Effects of cigarette smoking on intraocular pressure and vision

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SUMMARY In a survey of 426 patients of Toronto ophthalmologists the correlations of reported smoking habits with (1) intraocular pressure and (2) visual acuity were examined. Average tonometer readings were closely similar in smokers, ex-smokers, and non-smokers, and multiple regression analysis showed similar age coefficients for the 3 categories. However, in women (but not in men) there was also a significant coefficient related to total cigarette exposure (puff-pack-years). It is suggested that this was due to recent smoking rather than a permanent effect on tonometer pressures, pointing the need to standardise this aspect of ocular pressure measurements. Visual acuity showed similar age coefficients in smokers, ex-smokers, and non-smokers, with no independent effect of exposure to cigarette smoke.

Previous papers from our laboratories have noted direct and 'passive' effects of cigarette smoke exposure on the eye (Sebben *et al.*, 1977; Basu *et al.*, 1977; Shephard *et al.*, 1978). Reactions include irritation, with an immediate disturbance of vision (Shephard *et al.*, 1978), lacrimation (Shephard *et al.*, 1978), and a shortening of the time to break up of the tear film (Basu *et al.*, 1977). In other contexts it has been widely accepted that exposure to irritant gases can cause open-angle glaucoma (Duke-Elder and Jay, 1969), with both acute and more long-term increases of intraocular pressure (Ballantyne and Swanston, 1977; Ballantyne *et al.*, 1977).

The situation with regard to cigarette smoking is less clearly established. Mehra *et al.* (1976) reported an acute rise of intraocular pressure >0.67 kPa* (5 mmHg) in 11.4% of normal subjects and 37.1% of patients with primary glaucoma; measurements were made within 5 minutes of the last puff on a cigarette, and normal pressures were restored within 15 to 30 minutes. On the other hand Bahna and Bjerkedal (1948) found no relationship between

tonometer readings and reported smoking habits. Morgan and Drance (1975) also observed no association between smoking habits and the development of chronic open-angle glaucoma with associated optic disc change and field defects. However, in their study what was described as uncomplicated chronic glaucoma (ocular tension >2.79 kPa, 21 mmHg) was significantly associated with a high current cigarette consumption (more than 20 cigarettes a day).

The present report further examines the relationship of smoking habits to (1) intraocular pressures and (2) corrected vision.

Methods

The survey was conducted in co-operation with a number of ophthalmologists in Toronto who were measuring intraocular pressures as part of routine examinations of the visual system. A nurse attended the physicians' offices, soliciting volunteers, who completed a questionnaire on their smoking habits and visual reactions to cigarette smoke (Shephard *et al.*, 1978); they also agreed to release the data resulting from their ophthalmological examination.

A total of 426 adults over the age of 20 years were seen. After a standard clinical ophthalmological examination intraocular pressures were recorded by standard tonometric procedures, while visual acuity

*The kilopascal is the unit of pressure now recommended by the International Committee on the standardisation of units.

Table 1 *Reported current cigarette consumption of smokers, by age and sex*

Number of cigarettes per day	Men				Women			
	21-40 years (%)	41-60 years (%)	>60 years (%)	All ages (%)	21-40 years (%)	41-60 years (%)	>60 years (%)	All ages (%)
1-10	21.1	28.6	28.6	26.2	16.7	25.0	39.4	28.7
11-20	31.6	19.0	38.1	29.5	38.9	27.9	21.2	27.6
21-40	42.1	42.9	33.3	39.3	44.4	41.7	36.4	40.2
41 or more	5.3	9.5	—	4.9	—	5.6	3.0	3.4

Table 2 *Reported age of starting to smoke in relation to current consumption and to sex*

Number of cigarettes per day	Men					Women					
	Age of starting to smoke					Age of starting to smoke					
	1-12 years (%)	13-20 years (%)	21-40 years (%)	41-60 years (%)	All ages (%)	1-12 years (%)	13-20 years (%)	21-40 years (%)	41-60 years (%)	61 or more years (%)	All ages (%)
1-10	0	25.8	26.9	100.0	26.2	66.7	16.7	24.3	77.8	100.0	28.7
11-20	33.3	25.8	34.6	0	29.5	33.3	36.1	27.0	0	0	27.6
21-40	66.7	38.7	38.5	0	39.3	0	41.7	45.9	22.2	0	40.2
41 or more	0	9.7	0	0	4.9	0	5.6	2.7	0	0	3.4
Percentage of total sample	4.9	50.8	42.6	1.6	100.0	3.4	41.4	42.5	10.3	1.1	100.0

(corrected and uncorrected) was assessed by Snellen test charts.

Results

SUBJECTS AND SMOKING HABITS

Perhaps because the clinics were held during the daytime the sample included more women (269) than men (157); 89 subjects were aged 21 to 40 years, 167 were 41 to 60 years, and 170 were over the age of 60 years.

The proportion of current smokers (38.9% of the men, 32.3% of the women) was slightly lower than in previous Toronto (Shephard and LaBarre, 1978) and Provincial (Non-Medical Use of Drugs Directorate, 1976) samples, with 148 smokers (61 men, 87 women), 96 ex-smokers (50 men, 46 women), and 182 non-smokers (46 men, 136 women). The pattern of current cigarette usage (Table 1) was much as expected; probably for financial reasons there were somewhat fewer heavy smokers (more than 20 cigarettes a day) in people aged over 60 years.

The largest number of subjects had begun to smoke between 13 and 20 years of age (Table 2),

and this group seemed particularly vulnerable to a very high (more than 40 cigarettes a day) current consumption. Total cigarette exposure was calculated in terms of pack years and cigarette-puff years (puffs per cigarette $\times$ average daily consumption $\times$ 365 $\times$ years of smoking). The men tended to take more puffs per cigarette than the women (Table 3), average lifetime scores for the 2 groups being 2.45 and 1.46 million puffs respectively.

TONOMETRIC PRESSURES

Tonometric pressures conformed closely with previously reported data from other laboratories (Table 4). Values varied little with the reported cigarette consumption. If 2.8 kPa (21 mmHg) is taken as an upper limit of normality, this pressure was exceeded by 8 of 150 readings on smokers, 5 of 98 readings on ex-smokers, and 12 of 185 readings on non-smokers. However, in most of the smokers the excess pressure was small. Thus, if the limit of normality were extended to 2.1 kPa (22 mmHg), 2 of 150 smokers, 3 of 98 ex-smokers, and 10 of 185 non-smokers would have been regarded as abnormal.

When mean values were considered, there was a

suggestion of an increment of pressure in the heavy smokers, particularly the women. This trend was supported when data were classified in terms of the number of puffs per cigarette (Table 5).

To test the significance of this tendency, multiple regression equations were established relating tonometer pressure, T (mean of right and left, mmHg), to age, A (years), and total cigarette

Table 3 *Puffs per cigarette and total cigarette exposure (puffs per lifetime)*

Puffs per cigarette		Percent of sample	Total cigarette exposure (million puffs per lifetime)
Men	1-5	4.9	0.457
	6-10	42.6	1.984
	11-15	31.1	1.893
	16-20	19.7	4.632
	>20	1.7	5.183
Women	1-5	13.8	0.528
	6-10	47.1	0.909
	11-15	23.0	1.851
	16-20	14.9	3.112
	>20	1.2	6.027
Both sexes	1-5	10.1	0.514
	6-10	45.3	1.327
	11-15	26.4	1.871
	16-20	16.9	3.841
	>20	1.3	5.605

Table 5 *Intraocular pressure and puffs per cigarette. Mean $\pm$ SD*

Puffs per cigarette	Intraocular pressure			
	Right eye		Left eye	
	(mmHg)	(kPa)	(mmHg)	(kPa)
1-5 (n = 15)	14.7 $\pm$ 4.2	1.96	15.5 $\pm$ 3.9	2.06
6-10 (n = 64)	14.7 $\pm$ 3.4	1.96	14.7 $\pm$ 3.7	1.96
11-15 (n = 36)	15.0 $\pm$ 4.4	2.00	15.4 $\pm$ 4.3	2.05
16-20 (n = 23)	16.9 $\pm$ 3.1	2.25	16.8 $\pm$ 2.7	2.23
21 (n = 2)	17.3 $\pm$ 1.8	2.30	17.3 $\pm$ 1.8	2.30

exposure (pack years (PY) or puff-pack years (PPY); the significance of the 2 independent variables is shown in parenthesis:

Men and women

T = 0.076 (A) - 0.0013 (PY) + 11.46 (P < 0.005, NS)

T = 0.069 (A) - 0.0024 (PPY) + 11.58 (P < 0.008, NS)

Men

T = 0.141 (A) - 0.0352 (PY) + 9.61 (P < 0.009, NS)

T = 0.128 (A) - 0.0108 (PPY) + 10.00 (P < 0.018, NS)

Women

T = 0.071 (A) + 0.0268 (PY) + 10.83 (P < 0.031, NS)

T = 0.075 (A) + 0.0106 (PPY) + 10.58 (P < 0.021, 0.040)

The age effect was highly significant in all of these analyses, but after allowance for this variable the effects of cigarette exposure were relatively small, the one significant coefficient (P < 0.040) being for puff-pack years in the women.

The age coefficients for non-smokers (0.075 $\pm$

Table 4 *Mean tonometer pressures and cigarette smoking. Mean $\pm$ SD*

	Male				Female				Mean of right and left
	Right		Left		Right		Left		
	(mmHg)	(kPa)	(mmHg)	(kPa)	(mmHg)	(kPa)	(mmHg)	(kPa)	
Non-smokers	16.1	2.14	15.1	2.01	15.5	2.06	15.3	2.03	15.4 (n = 182)
Ex-smokers	15.6	2.07	16.1	2.14	15.1	2.01	15.2	2.02	15.3 (n = 96)
Smokers									
1-10/day	16.0±3.9	2.13	16.3±4.5	2.17	14.9±3.5	1.98	15.2±3.3	2.02	15.5 (n = 69)
11-20/day	13.1±2.7	1.74	13.8±2.8	1.84	15.0±3.3	2.00	15.2±3.7	2.02	14.4 (n = 40)
21-40/day	16.9±4.7	2.25	16.2±4.1	2.15	15.2±4.5	2.02	15.2±4.6	2.02	16.0 (n = 25)
41 or more	16.0±4.2	2.13	15.5±3.5	2.06	18.3±3.8	2.43	18.8±4.5	2.50	17.2 (n = 4)

Table 6 Visual acuity and cigarette consumption (% poor)*

	Uncorrected					Corrected				
	Male		Female		All subjects mean of	Male		Female		All subjects mean of
	Right	Left	Right	Left		Right	Left	Right	Left	
Non-smokers	70.6	80.4	73.5	54.3	66.8	54.3	54.3	54.4	53.7	54.2 (n = 182)
Ex-smokers	65.2	63.0	80.0	80.0	76.0	50.0	50.0	40.0	42.0	43.3 (n = 96)
Smokers										
1-10/day	88.9	81.5	83.0	85.1	84.5	33.3	25.9	34.0	40.4	34.4 (n = 67)
11-20/day	93.8	75.0	56.0	56.0	67.1	31.3	37.5	52.0	56.0	46.4 (n = 40)
21-40/day	81.3	81.3	61.5	69.2	74.2	43.8	62.5	30.8	46.2	46.6 (n = 25)
> 40	100.0	100.0	100.0	100.0	100.0	50.0	50.0	50.0	50.0	50.0 (n = 4)

*Poor is here defined as an acuity <10/20

Table 7 Visual acuity and puffs per cigarette (% of sample in each category)

Vision		Puffs per cigarette					
		1-5	6-10	11-15	16-20	>21	All categories
Uncorrected							
Right	Poor*	9.3	41.5	30.5	15.9	1.7	78.7 (n = 118)
	Normal	12.5	56.5	15.6	15.6	0	21.3 (n = 32)
Left	Poor	8.7	43.5	31.3	15.7	0.9	76.7 (n = 115)
	Normal	14.3	48.6	14.3	20.0	2.9	23.3 (n = 35)
Average right and left	Poor	9.0	42.5	30.9	16.3	1.4	77.7
	Normal	13.4	52.6	15.0	17.8	1.5	22.3
Corrected							
Right	Poor	12.1	44.8	20.7	20.7	1.7	38.7 (n = 58)
	Normal	8.7	44.6	31.5	14.1	1.1	61.3 (n = 92)
Left	Poor	12.1	50.0	16.7	18.2	3.0	44.0 (n = 66)
	Normal	8.3	40.5	35.7	15.5	0	56.0 (n = 84)
Average right and left	Poor	12.1	47.9	18.7	19.5	2.4	41.4
	Normal	8.5	42.6	33.6	14.8	0.6	58.7

*Poor is here defined as an acuity <10/20

0.027) and ex-smokers (0.115 ± 0.034) did not differ significantly from those for smokers.

VISUAL ACUITY

In view of the nature of our sample, most subjects had some impairment of visual acuity. Nevertheless, for purposes of statistical comparison it was possible to distinguish 2 categories—mild impairment (vision >10/20) and 'poor' vision (acuity <10/20). On this

criterion the uncorrected vision of the smokers (78.1% of the sample with 'poor' vision) was possibly ($0.2 > P > 0.1$) a little poorer than that of the non-smokers (66.8% of the sample with 'poor' vision). The corrected vision was poorer in the heavy than the light smokers (Table 6) but was at least equally poor in the non-smokers.

The gradient of visual acuity with cigarette exposure was also seen when results were classified

by puff frequency (Table 7). Those taking more than 10 puffs per cigarette included 48.5% of those with poor uncorrected vision but only 34.0% of those with normal vision. In terms of corrected vision the dividing line of 10 puffs per cigarette was less satisfactory, 40.0% of those with poor vision and 48.9% of those with normal vision exceeding this exposure. However, among those taking more than 15 puffs per cigarette were 21.3% of those with poor vision and only 15.3% of those with good vision.

Expressing the corrected visual acuity in digital terms ($20/20=1.0$)*, multiple regression equations were computed as follows:

Men and women

$$V = -0.0086 (A) - 0.006 (PY) + 1.25 (P < 0.001, NS)$$

$$V = -0.0089 (A) - 0.0001 (PPY) + 1.26 (P < 0.001, NS)$$

Men

$$V = -0.0100 (A) - 0.0005 (PY) + 1.34 (P < 0.001, NS)$$

$$V = -0.0115 (A) - 0.0001 (PPY) + 1.38 (P < 0.001, NS)$$

Women

$$V = -0.0069 (A) - 0.0001 (PY) + 1.14 (P < 0.001, NS)$$

$$V = -0.0069 (A) - 0.0001 (PPY) + 1.14 (P < 0.001, NS)$$

Again, the effect of age was highly significant, but after allowance for this variable the contribution of cigarette exposure was negligible, whether measured in pack years or puff-pack years. Age coefficients for ex-smokers (-0.0085 ± 0.0020) and non-smokers (-0.0099 ± 0.0013) were very similar to those for the smokers.

OVERT PATHOLOGY

Of the 148 smokers 1 had an overt cataract and 1 'vitreous floaters'. None of the 96 ex-smokers or 182 non-smokers had diagnoses related to glaucoma.

Discussion

TONOMETER PRESSURES

The present report supports the observations of Bahna and Bjerkedahl (1948) in showing almost identical mean intraocular pressures for non-smokers, ex-smokers, and smokers. However, the observations of Morgan and Drance (1975) are also substantiated in that (1) pressures are slightly higher in the small subgroup of subjects with a very high cigarette consumption, and (2) in women at least the multiple regression equation shows a significant effect of puff-pack years after allowance for the influence of age.

The average effect is of doubtful clinical signifi-

cance (a pressure increment of about 0.27 kPa (2 mmHg)), although in the worst case (consumption of 2 packs per day for 40 years, with 20 puffs per cigarette), the multiple regression equation suggests that the rise of pressure could amount to 2.1 kPa (16 mmHg). The apparently larger effect on women is in keeping with their greater susceptibility to glaucoma (Armaly, 1965), and the correlation with puff-pack years but not pack years also suggests a true pharmacological effect. However, there was not a fixed period of abstinence from cigarettes either in the present study or in that of Morgan and Drance (1975), and the distribution of the increased pressures ($6/8 < 2.9$ kPa (22 mmHg)) supports the working hypothesis that we are seeing a transient response to recent smoking rather than a permanent elevation of pressure. This points the need for regulation of recent smoking when recording intraocular pressures. In the absence of such controls it is probably incorrect to regard as suffering from chronic uncomplicated glaucoma a patient who is a heavy smoker and has a pressure only a few millimetres of mercury above the average reading for non-smokers.

VISUAL ACUITY

The suggestion of a deterioration in visual acuity with an increase of cigarette consumption was not confirmed by our multiple regression analyses. We must conclude that neither the potential corneal irritation and lacrimation nor the threat of glaucoma has any effect on the ability to read standard clinical test type.

No great significance can be attached to the fact that the 1 case of overt cataract and the 1 case with vitreous floaters were both smokers. Since glaucoma develops only in about 1 patient in 200 over the age of 40 years (Armaly, 1965; Hollands and Graham, 1966; Bankes *et al.*, 1968), a much larger sample would be needed to compare the incidence of pathological changes between smokers and non-smokers.

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*Transformation of visual acuity into standard decimal format (e.g., $10/20 = 0.5$) is a necessary preliminary to calculation of the multiple regression.

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