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BRIEF COMMUNICATION

Smoking Behavior in Low-Yield Cigarette Smokers and Switchers in the Natural Environment[1]

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KOLONEN, S., J. TUOMISTO, P. PUUSTINEN AND M. M. AIRAKSINEN. *Smoking behavior in low-yield cigarette smokers and switchers in the natural environment.* PHARMACOL BIOCHEM BEHAV **40**(1) 177–180, 1991.—Urinary cotinine and puffing parameters were studied in 36 smoking students. Three smoking groups, formed according to the tar content of their preferred cigarette, were compared. Eighteen students had always smoked low-yield, 10 medium-yield and 8 were switchers from medium- to low-yield cigarettes. The subjects smoked their preferred brand (the first week), low-yield cigarettes (the second week) and medium-yield cigarettes (the third week). Day urine samples were collected for cotinine analysis during the two last days of the test weeks. Puffing indices were reported on the last day of every test week with a portable microcomputer assisted analyzer with flowhead cigarette holder. Urinary cotinine concentrations were rather constant within the groups, but lower among the low-yield cigarette smokers as compared to the switchers ($p<0.05$). Also the female smokers had lower cotinine concentrations than the male smokers ($p<0.05$). The compensatory behavior seen in every smoking group while they were smoking low-yield cigarettes was based on up-regulation in single puff volume, puff duration and total smoking time when compared to values with medium-yield cigarettes. The correlation between cotinine concentration and diurnal puff volume (l/day) was poor. It is concluded that the benefit possibly gained with low-yield cigarettes is not long lasting.

Cigarette Smoking Nicotine Cotinine Puffing behavior Cigarette brands

LOW-TAR and nicotine cigarettes have gained popularity among smokers, partly due to the general assumption that switching to low-yield cigarettes will reduce the health hazards of smoking. However, several studies have suggested that the effect of smoke dilution techniques used in low-yield cigarettes is mainly eliminated by changes in smoking behavior. It was concluded in the U.S. Surgeon General's report (7) that switching to low-level brands might reduce the risk of smoking-related diseases only to the extent that the smoker does not compensate by changing the pattern in which the cigarette is smoked. In this study nicotine intake and puffing behavior were examined with low- and medium-yield cigarettes in three smoker groups. The novel aspects studied were: topographical features of smoking behavior in the natural environment and in smokers with different smoking histories.

METHOD

Subjects

Puffing behavior was measured in 36 smoking students who were divided into three groups according to their smoking history obtained from a questionnaire before recruiting them to the study. The first group consisted of 18 subjects who had always smoked low-tar/nicotine yield cigarettes, the second group consisted of 10 smokers of medium-tar/nicotine yield cigarettes and the third group of 8 switchers from medium- to low-yield cigarettes 2.8 ± 1.3 (range 1–5) years, previously. Mean smoking times were 3.9, 9.4 and 5.7 years respectively. Written informed consent was obtained after the nature of the procedures had been explained.

Study Procedure

Volunteers were investigated in three one-week smoking blocks. The subjects smoked, with no limits imposed, for the first week their preferred brand (own brand), the second week low-yield cigarettes (tar 5 mg, nicotine 0.4 mg) and the third week medium-yield cigarettes (tar 15, nicotine 0.9 mg). According to the instructions given at the beginning of the study, the volunteers were given permission to smoke as much as they wanted, but

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TABLE 1

CIGARETTE CONSUMPTION AND PUFFING BEHAVIOR IN SMOKING GROUPS DURING TEST DAYS WHEN ALL CIGARETTES WERE PUFFED THROUGH THE SMOKING DEVICE

	Smoker Group by Smoking History[a]		
	L-Y Smokers (n=18)	Switchers (n=8)	M-Y Smokers (n=10)
Cigarette Consumption per Day			
Preferred brand	9.1 ± 1.2	14.9 ± 3.4	9.3 ± 1.7
Low-tar cigarettes	9.0 ± 1.5	15.8 ± 3.7	8.3 ± 1.8
Medium-tar cigarettes	9.6 ± 2.0	14.2 ± 4.2	8.7 ± 1.7
Puff Duration (s)			
Preferred brand	2.6 ± 0.2	3.0 ± 0.3	2.6 ± 0.4
Low-yield cigarette	2.8 ± 0.2	3.0 ± 0.3	2.9 ± 0.3
Medium-yield cigarette	2.3 ± 0.2‡	2.5 ± 0.2†	2.5 ± 0.3†
Puff Volume (ml)			
Preferred brand	64.0 ± 7.2	55.8 ± 9.4	62.3 ± 13.1
Low-yield cigarette	67.0 ± 8.9	61.4 ± 7.9	76.9 ± 8.9
Medium-yield cigarette	54.2 ± 7.7‡	45.6 ± 5.2‡	64.6 ± 11.8†
Number of Puffs			
Preferred brand	16.8 ± 1.0	14.2 ± 1.2	14.0 ± 1.7
Low-yield cigarette	19.2 ± 1.1	17.5 ± 1.9	18.7 ± 2.4
Medium-yield cigarette	14.9 ± 0.8	14.5 ± 1.1	14.4 ± 1.5
Puff Volume/Cigarette (ml)			
Preferred brand	1045 ± 149	801 ± 81	740 ± 133
Low-yield cigarette	1194 ± 160	1094 ± 71	1231 ± 136
Medium-yield cigarette	754 ± 105‡	685 ± 65‡	832 ± 144‡
Puff Interval (s)			
Preferred brand	16.3 ± 1.5	17.0 ± 1.8	18.4 ± 2.4
Low-yield cigarette	16.8 ± 1.9	15.7 ± 1.7	15.4 ± 2.5
Medium-yield cigarette	16.8 ± 1.4	14.7 ± 1.7*	19.7 ± 2.3†
Total Smoking Time/Cigarette (s)			
Preferred brand	270 ± 15	277 ± 29	271 ± 37
Low-yield cigarette	315 ± 17	317 ± 22	281 ± 28
Medium-yield cigarette	244 ± 14‡	239 ± 24‡	264 ± 21*

Values are given as means ± SE. Number of subjects in parentheses, volunteers dropped out due to device error; L-Y Smokers: one with all brands, M-Y Smokers: one with the low-yield and two with the preferred brand. [a]Groups are formed by the habitual cigarette type smoked; L-Y Smokers = Low-yield cigarette smokers, M-Y Smokers = Medium-yield cigarette smokers, Switchers have changed their cigarette brand from medium- to low-yield cigarette. Significant differences in groups between low-yield and medium-yield cigarettes, so that *$p<0.05$, †$p<0.01$, ‡$p<0.001$ (Friedman ANOVA).

only the cigarettes selected for that week. Subjects were requested to smoke the cigarettes so that the butt length was the tip plus about 0.5 cm tobacco-containing rod. The number of cigarettes smoked on the preceding day was recorded every morning from their smoking diary. Diurnal puffing indices were recorded on the last day of every test week. Urine samples were collected over 24 hours so that the subjects started the test days by emptying their bladder at 0800. Urinary cotinine was analyzed with the HPLC-method previously described (4) with minor modifications in the extraction procedure.

A portable microcomputer-assisted flow transducer for measuring puff parameters of smokers was used (5). Cigarettes were smoked through a holder connected to a flowmeter unit which measured the following puff parameters: puffing rate, puff duration, number of puffs, puff interval, smoking time, puff volumes and the number of cigarettes smoked.

Statistical Analysis

Differences between groups were analyzed by the repeated measures analysis of variance (one- and two-way ANOVA) with post hoc comparisons by the Scheffé multiple comparison test. Differences within the three groups while smoking different test cigarettes were examined using the Friedman two-way analysis of variance by ranks followed with multiple comparisons between the smoking blocks. Linear association between groups was estimated by the Pearson's correlation coefficient with an indication of significance level (10).

RESULTS

Puff Parameters

Smokers in every group changed their smoking behavior in all parameters except for the number of cigarettes per day which

TABLE 2

URINARY COTININE CONCENTRATIONS (μg/ml) IN DIFFERENT SMOKING GROUPS WHEN PREFERRED BRAND, LOW-YIELD AND MEDIUM-YIELD CIGARETTES WERE SMOKED

	Smoker Type by the Smoking History[a]				
Cigarette	L-Y Smokers	Switchers	M-Y Smoker	F-Value*	Sig. Level
Preferred Brand					
1st day's urine†	1.07 ± 0.15	1.76 ± 0.21	1.29 ± 0.25	3.04	0.059
2nd day's urine	1.12 ± 0.14	1.45 ± 0.18	1.54 ± 0.24	1.77	0.186
Low-Yield Cigarette					
1st day's urine†	1.03 ± 0.12‡	1.87 ± 0.21	1.49 ± 0.29	4.88	0.014
2nd day's urine	0.90 ± 0.11‡	1.78 ± 0.35	1.33 ± 0.22	5.24	0.011
Medium-Yield Cigarette					
1st day's urine†	1.14 ± 0.17	1.97 ± 0.38	1.33 ± 0.21	3.02	0.061
2nd day's urine	1.23 ± 0.18	1.64 ± 0.25	1.51 ± 0.23	0.99	0.383

Values are given as means ± SE, Number of subjects in each group is same as in Table 1. [a]Groups are formed by the habitual cigarette type smoked; L-Y Smokers = Low-yield cigarette smokers, M-Y Smokers = Medium-yield cigarette smokers, Switchers have changed their cigarette brand from medium- to low-yield cigarette. *F-values and significance levels indicates difference between the three groups. †1st day's urine was taken before the device smoking day, the 2nd day's urine during it. ‡$p<0.025$ (ANOVA followed by the Scheffé test), differences between low-yield cigarette smokers and switchers groups.

was rather constant within each group (Table 1). When cigarettes were smoked with the smoking device, the number of cigarettes was reduced with all cigarette types, $F(2,31)=2.89$, $p=0.069$. All groups had highest puff volumes per day while smoking low-yield and lowest while smoking medium-yield cigarettes. Habitual low-yield cigarette smokers while switching from low-tar/nicotine brand to medium brand decreased their mean daily volumes from 12.2 ± 3.2 l to 7.2 ± 1.7 l ($\chi^2=7.60$, $p< 0.01$). Switchers had highest volumes per day of all with low-yield cigarettes (16.9 ± 3.8 l), but after switching to medium-yield cigarettes, their mean values fell to 9.1 ± 2.8 l ($\chi^2=12.25$, $p<0.001$). A similar trend ($\chi^2=3.43$, $p<0.05$) was observed among the habitual medium-yield cigarette smokers, while changing from the low- to the medium yield brand, volumes averaged 10.6 ± 2.5 l and 7.1 ± 1.7 l, respectively.

Individual puff parameters show the reasons for changes in diurnal puff volumes between smoking blocks (Table 1). Between smoking groups there were no significant differences in any parameters while being in the same smoking block (horizontal differences in Table 1).

Within the groups similar changes were observed in all parameters during switching of the cigarette type (vertical differences in Table 1). There was a decrease when switching to higher yield cigarettes. The difference in puff volume per cigarette in low- and medium-yield smoking blocks was statistically significant in all groups ($p<0.001$). The change in mean puff volume was 37% in low-yield cigarette smokers group ($\chi^2=26.13$), 37% among switchers ($\chi^2=10.75$) and 32% in medium-yield cigarette smokers group ($\chi^2=8.86$), while switching from low- to medium-yield brand. The difference was based mainly on the significant changes in single puff duration ($8.02<\chi^2<18.63$) and single puff volumes ($6.28<\chi^2<15.23$). Also total puff duration/cigarette ($9.00<\chi^2<20.93$) and smoking time ($3.71<\chi^2<14.80$) were significantly longer when low-yield cigarettes were being smoked.

Smoke Exposure by Urinary Cotinine Concentrations

There was a significant difference between groups but no significant difference within any group between the three smoking blocks tested. The urinary cotinine excretion (mg/24 h) among the low-yield cigarette smokers was significantly lower than among the switchers while smoking low brand through the smoking device, $F(2,31)=5.24$, $p<0.020$, or without it, $F(2,33)=4.87$, $p<0.025$. Results were consistent with the daily cotinine concentrations in urine (Table 2). The number of cigarettes smoked a day correlated strongly ($r>.85$, $p<0.001$) with smoking years in switchers and medium-yield cigarette smoker's groups during every smoking block but not in the low-yield cigarette smokers' group. The latter group had a good correlation between the number of cigarettes smoked and urinary cotinine concentrations while smoking their preferred brand ($r=.653$, $p<0.008$) and the medium-yield brand ($r=.485$, $p<0.008$). Urinary cotinine concentrations correlated well with total puff volume/cigarette ($r=.589$, $p<0.021$) and diurnal puff volume ($r=.741$, $p<0.020$) only in the low-yield cigarette smokers group while smoking their preferred brand.

Gender Effects on Puffing Behavior and Smoke Exposure

Also gender difference in cotinine excretion and total puff volume per day in smoking groups was analysed (gender × cigarette brand, two-way ANOVA). The only significant difference, $F(2,24)=4.77$, $p<0.025$, was found in cotinine concentrations which were lower in female subjects with preferred brand. When smoking groups were pooled, the trend that female subjects had lower cotinine excretions in urine became obvious. All the mean values of cotinine concentrations and diurnal puff volumes were lesser in the women than in the men but the only statistically significant difference, $F(1,28)=4.27$, $p<0.05$, was found with medium-yield test cigarettes.

DISCUSSION

Numerous experimental brand switching studies have been published, but few report on the puffing behavior of habitual low-yield cigarette smokers (2). Also puffing topography of smokers who have switched to a lower brand has been scarcely studied in a nonlaboratory environment (3). No significant change was found in cigarette consumption, while switching the ciga-

rette brands in controlled conditions, but individual and group variations were large. It has been reported in some brand switching studies that the cigarette consumption does not significantly differ from that with the subject's usual brand (11). On the other hand, the results of the present and our previous studies (4,5) suggest that the device smoking situation itself may decrease cigarette consumption and influence puffing behavior.

Puff parameters revealed that when habitual smokers of medium-yield cigarettes changed from their preferred to low brand they increased (up-regulation), as also reported previously, mean puff volume, and the number of puffs which also resulted an elevation in total puff volume per cigarette (2,11). Smokers in every group decreased puff volume (per cigarette or day) while switching from low- to medium-yield brand (down-regulation), the decrease was not proportional to the increase of nicotine yield in the cigarette. Diurnal puff volumes varied by cigarette type but there was no significant differences between smoking groups. While switching from low- to medium-yield test brand to low-yield cigarette smokers ($p<0.01$), switchers ($p<0.001$) and medium-yield cigarette smokers ($p<0.05$) decreased diurnal puff volume. As the results indicate smokers shorten the puff duration and also slightly decrease the number of puffs to down-regulate their puffing behavior.

Urinary cotinine excretion in smokers of the medium-yield cigarettes were consistent with the earlier report where the cigarette was switched in test conditions to a lower yield brand (6). However, relatively short-term laboratory studies have shown that smokers switching to low-tar and nicotine cigarettes or inhaling diluted smoke, do not completely compensate for the reduction in nicotine. Results of cotinine excretion in the switchers' group were in line with earlier reports which have shown that long-term switchers have no significant decrease in plasma and urine cotinine and nicotine (7,8). The lower 24-h cotinine urinary excretion in the habitual low-yield cigarette smokers than in the switchers, may be due to a shorter, $F(2,33)=5.19$, $p<0.025$, smoking history of low-yield cigarette smokers. The results of the group are in accordance with the previously cited long-term switching studies (2). One natural reason for this phenomenon is development of tolerance to nicotine and other substances but probably adaptation to the taste of smoke may also cause higher exposure levels in smokers with increasing smoking years.

Changes in puff volume do not explain entirely the stability of nicotine exposure in these groups. There were poor correlations between cotinine concentration in urine and diurnal puff volume in all groups. The only significant correlation was found in low-yield smokers group while smoking their preferred cigarette ($r=.741$, $p<0.02$). The poor correlation between the abovementioned indices and negligible change in cigarette consumption while switching brand suggests that experienced smokers probably inhale more smoke into their lungs than low-yield smokers. It has been reported previously that smokers change their inhalation grade while switching to a lower brand (9). Because of filter ventilation technique, some smokers probably block ventilation holes with their lips or fingers (7,8). In the present study, however, the construction of the cigarette holder meant that blocking of ventilation holes was very difficult.

An order effect of the cigarette type on smoking behavior when test cigarettes were smoked was not controlled with group arrangements in this study. Our previous studies (4,6), which were carried out with cross-over study design, suggest that any order effect is negligible and, therefore, it was not guarded so strictly in this experiment. There might be also some substantial difference caused by the gender of volunteers. Subjects participating this study were in all groups predominantly (62–72%) women. In spite of smaller number of the male subjects results gave a trend that women probably have lower exposure levels of nicotine than men. It has been pointed out by serum cotinine measurements that nicotine exposure levels seem to be significantly higher among men than women (1).

The results of the present study agree well with the nicotine titration hypothesis. It is apparent that smokers in every group changed their puffing behavior to compensate for lower delivery. However, the change was not proportional to cigarette nicotine yields suggesting a role of the inhalation level in compensation behavior. Urinary cotinine measurements indicated that smokers of medium-yield cigarettes regulate nicotine intake completely, but the nicotine exposure in inexperienced smokers of low-yield cigarettes was significantly lower, probably due to their short smoking history. The results also suggest that nicotine exposure is lower in the female than the male persons. It is concluded that the advantage to start smoking with low-yield cigarettes does not give any long lasting benefit over higher yield products, and for experienced smokers, switching to lower brand is virtually worthless.

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