Effects of moderate smoking on the central visual field

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ABSTRACT.

Purpose: **To investigate whether moderate cigarette smoking has any effects on the central visual field.**

Methods: **This study included 30 healthy, moderate cigarette smokers (10–20 cigarettes per day for at least the past 5 years) and 22 healthy non-smokers. After two training test sessions, all individuals underwent computerized visual field examinations (Humphrey 30–2 Full Threshold Test) with both white-on-white (W-W) perimetry and blue-on-yellow (B-Y) perimetry. One eye of each subject with reliable visual field test results was evaluated. The foveal threshold, mean deviation (MD), pattern standard deviation (PSD), short-term fluctuation (SF), corrected pattern standard deviation (CPSD), glaucoma hemifield test (GHT) and number of significantly depressed points deviating at $p < 5\%$, $p < 2\%$, $p < 1\%$ and $p < 0.5\%$ on the pattern deviation probability map of the smokers were compared with those of the non-smokers.**

Results: **When the results of W-W perimetry were analysed, the smokers were found to have significantly lower foveal thresholds ($p = 0.001$) and mean retinal sensitivity ($p = 0.02$), and higher PSD ($p = 0.002$) and CPSD ($p = 0.01$) than the non-smokers. Short-term fluctuation was similar in both groups ($p = 0.55$). The number of significantly depressed points deviating at $p < 5\%$, $p < 2\%$ and $p < 1\%$ on the pattern deviation probability map was similar for both groups ($p > 0.05$). The number of depressed points deviating at $p < 0.5\%$ on the pattern deviation probability map was higher for the smokers than for the non-smokers ($p = 0.03$). The results of B-Y perimetry showed the smokers to have a significantly lower foveal threshold than the non-smokers ($p = 0.03$). However, there were no significant differences in the global indices of the two groups ($p > 0.05$). The number of significantly depressed points deviating at $p < 5\%$, $p < 2\%$, $p < 1\%$ and $p < 0.5\%$ on the pattern deviation probability map was similar in both groups ($p > 0.05$). No significant difference in GHT was determined with either perimetry for the smokers compared with the non-smokers ($p > 0.05$).**

Conclusion: **This study suggests that moderate cigarette smoking is associated with both diffuse and localized reductions in retinal sensitivity with W-W perimetry. Only reduction in the foveal threshold was observed with B-Y perimetry, with no hints of diffuse and localized reductions.**

Key words: moderate cigarette smoking – visual field – white-on-white perimetry – blue-on-yellow perimetry

Acta Ophthalmol. Scand. 2004: 82: 432–435

doi: 10.1111/j.1600-0420.2004.00301.x

Introduction

Cigarette smoking intensifies a variety of serious health problems, including cardiovascular, cerebral and respiratory tract diseases and malignancies (Fielding 1985). Toxic compounds in tobacco smoke also affect ocular tissues, mainly through ischaemic or oxidative mechanisms (Solberg et al. 1998). Some common eye diseases, such as cataract (Congdon 2001), age-related macular degeneration (Age-Related Eye Disease Study Research Group 2000; McCarty et al. 2001), retinal vein occlusion (Klein et al. 2000), anterior ischaemic optic neuropathy (Chung et al. 1994), thyroid ophthalmopathy (Shine et al. 1990), and primary open-angle glaucoma (Wilson et al. 1987; Wu & Leske 1997) have been found to be associated with cigarette smoking. Tobacco-alcohol optic neuropathy, a once common but now rare disease characterized by bilateral central visual disturbance, may occur as a result of direct toxic damage to the optic nerve, particularly in chronic heavy smokers (Potts 1973; Rizzo & Lessell 1993).

A recent study found diffusely decreased retinal sensitivity and peripheral scotomata in the visual fields of healthy heavy cigarette smokers (Hepsen & Evereklioglu 2001). Because the effects of smoking on ocular diseases are significantly dose-dependent, risks and morbidity increase in parallel with the increase in smoking index (Solberg et al. 1998). In this study, we investigated whether moderate cigarette smoking has any effects on the central visual field.

Material and Methods

Participants were recruited consecutively from among the volunteering relatives of patients visiting the Department of Ophthalmology, University of Kırıkkale, between January 1st, 2001, and June 30th, 2001. Smoking status and general health were recorded at interview. Thirty volunteers, who had smoked 10–20 cigarettes per day for at least the past 5 years, constituted the smoker group. Twenty-two healthy non-smokers served as the control group. The Ethics Committee of the hospital approved the study protocol and the participants gave written informed consent.

All participants underwent a thorough ophthalmic examination in a masked manner, including measurement of best corrected visual acuity, biomicroscopy, applanation tonometry, funduscopy and measurement of vitamin B12 and folic acid levels. Exclusion criteria included age older than 40 years, history of systemic diseases, family history of glaucoma, past visual field experiences, use of systemic or local medication, any neurological disorder, visual acuity (VA) worse than 20/20 with correction (-1 D to $+1$ D spherical equivalent), colour vision defects, intraocular pressure (IOP) greater than 21 mmHg, and abnormal vitamin B12 and folic acid levels. Previous or current serious eye disease or trauma, intraocular surgery, optic disc or retinal pathologies and corneal abnormalities were also considered reasons for exclusion. Particular attention was given to the clarity of optical media and subjects with yellowing of the lens were not included.

Both eyes were tested with the central 30–2 Full Threshold Program of the Humphrey Visual Field Analyzer II, model 750 (Humphrey Instruments, San Leandro, California, USA). The thresholds of 77 locations were determined within the central 30 degree field using a repeated, up and down staircase procedure with steps of 4 dB and 2 dB. After two training sessions with each test, all participants underwent white-on-white (W-W) perimetry (using the Goldmann size III stimulus) and blue-on-yellow (B-Y) perimetry (using the Goldmann size V stimulus). The testing order and the eye tested first were determined randomly. Each test was performed bilaterally in one session. Testing sessions were separated by at least 1 day and all tests were completed within 2 weeks. A minimum of 5 min was given to all subjects to adapt to the background luminance before each examination. Rest periods were given between the examination of each eye to minimize fatigue. During examination, fixation was constantly monitored by an experienced technician using the video monitor. The criteria for a reliable test were as follows: fixation loss less than 20%, false-positive rate less than 20%, false-negative rate less than 20%, and pupil diameter larger than 3 mm.

One eye of each participant was chosen for the current study, but if both eyes of the participant met the inclusion criteria, the eye with more reliable criteria was included in the study. Thus, this study was performed on 30 eyes of 30 moderate smokers and 22 eyes of 22 healthy non-smokers. Regarding interpretation of visual fields, foveal threshold, glaucoma hemifield test (GHT) and global indices, including mean deviation (MD), pattern standard deviation (PSD), short-term fluctuation (SF), and corrected pattern standard deviation (CPSD), were evaluated. Due to the frequent artifacts at the edges (Advanced Glaucoma Intervention Study Investigators 1994), the most peripheral points on a 30–2 visual field were excluded, evaluating the number of significantly depressed points deviating at $p < 5\%$, $p < 2\%$, $p < 1\%$ and $p < 0.5\%$ on the pattern deviation probability map. The Student's *t*-test was used for continuous measurements and the chi-square test or Fisher exact test were used for non-parametric values. A $p < 0.05$ was considered significant.

Results

There were no significant differences between the smokers and non-smokers regarding age ($p = 0.84$), sex ($p = 0.54$), mean IOP ($p = 0.51$), and pupil size ($p = 0.24$ for W-W perimetry and $p = 0.87$ for B-Y perimetry) (Table 1). The smokers had been smoking for 8.1 ± 2.2 years. The mean number of cigarettes smoked per day was 15.8 ± 4.6. Folic acid and vitamin B12 levels were within the reference ranges and were similar in both groups ($p = 0.68$ and $p = 0.88$, respectively) (Table 1).

The foveal thresholds and global perimetric indices are listed in Table 2. Analysis of the results of W-W perimetry showed that the smokers had significantly lower foveal thresholds ($p = 0.001$) and mean retinal sensitivity ($p = 0.02$), and higher PSD ($p = 0.002$) and CPSD ($p = 0.01$) than the non-smokers. Short-term fluctuations were similar in both groups ($p = 0.55$). Of the number of points on the pattern deviation probability map, the number of significantly depressed points deviating at $p < 5\%$, $p < 2\%$ and $p < 1\%$ were similar in both groups ($p = 0.46$, $p = 0.32$ and $p = 0.50$, respectively). The number of depressed points deviating at $p < 0.5\%$ on the pattern deviation probability map was higher in the smokers group than in the non-smokers group ($p = 0.03$) (Fig. 1). The comparison of GHT between the smokers and non-smokers was of no significance ($p = 0.22$). Using B-Y perimetry, the smokers had significantly lower foveal thresholds than the non-smokers ($p = 0.03$). There were no differences in the global indices (MD, PSD, SF and CPSD) between the two groups

Table 1. Characteristics of 30 moderate cigarette smokers and 22 non-smokers.*

	Smokers	Non-smokers	p-value
Age, years	32.7 ± 5.8	32.5 ± 5.4	0.84†
Sex, M : F	20 : 10	17 : 5	0.54‡
Intraocular pressure, mmHg	16.9 ± 2.2	16.5 ± 2.1	0.51†
Pupil size, mm			
W-W perimetry	5.1 ± 1.0	5.4 ± 1.1	0.24†
B-Y perimetry	4.6 ± 1.0	4.6 ± 1.3	0.87†
Vitamin B_{12}, pg/mL	345.2 ± 33.9	343.6 ± 36.5	0.88†
Folic acid, ng/mL	4.7 ± 1.6	4.9 ± 1.8	0.68†

M = male; F = female.
* Data are given as mean ± SD except where indicated otherwise.
† Student's *t*-test; ‡ chi-square test.

Table 2. Results of visual field examinations of moderate cigarette smokers ($n = 30$ eyes) and non-smokers ($n = 22$ eyes) using the Humphrey Central 30–2 Full Threshold Program.*

	Smokers	Non-smokers	p-value†
White-on-white perimetry			
Foveal threshold	30.7 ± 4.2	34.1 ± 2.8	0.001
MD	− 3.5 ± 2.4	− 2.1 ± 1.8	0.02
PSD	2.8 ± 1.0	2.1 ± 0.5	0.002
SF	1.6 ± 0.5	1.5 ± 0.6	0.55
CPSD	1.9 ± 1.3	1.0 ± 1.0	0.01
Blue-on-yellow perimetry			
Foveal threshold	22.2 ± 6.3	25.5 ± 4.0	0.03
MD	− 5.6 ± 5.2	− 4.7 ± 3.3	0.47
PSD	3.9 ± 1.6	4.6 ± 1.7	0.13
SF	2.3 ± 0.7	2.5 ± 1.1	0.42
CPSD	2.7 ± 2.2	2.9 ± 2.1	0.74

MD = mean deviation; PSD = pattern standard deviation; SF = short-term fluctuation; CPSD = corrected pattern standard deviation.
* Data are given as mean ± SD (dB).
† Student's *t*-test.

($p > 0.05$). The number of significantly depressed points deviating at $p < 5\%$, $p < 2\%$, $p < 1\%$ and $p < 0.5\%$ on the pattern deviation probability map was similar in both groups ($p > 0.05$). No significant difference was found in the GHT of the smokers compared with that of the non-smokers ($p = 0.67$).

Discussion

A recent study (Hepsen & Evereklioglu 2001) using W-W perimetry found significant changes in the visual fields of healthy chronic heavy smokers (more than 20 cigarettes per day for at least the last 10 years), including elevation in PSD and CPSD and a diffuse decline in retinal sensitivity. In addition, peripheral scotomata located between 20 degrees and 30 degrees were observed in all eyes.

In this study, we investigated whether moderate cigarette smoking had any effects on the central visual field using both W-W perimetry and B-Y perimetry. Using W-W perimetry, moderate smokers were found to have a significantly lower foveal threshold and more negative MD than non-smokers. Similarly, PSD and particularly CPSD, which reflect localized sensitivity loss, were significantly increased in the smokers compared with the non-smokers. Although similar equipment and examination methods were used in both studies, some differences between the visual fields of moderate and heavy smokers have been noticed (Hepsen & Evereklioglu 2001). The mean PSD and CPSD values were higher in heavy smokers than in moderate smokers in our study (3.99 dB versus 2.8 dB and 3.19 dB versus 1.9 dB, respectively). The difference is less apparent in the mean MD values (− 3.84 dB in heavy and − 3.5 dB in moderate smokers). These findings were in agreement with the peripheral localized defects observed in the heavy smokers.

Using B-Y perimetry, the foveal threshold was significantly lower in the smokers than in the non-smokers. However, no significant difference was found between smokers and non-smokers regarding both global indices and the number of significantly depressed points on the pattern deviation probability map. It is well known that B-Y perimetry identifies glaucomatous defects earlier and to a wider extent than W-W perimetry (Johnson et al. 1993; Wild 2001). Additionally, B-Y perimetry may determine the functional abnormality earlier than structuralabnormality of the optic nerve head or the retina (Wild 2001). On the other hand, B-Y perimetry has greater variability in the estimation of threshold and an additional learning effect compared to W-W perimetry (Wild 2001). It is well known that perimetric learning effects are clinically important and should be taken into consideration when assessing the visual field (Heijl & Bengtsson 1996). Therefore, in small cohorts of patients, the conclusions drawn from B-Y perimetry may be unconvincing when compared to those drawn from W-W perimetry. Thus, this may explain why we were unable to use B-Y perimetry to determine perimetric changes similar to those found with W-W perimetry.

Several studies have shown that cigarette smoking is a major risk factor in many vascular eye diseases, such as anterior ischaemic optic neuropathy, retinal vein occlusion, and age-related macular degeneration (Chung et al. 1994; Age-Related Eye Disease Study Research Group 2000; Klein et al. 2000; McCarty et al. 2001). Smoking may affect chorioretinal and optic nerve circulation by stimulating α-adrenergic vascular receptors (Cryer et al. 1976) or increasing production of vasoconstricting eicosanoids (Raij et al. 2001). It is well known that tobacco smoke increases the level of carbon monoxide, thereby reducing the oxygen-carrying capacity of haemoglobin, which, when associated with reduced blood flow, may reduce retinal oxygen delivery (Age-Related Eye Disease Study Research Group 2000). In addition, smoking increases the amount of free radicals while reducing antioxidants by increasing lipid peroxidation and oxidative stress (Morrow et al. 1995). All or some of these changes related to smoking may be responsible for the visual field abnormalities. Nevertheless, it is beyond the scope of this study to determine the mechanisms with which cigarette smoking affects retinal function.

In a study of B-Y perimetry, yellowing of the lens should be evaluated. An increased rate of yellowing of the lens has been reported in smoking patients (Congdon 2001). Yellowing of the lens could cause a reduction in sensitivity determined by B-Y perimetry. In the present study, all participants were younger than 40 years of age and subjects with yellowing of the lens were excluded from the study. Additionally, with B-Y perimetry, we showed that only the foveal threshold was significantly decreased in the smokers and not in the non-smokers, despite diffuse and localized reductions in retinal sensitivity with W-W perimetry. If these differences were due to yellowing of the lens, we could expect to observe a similar or greater decrease in sensitivity with B-Y perimetry.

In summary, this study suggests that moderate cigarette smoking is associated with both diffuse and localized

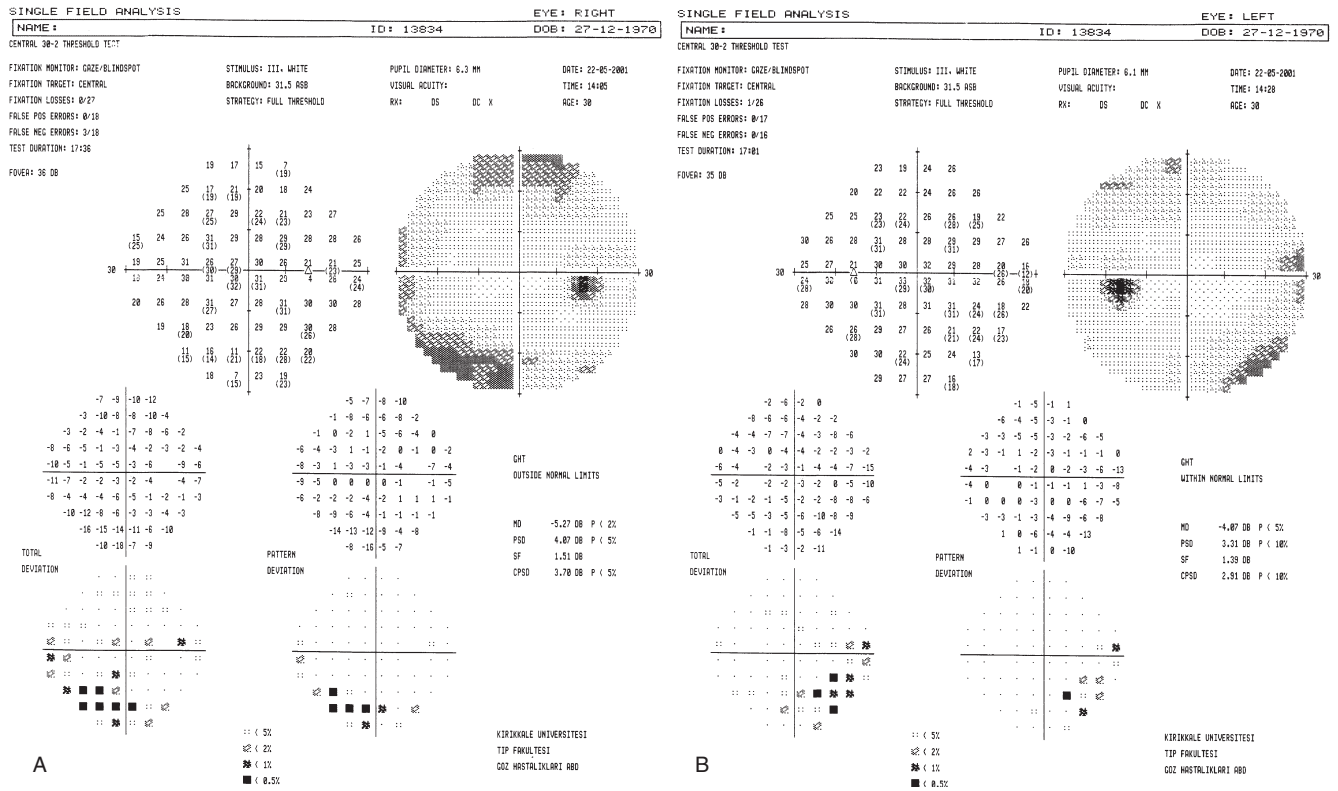

Fig. 1. (A, B) Central 30–2 visual field tests of a 30-year-old, healthy, moderate cigarette smoker using W-W perimetry. In both eyes, retinal sensitivity is generally reduced, and the defective points on the pattern deviation probability map depressed at $p < 0.5\%$ are grouped in the lower hemifield.

reductions in retinal sensitivity with W-W perimetry. With B-Y perimetry, only reduction in the foveal threshold is significant, whereas there are no hints of both diffuse and localized reductions in retinal sensitivity. We conclude that further evaluation is necessary to define the effects of cigarette smoking on B-Y perimetry.

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Received on October 7th, 2003.
Accepted on May 5th, 2004.

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