT Ultra Mild	1	0.2	2	4.60
Number 7 Light KS FT	13	1.1	13	20.19
Number 7 RS FT	16	1.3	16	19.74
Players Extra Light RS FT	11	1	11	15.65
Players Light KS FT	16	1.3	17	18.93
Players Light RS FT	16	1.3	15	15.49
Players RS FT	19	1.4	19	27.34
Rothmans Extra Light KS FT	10	1.1	9	10.49
Rothmans KS FT	16	1.2	16	17.69
Sportsman FT KS	16	1.2	16	25.37
Vantage KS FT	9	1	11	17.30
Vantage Light KS FT	4	0.5	5	7.59
Viscount 1 Ultra Mild KS FT	0.7	0.09	0.7	3.39

Note. KS = king size; RS = regular size; FT = filter tip.

of commercially available Canadian fine-cut tobaccos for making roll-your-own cigarettes.

Methods

Smoking Procedures and Sample Collection

The 35 brands of cigarettes and 5 brands of fine-cut tobaccos were collected at the retail level in March and April of 1989 in Montreal and Vancouver. Brands were chosen to include some of the most popular brands in the market, including Players Light Regular Size (12.9% market share), Export A Regular Size (5.7% market share), and Rothmans King Size (3.7% market share).[11] The preparation of roll-your-own cigarettes and the smoking conditions for all cigarettes are described elsewhere.[12]

BaP was collected and analyzed according to the method described by Tomkins et al.[13] In this procedure, ^{14}C-labeled BaP is added to each sample and values, as determined by high-pressure liquid chromatography (HPLC), are corrected for ^{14}C recovery.

Recovery Study

Five Canadian control cigarettes (Monitor 4) were smoked per port on 10 randomly selected ports of a 20-port smoking machine and the mainstream particulate fraction was collected on a Cambridge filter pad, providing a total of 10 samples.

During cleanup, 100 μl of tracer solution was added to six of these samples at six different steps before HPLC isolation and 25 μl of tracer solution was added to two of the samples at two different steps after isolation and before HPLC quantitation. To determine 100% recovery, two of the samples were left unspiked (no tracer solution added) until just prior to injection onto the HPLC analytical column.

Validation Study

Five Kentucky Reference 2R1 cigarettes were smoked per port on 10 randomly selected ports of a 20-port smoking machine and the mainstream tar was collected on a Cambridge filter pad, resulting in another 10 samples. All samples were spiked with 100 μl of the tracer solution. Five of the pads were further spiked with 107.6 ng of unlabeled BaP. The workup then proceeded as described by Tomkins et al.[13]

Results and Discussion

Recovery and Validation Studies

The recovery and validation studies provide a measure of the precision, accuracy, and efficiency of the methods used. Observed recovery rates of BaP were 100% ± 8%. During the course of the experiment, the average recovery rate was 89% for the control cigarettes and 91% for fine-cut tobacco cigarettes; these rates were in good agreement with published results of 85% BaP recovery.[13] The results of the validation study provided a value of 31.9 ± 3.7 ng per cigarette for the unspiked 2R1 cigarette; this value was in good agreement with published values of 32 ng per cigarette[9] and 28.4 ± 3.4 ng per cigarette.[13]

Cigarette and Fine-Cut Tobacco Studies

Table 1 shows declared pack values for tar, nicotine, and carbon monoxide, and values for BaP as determined in this study. The results for BaP are averages of five observations per brand (25 cigarettes). (Although the current practice is to report yields on a per-cigarette basis, it should be pointed out that five cigarettes are required for each analytical value and the per-cigarette yield is obtained by division.)

Mean values for BaP range from 3.36 ng per cigarette to 28.39 ng per cigarette and are linearly related to declared tar values (correlation coefficient of 0.89 for all samples). Because the reported values reflect smoke concentrations under standard conditions, the smoker of low-yield cigarettes is probably exposed to higher amounts than those reported in Table 1.

Figure 1 shows the results of a regression analysis of mean BaP on declared tar. Although the simple linear correlation coefficient is fairly high at .89, the points are widely dispersed about the regression line, resulting in broad 95% confidence limits for the regression line. This means, for example, that at 16 mg declared tar, the BaP level is predicted to lie between 15 and 28 ng per cigarette. Thus, although

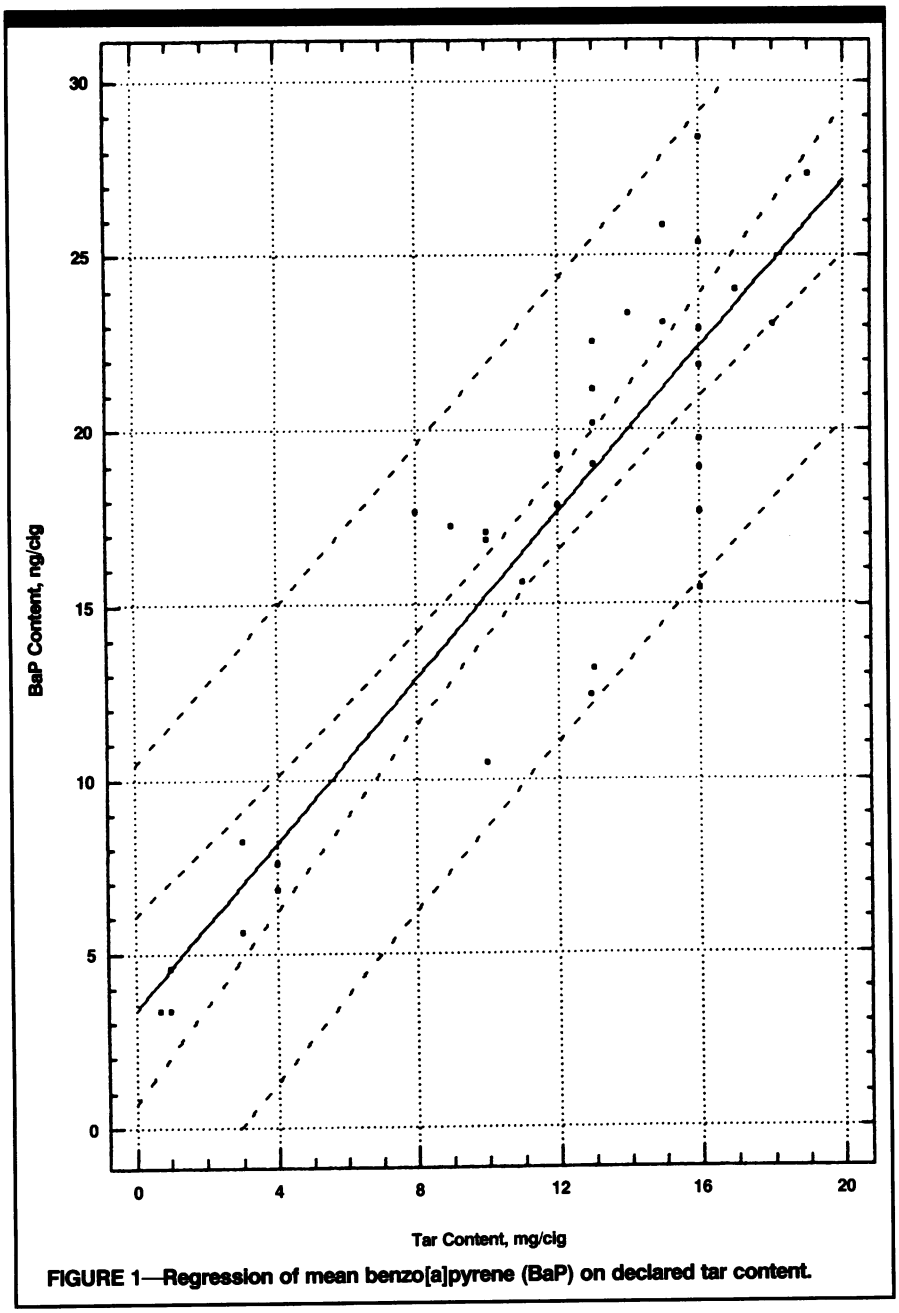

FIGURE 1—Regression of mean benzo[a]pyrene (BaP) on declared tar content.

TABLE 2—Mean Benzo[a]pyrene (BaP) and Declared Tar, Nicotine, and Carbon Monoxide (CO) Concentrations per Cigarette for Cigarettes Prepared from Five Brands of Roll-Your-Own Tobacco

Brand	Tar, mg	Nicotine, mg	CO, mg	BaP, ng
Players	23	1.8	19	25.02
Export	17	1.5	17	25.93
Craven A	19	1.5	19	23.34
Rothmans	19	1.5	19	26.27
Number 7	19	1.5	19	22.92

BaP is linearly related to declared tar, declared tar is not a good predictor of BaP.

Table 2 shows declared tar, nicotine, and carbon monoxide values and mean analytical BaP values for the five brands of fine-cut tobaccos used in preparation of roll-your-own cigarettes. Once again, BaP yields are averages of five observations per brand. These values range from 22.92 to 26.27 ng per cigarette; the average value was 24.7 ng per cigarette.

The Occupational Safety and Health Administration (OSHA) in the United States has set advisory levels for BaP of 0.2 μg/m^3 (8-hour time-weighted average permissible exposure limit for occupational exposure).[5] Assuming average breathing rates of 0.63 m^3/hour (women) to 1.08 m^3/hour (men) for alternating periods of light work and rest,[14] the permitted maximum amount of inhaled BaP in an occupational environment would be from 1.01 μg in 8 hours to 1.73 μg in 8 hours. A pack-a-day smoker who consumed 20 cigarettes in 8 hours could be expected to inhale from 0.067 μg to 0.568 μg from this source. Although the actual amount would vary depending upon individual smoking behavior, it is obvious that, for smokers, cigarette smoke is a significant source of exposure to BaP, contributing as much as one third the daily permitted exposure recommended by OSHA.

To clarify the risk further, the state of California mandates a "no significant risk" level for BaP of 0.06 μg per day.[6] A pack-a-day smoker (20 cigarettes) will inhale between one and ten times this level. For smokers, current advisory levels should be modified to take into account the contribution from tobacco smoke.

Although BaP is just one of 60 to 70 known toxic constituents of tobacco smoke,[1,2,7] many smokers continue to believe that tar is the most significant toxic constituent of tobacco smoke and that cigarettes with reduced tar are safer.[1,15] One reason for this misconception may be lack of knowledge of the components of tobacco smoke in a familiar context. □

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Discrepancies between Self-reported Smoking and Carboxyhemoglobin: An Analysis of the Second National Health and Nutrition Survey

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ABSTRACT

Environmental, self-report, and demographic factors mediated the relationship between self-reported cigarette smoking and carboxyhemoglobin among 2114 smokers and 3918 nonsmokers. Self-reported nonsmokers with carboxyhemoglobin levels between 2% and 3% were more likely to be self-reported ex-smokers, to live in a larger community, and to be younger, less educated, and male than were self-reported nonsmokers with carboxyhemoglobin levels of less than 2%. Self-reported nonsmokers with strong evidence of cigarette consumption (carboxyhemoglobin level > 3%) were more likely to be self-reported ex-smokers, younger, less educated, and non-White than were nonsmokers with carboxyhemoglobin levels of less than 2%. (*Am J Public Health.* 1992;82:1026–1029)

Introduction

Because of uncertainties inherent in measurement of smoking behavior using self-report,[1] biochemical measures are frequently used to validate reported smoking exposure. Although cotinine is often the preferred biochemical measure of smoking exposure,[2] blood carbon monoxide concentration is useful in many circumstances. It is less expensive to measure and can discriminate smokeless tobacco products from cigarette, pipe, and cigar smoking. It can also verify smoking cessation in treatment programs using nicotine replacement. Carbon monoxide is particularly useful in establishing health risks of smoking because of its strong relationship with cardiovascular disease.[3]

The current study sought to investigate factors associated with discrepancies between self-reported smoking status and carboxyhemoglobin levels. By identifying circumstances under which carboxyhemoglobin levels and self-reported smoking status do not agree, investigators can make more informed judgments about the validity of these measures of smoking and the associations between smoking and morbidity when carboxyhemoglobin is used.

Methods

The study sample consisted of 6032 participants from the Second National Health and Nutrition Examination Survey (NHANES II), aged 18 to 74 years, who completed a carboxyhemoglobin assessment. Detailed description of the survey methodology for NHANES II is available.[4] Self-reported smoking status was ascertained by asking participants whether they currently smoked cigarettes, how many they smoked on average, and whether they smoked cigars or pipes. Subjects reporting no current use of tobacco products were considered nonsmokers, while those smoking pipes or cigars were excluded. Carboxyhemoglobin concentrations, determined by spectrographic assay,[5] are expressed as percentages of total hemoglobin combined with carbon monoxide. Statistical analyses were performed using the Statistical Analysis System.[6] Collinearity diagnostics, as discussed by Hosmer and Lemeshow,[7] did not reveal unreliable estimates.

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