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Effect of Filter Vent Blocking on Carbon Monoxide Exposure From Selected Lower Tar Cigarette Brands

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SWEENEY, C. T., L. T. KOZLOWSKI AND P. PARSA. *Effect of filter vent blocking on carbon monoxide exposure from selected lower tar cigarettes brands.* PHARMACOL BIOCHEM BEHAV **63**(1) 167–173, 1999.—Two studies were conducted to determine the effect of blocking filter vents on carbon monoxide (CO) exposure under ad lib smoking conditions. In Study 1, 12 daily cigarette smokers smoked cigarettes from the brands Now® (1 mg tar by the FTC Method) and Marlboro Lights® (10 mg tar) under each of two vent-blocking conditions (unblocked and finger blocked). Blocking filter vents with fingers led to an 85% increase in CO for the brand Now, but had no added effect on CO exposure from the Marlboro Lights. In Study 2, another 12 daily cigarette smokers smoked cigarettes from each of four additional brands: Carlton® (1 mg tar), Now (2 mg tar), Virginia Slims Ultra-lights® (5 mg tar), and Virginia Slims Lights® (8 mg tar). Blocking filter vents with the lips caused all four brands to produce equal CO exposures. Blocking vents increased smokers' exposure to CO by 239% when smoking Carltons and by 44% when smoking Nows. No significant increases in CO with blocking were found for either of the Virginia Slims brands. These results suggest that the degree to which a brand is ventilated determines whether that brand is susceptible to increased CO yields as a result of vent blocking. © 1999 Elsevier Science Inc.

Cigarettes Smoking Carbon monoxide Filter ventilation Vent blocking Low-yield cigarettes

ULTRA-LIGHT [about 1–5 mg tar by the Federal Trade Commission (FTC) method (4)] and Light (about 6–15 mg tar) cigarettes can achieve their lower tar, nicotine, and carbon monoxide (CO) yields during standardized smoking machine tests by means of air dilution vents on the filters (3,12,18). It is easy for smokers to "block" these vents with their lips or fingers, thereby compromising this air dilution effect (9,13). Using an unobtrusive indicator of vent blocking, one study found that 58% of 135 cigarette filters from various ultralight brands (4 mg tar or less) gave evidence of at least some vent blocking (11). Using similar procedures, another study found evidence of vent blocking in 53% of 158 filters of Light brands that were collected (10). One study from the tobacco industry estimated that 45% of smokers when smoking an Ultra-light brand (2.2 mg tar) blocked filter vents to some degree with the lips (1).

Smoking machine estimates used to simulate the effect of vent blocking on smoke exposure have demonstrated that yields of tar, nicotine, and CO increase dramatically when filter vents on heavily ventilated cigarettes are blocked (12,16). The first study to systematically evaluate the effect of vent blocking on smoke exposure in human smokers found that blocking 0, 50, and 100% of the filter vents on a 1-mg tar cigarette with tape, while holding all other smoking parameters as constant as possible, increased CO exposure in a monotonic manner (21). A study of behavioral vent blocking showed that blocking filter vents with lips more than doubled the CO exposure from a 1-mg tar brand (13). More popular cigarette brands in the United States, such as the best-selling "Light" brands (14) (e.g., Marlboro Lights®, Camel Lights®, Winston Lights®), also have ventilated filters. A recent study examining the effect of vent blocking on CO exposure with the best-selling cigarette brand, Marlboro Lights, found no difference in exposure when filter vents were either unblocked, blocked with fingers, blocked with lips, or blocked with tape (19).

Puff number, puff duration, and puff interval were all controlled in these studies. Only two studies to date have examined the effect of vent blocking under more naturalistic conditions when puffing parameters are free to vary (9,21). Participants had greater smoke exposure when smoking vent-

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blocked as compared with unblocked cigarettes. The present study extends vent blocking research by examining under ad lib conditions the effects of a behavioral vent-blocking maneuver on smoke exposure and puff number with both an Ultra-light and a Light cigarette brand.

STUDY 1: METHOD

Participants

Twelve cigarette smokers (six women and six men) were recruited through announcements posted on University bulletin boards and a television advertisement on a government education access channel. The average participant was 22 years old (range 19–33, SD = 4.0), smoked 22 cigarettes per day (range 15–30, SD = 5.3), and had been smoking regularly for 6.1 years (range 4–20, SD = 4.4). Two participants reported their usual brand as being Marlboro Full Flavor®, four Marlboro Lights, one Marlboro Medium®, one Camel Full Flavor®, three Camel Lights®, and one Parliament®.

Cigarettes

During the session participants smoked both Marlboro Light and Now® cigarettes (see Table 1). Participants smoked mentholated cigarettes if their usual brand was mentholated and nonmentholated cigarettes if their usual brand was nonmentholated. Two participants smoked mentholated cigarettes.

Procedure

Participants were initially screened through a brief telephone interview. Meeting times were arranged. Eligible participants were daily smokers of at least 15 cigarettes per day who were also at least 18 years of age and had been smoking regularly for at least 4 years. Each participant was scheduled for one session lasting approximately 2.5 to 3.0 h. Participants were instructed to maintain their normal smoking patterns prior to the session.

The following two vent-blocking conditions were studied using both cigarette brands for a total of four experimental conditions): (a) 0% of the filter vents were blocked (i.e., unaltered cigarettes were used); and (b) as many vents as possible were blocked with the participant's fingers (i.e., participants were instructed to hold the cigarette between their thumb and forefinger when taking a puff, covering as many of the vents as possible). A red marking was drawn on the filter of each cigarette to indicate the location of the filter vents.

Each session was held in a room containing a one-way mirror through which the investigator could observe the subjects smoking from an adjoining room. During each session the participants were instructed to smoke each cigarette as they wished (i.e., puff and inhalation parameters were free to vary) while making sure to follow the proper vent-blocking manipulation (i.e., either covering the filter vents with their fingers, or leaving the filter vents uncovered). They were then left alone to smoke each of the four cigarettes. Thirty minutes elapsed between the last puff under one experimental condition and the first puff under the next experimental condition. Order of presentation of the four conditions was balanced for the 12 participants using an orthogonal Latin square design (6). All participants were paid $15.00 at the conclusion of the session.

Measurement Procedures

CO boost measure. Two expired-air CO samples were collected from each participant immediately prior to smoking a cigarette under each of the four experimental conditions using a Vitalograph® BreathCO machine (Model No. 29.700; McNeil International, Inc., Lenexa, KS). Participants were instructed to 1) inhale deeply, 2) place a pair of disposable nose clips on their nose, 3) hold their breath for 15 s, and 4) exhale slowly and steadily through a disposable cardboard mouthpiece for 15 s. The highest CO reading in parts per million (ppm) was then taken from the digital display. If the two readings were highly discrepant (i.e., greater than 5 ppm), a third CO sample was collected.

The two expired-air CO samples collected prior to smoking each cigarette under each experimental condition were averaged to obtain the mean precigarette CO. (If three CO samples were collected, the two most similar values were averaged to obtain the mean precigarette CO). Exactly 2 min after the last puff was taken from each cigarette, the first of two additional expired-air CO samples were collected. Again, a third

TABLE 1
BRANDS BY TAR, NICOTINE AND CARBON MONOXIDE (CO) YIELDS* AND BY PERCENTAGE OF FILTER VENTILATION

Brand†	Tar (mg)	Nicotine (mg)	CO (mg)	Percent ventilation ± SEM‡
Study 1				
Now 85 SP	1	0.1	2	—§
Marlboro L 85 SP	10	0.8	11	22.5 ± 0.60
Study 2				
Carlton 100 HP	1	0.1	1	82.5 ± 0.29
Now 100 SP	2	0.2	3	66.3 ± 0.59
Virginia Slims UL 100 HP	5	0.5	6	55.6 ± 0.72
Virginia Slims L 100 HP	8	0.7	9	39.7 ± 0.46

*Source: (4).
†HP = hard pack; SP = soft pack; UL = Ultra-light; L = Light; 85 and 100 refer to mm.
‡Source: (3).
§Measurement not available, estimated at about 66%, based on Now 100 values.

CO sample was taken if the first two readings were highly discrepant. These two values were averaged to obtain the mean postcigarette CO. (If three CO samples were collected, the two most similar values were averaged to obtain the mean postcigarette CO). The CO boost measure was calculated as the difference between the mean postcigarette CO and the mean precigarette CO.

Subjective reports. Immediately following the last puff from each cigarette, participants were asked to rate six characteristics of the cigarette using a 100-mm visual analog scale. The characteristics rated were strength ("very weak"/"very strong"), harshness ("very mild"/"very harsh"), heat ("no heat"/"very hot"), draw ("easy"/"hard"), taste ("very bad"/ "very good"), and satisfaction derived from smoking ("very unsatisfying"/"very satisfying").

Puff number. The number of puffs taken on each cigarette was recorded by the experimenter who observed the participants from an adjoining room.

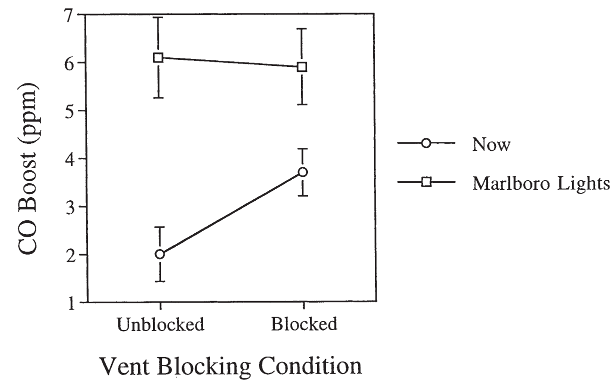

FIG. 1. Mean CO boosts with standard errors for both Nows and Marlboro Lights under both blocking conditions.

Data Analysis

Effects of vent blocking on CO boost, puff number, and six ratings of cigarette characteristics were assessed using a 2 × 2 (brand × blocking) analysis of variance (ANOVA) with repeated measures on both factors. "Brand" refers to Nows and Marlboro Lights. "Blocking" refers to the unblocked and finger-blocked manipulations. To determine whether the results replicate findings from previous studies using controlled smoking conditions (13,19) the key analyses are those assessing the significance of the interaction between the two repeated factors. It was hypothesized that blocked Nows would have a significantly higher CO boost than unblocked Nows. It was further hypothesized that there would be no significant difference in CO boost between unblocked and blocked Marlboro Lights. With respect to cigarette characteristics, post hoc comparisons were done when warranted by significant interaction effects, using an adjusted Bonferroni alpha level to help control for the increased probability of type I errors as a result of multiple testing (7). The adjusted significance level for each individual pairwise comparison was calculated as alpha = 0.01.

To deal with the nonnormal distribution of the error terms, a logarithmic transformation was used [log (1+X)]. To perform this transformation, however, it was first necessary to add 3 ppm to each of the CO boost scores for all 12 participants to deal with a negative boost score for one participant when smoking the unblocked Now.

STUDY 1: RESULTS

Biological Exposure Measure

Baseline CO levels (i.e., expired-air CO scores at the start of each session, prior to smoking any cigarettes) ranged from 3.0 ppm to 49.0 ppm for the 12 participants (mean = 22.0; SD = 13.9).

Figure 1 shows the mean CO boosts with standard errors for both brands under both blocking conditions. Mean CO boosts were 2.0 ppm (SE = 0.57), 3.7 ppm (SE = 0.49), 6.1 ppm (SE = 0.84), and 5.9 ppm (SE = 0.79) for the unblocked Nows, blocked Nows, unblocked Marlboro Lights, and blocked Marlboro Lights, respectively.

The "brand" × "blocking" interaction had a statistically reliable effect on CO boost, $F(1, 11) = 5.4$, $p = 0.04$. Analysis of simple effects revealed that the CO boost from the blocked Now was significantly higher than the boost from the unblocked Now, $F(1, 11) = 9.8$, $p = 0.009$. The CO boosts from the blocked and unblocked Marlboro Lights were not significantly different.

Puff Number

Mean puff numbers for the unblocked Nows, blocked Nows, unblocked Marlboro Lights, and blocked Marlboro Lights were 14.6 (SE = 2.1), 13.5 (SE = 1.8), 17.2 (SE = 3.3), and 15.7 (SE = 2.4), respectively. A logarithmic transformation was again done. Subjects took significantly more puffs from the Marlboro Lights than from the Nows, regardless of vent blocking condition, $F(1, 11) = 14.2$, $p = 0.0031$. Neither the blocking main effect nor the interaction effect achieved statistical significance.

Subjective Report Measures

The "brand" main effect was significant with respect to cigarette strength, with the Marlboro Lights rated as being significantly stronger than the Nows, $F(1, 11) = 27.0$, $p = 0.0003$. Both the blocking main effect and the interaction effect approached, but did not reach statistical significance at $F(1, 11) = 4.6$, $p = 0.05$, and $F(1, 11) = 4.1$, $p = 0.07$, respectively. Blocked cigarettes were rated as being significantly harsher than unblocked cigarettes, $F(1, 11) = 14.9$, $p = 0.003$. There was also a trend for Marlboro Lights to be rated as harsher than Nows, but this trend did not achieve statistical significance, $F(1, 11) = 3.9$, $p = 0.07$. The interaction effect was not significant for perceived harshness.

Marlboro Lights were also rated as being significantly hotter than the Nows, $F(1, 11) = 8.1$, $p = 0.02$. Neither the "blocking" main effect nor the interaction effect achieved statistical significance. No significant main effects or interactions were obtained for ratings of cigarette draw.

Marlboro Lights were rated as tasting significantly better than the Nows, $F(1, 11) = 8.1$, $p = 0.02$. Also, unblocked cigarettes were rated as tasting significantly better than blocked cigarettes, $F(1, 11) = 10.0$, $p = 0.009$. The interaction effect was not statistically significant.

Analyses of cigarette satisfaction revealed a significant "brand"× "blocking" interaction effect, $F(1, 11) = 5.5$, $p = 0.04$. The blocked Nows were rated as being significantly more satisfying than the unblocked Nows, $F(1, 11) = 5.8$, $p = 0.03$. There was no perceived difference in satisfaction between the unblocked and blocked Marlboro Lights.

STUDY 1: DISCUSSION

These results obtained under ad lib smoking conditions are very similar to those previously obtained under controlled smoking conditions. Blocking approximately half the filter vents with fingers on the Ultra-light cigarette brand Now led to almost a doubling (an 85% increase) of exposure to CO. In a previous study using the same vent blocking manipulation (i.e., finger blocking) a 93% increase in CO exposure due to vent blocking was observed for participants also smoking the brand Now (19). The slight attenuation in the increase in CO boost from the previous study to the present study is likely due to our participants' unrestricted puffing.

The results replicate the earlier finding (19) that blocking vents on Marlboro Lights has no effect on CO exposure. Although CO exposure levels were increased with the brand Now as a result of vent blocking, they were still less than those obtained with the Marlboro Lights. However, it should be emphasized that this study examined exposure to CO on a per-cigarette basis. Smokers could significantly enhance their exposure by simply increasing the number of cigarettes smoked, for example.

STUDY 2

The purpose of Study 2 was to examine using additional cigarette brands the effects of vent blocking on smoke exposure, cigarette characteristics, and puff number under ad lib smoking conditions. Brands of varying ventilation levels and standard tar yields were used, allowing for a more specific examination of the influence of degree of filter ventilation on the effects of vent blocking. We wanted to examine whether brands within the Ultra-light tar yield category behave similarly with respect to the influence of vent blocking on smoke exposure. We also wanted to explore whether the effects of vent blocking on CO exposure are negligible for all "Light" cigarette brands, or whether a heavily ventilated "Light" brand would also be subject to increased yields as a result of vent blocking.

The experience of the prior study suggested some procedural refinements. For example, in Study 1 participants were allowed to maintain their normal smoking patterns prior to an experimental session. A participant could therefore have conceivably had a cigarette just minutes before an experimental session. In Study 2, participants were instructed to not smoke any cigarettes from the time they awoke until the time of their session. A second procedural refinement was the inclusion of an orientation session, the primary purpose of which was to familiarize participants with the expired-air measurement procedure prior to any experimental sessions. It was hoped that the incorporation of this training session into the experimental protocol would reduce error variance.

STUDY 2: METHOD

Participants

Twelve female cigarette smokers were recruited through newspaper advertisements, fliers posted on University bulletin boards, and a television advertisement on a government education access channel. The average participant was 23 years old (range 18–50, SD = 9.0), smoked 20 cigarettes per day (range 15–35, SD = 6.0), and had been smoking regularly for 6.7 years (range 3–30, SD = 7.4). Seven participants reported their usual brand as being Marlboro Lights, two Camel Lights, two Parliament Lights, and one Virginia Slims Lights.

Cigarettes

During each of four experimental sessions participants smoked four cigarettes. On two of the session days participants smoked Carltons and Nows for their first two cigarettes of the session. On the other two session days participants smoked Virginia Slims Ultra-Lights and Virginia Slims Lights for their first two cigarettes of the session. The third and fourth cigarettes smoked during each session were generated for a supplemental study examining the validity of the stain pattern technique for detecting vent blocking. Table 1 shows both the filter ventilation levels and the standard tar, nicotine, and CO yields for each of the four brands used for purposes of this study. For each of the four cigarette brands, the 100-mm variety of the brand was used.

Procedure

Initial telephone contact. Participants were initially screened through a brief telephone interview. Those eligible for the study scheduled a date and time for an initial orientation session. Eligible participants were: 1) 18 years of age or older; 2) smoking 15 or more cigarettes per day; 3) smoking daily for at least 3 consecutive years; 4) not attempting to quit or reduce their smoking during the time of the study; 5) normally smoking an "Ultra-light" or a "Light" cigarette brand; 6) not using any other tobacco products; and 7) not smoking a mentholated cigarette brand as their usual brand. All participants were instructed to bring a pack of their usual brand of cigarettes with them to the orientation session. They were also instructed to maintain their normal smoking behavior prior to the orientation session.

Orientation session. Two expired-air CO measures were first collected using the same procedures as described in Study 1. Participants were then asked to smoke one of their usual brand of cigarettes. Two minutes after the final puff was taken two additional CO measures were collected. In addition to serving to verify smoke inhalation, the orientation session also allowed participants to become comfortable with the CO measurement procedure. At the conclusion of the orientation session participants scheduled dates and times for the four remaining experimental sessions. Each participant was instructed to not smoke any cigarettes from the time they awoke on each of the four session days. They were also informed that their abstinence would be verified by a CO measure at the start of each experimental session.

Experimental session. Each of the four 75-min experimental sessions was held any time after 1100 h on any day of the week. Each session was held in a room containing a one-way mirror through which videotaped observations took place from an adjoining room. The participants were instructed to smoke each cigarette as they wished (i.e., puff and inhalation parameters were free to vary) while making sure to follow the proper vent-blocking manipulation.

On two of the session days, participants were instructed to smoke both cigarettes in such a way that they did not cover the ventilation holes with their lips or fingers when taking a puff (i.e., the "unblocked" manipulation). On the other two session days participants were instructed to place both cigarettes as far into their mouth as necessary to cover the ventilation holes with their lips (i.e., the "blocked" manipulation). A red marking was drawn on the filter of each cigarette to indicate the location of the filter vents. Twenty minutes elapsed between the last puff from the first cigarette and the first puff from the second cigarette of each session. The order of presentation of the conditions over each of the four sessions was balanced for the subjects using an orthogonal Latin square design (6). After completion of the fourth and final session, participants received $40.00 for their participation.

Measurement Procedures

CO boost measure. CO boost measures were calculated exactly as in Study 1.

Subjective reports. Immediately following both the third puff and the final puff from each cigarette, participants were asked to rate four characteristics of the cigarette using a 100-mm visual analog scale. The characteristics rated were strength ("very weak"/"very strong"), harshness ("very mild"/"very harsh"), heat ("no heat"/"very hot"), and satisfaction derived from smoking ("very unsatisfying"/"very satisfying").

Puff number. The number of puffs taken on each cigarette was videotaped and recorded by the experimenter who observed the participants smoking from an adjoining room.

Data Analysis

Effects of vent blocking on CO boost and puff number were assessed using a 4 × 2 (brand × blocking) ANOVA with repeated measures on both factors. Brand refers to the following four cigarette brands: Carlton, Now, Virginia Slims Ultra-lights (VSUL), and Virginia Slims Lights (VSL). Blocking refers to the unblocked and lip-blocked manipulations.

Effects of vent blocking on four ratings of cigarette characteristics were assessed using a 4× 2 × 2 (brand × blocking × puff) ANOVA with repeated measures on all three factors. The variable puff refers to measures taken both after the third puff and after the final puff.

STUDY 2: RESULTS

Biological Exposure Measure

Average baseline CO levels (i.e., expired-air CO score at the start of each session, prior to smoking any cigarettes) were 7.7 ppm (SD = 3.9) for session 1 , 8.3 ppm (SD = 4.6) for session 2, 8.0 ppm (SD = 3.6) for session 3, and 7.0 ppm (SD = 3.6) for session 4.

Figure 2 shows the mean CO boosts with standard errors for all four brands of cigarettes under both blocking conditions.

Mean CO boosts were 1.8 ppm (SE = 0.41) and 6.1 ppm (SE = 0.86) for unblocked and blocked Carltons, respectively; 3.9 ppm (SE = 0.68) and 5.6 ppm (SE = 0.74) for unblocked and blocked Nows, respectively; 5.0 ppm (SE = 0.89) and 5.8 ppm (SE = 0.69) for unblocked and blocked Virginia Slims Ultra-lights, respectively; and 5.5 ppm (SE = 0.82) and 5.9 ppm (SE = 0.95) for unblocked and blocked Virginia Slims Lights, respectively.

Analyses revealed a significant "brand" × "blocking" interaction effect, $F(3, 9) = 11.8$, $p = 0.0018$. Analysis of simple effects showed that the CO boost from the blocked Carltons was significantly higher than the boost from the unblocked Carltons, $F(1, 11) = 64.0$, $p = 0.0001$. Blocking filter vents also resulted in a significantly higher CO boost for the brand Now, $F(1, 11) = 10.3$, $p = 0.0075$. Blocking filter vents did not significantly increase CO boosts scores above those obtained with unblocked filter vents for either Virginia Slims Ultra-lights or Virginia Slims Lights.

Puff Number

Mean puff numbers were 14.3 (SE = 2.1) and 9.9 (SE = 1.1) for unblocked and blocked Carltons, respectively; 12.9

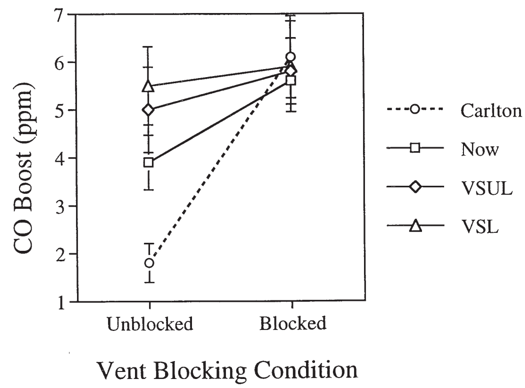

FIG. 2. Mean CO boosts with standard errors for all four brands of cigarettes under both blocking conditions.

(SE = 1.7) and 10.1 (SE = 1.3) for unblocked and blocked Nows, respectively; 14.4 (SE = 1.9) and 11.5 (SE = 1.4) for unblocked and blocked Virginia Slims Ultra-lights, respectively; and 13.4 (SE = 1.6) and 11.5 (SE = 1.6) for unblocked and blocked Virginia Slims Lights, respectively. Participants took significantly more puffs from cigarettes with unblocked filter vents than from cigarettes with blocked filter vents, $F(1, 11) = 17.2$, $p = 0.0016$.

Subjective Report Measures

A significant "brand" × "blocking" interaction effect was obtained for perceived strength, $F(3, 33) = 4.9$, $p = 0.02$. Analysis of simple effects showed that blocking vents significantly increased the perceived strength of both Carltons, $F(1, 11) = 32.3$, $p = 0.0001$, and Nows, $F(1, 11) = 8.9$, $p = 0.0117$. There was no perceived difference in strength, however, between unblocked and blocked Virginia Slims Ultra-lights, or unblocked and blocked Virginia Slims Lights. A significant puff main effect was obtained, with ratings of cigarette strength being higher after the final puff than after the third puff, $F(1, 11) = 7.8$, $p = 0.02$.

A significant brand effect was obtained for perceived harshness, $F(3, 33) = 6.3$, $p = 0.0039$, with the brand Now being rated as significantly harsher than the combination of each of the three other brands, $F(1, 11) = 17.4$, $p = 0.0006$. Also, cigarettes with blocked filter vents were rated as being significantly harsher than cigarettes with unblocked filter vents, $F(1, 11) = 17.8$, $p = 0.0014$. Ratings of cigarette harshness were also significantly higher after the final puff than after the third puff, $F(1, 11) = 8.1$, $p = 0.02$. No significant interaction effects were obtained.

Analyses revealed that cigarettes with blocked filter vents were rated as being significantly hotter than cigarettes with unblocked filter vents, $F(1, 11) = 6.3$, $p = 0.03$. Also, cigarettes were rated as being significantly hotter after the final puff than after the third puff, $F(1, 11) = 8.1$, $p = 0.02$. No significant brand main effect or interaction effects were obtained.

Analyses revealed a significant "brand" × "blocking" interaction effect for perceived satisfaction, $F(3, 33) = 7.5$, $p = 0.0022$. Carltons with blocked filter vents were rated as being significantly more satisfying than Carltons with unblocked filter vents, $F(1, 11) = 22.7$, $p = 0.0002$. There was no perceived difference in satisfaction, however, between unblocked and blocked Nows, unblocked and blocked Virginia Slims Ultra-lights, or unblocked and blocked Virginia Slims Lights. A significant puff main effect was not obtained.

STUDY 2: DISCUSSION

When the filter vents on the 83% ventilated brand Carlton were not blocked, it was difficult for the smokers in this study to attain high CO yields, no matter how intensively they smoked these cigarettes. On average, CO exposure levels from this brand were 1.8 ppm when filter vents were not blocked. By covering the filter vents, however, this same brand produced CO levels of 6.1 ppm, more than tripling participants' exposure to CO.

Somewhat smaller, though still statistically significant, was the influence of vent blocking on smoke exposure for the brand Now. Exposure to CO was 44% higher after smoking a Now with blocked filter vents than after smoking a Now with unblocked filter vents. In Study 1, an 85% increase in CO exposure due to vent blocking had been observed for the Now brand. Note that two different lengths of these cigarettes were used in Study 1 and Study 2 (see Table 1). The results overall suggest that added smoke exposure due to vent blocking is not a phenomenon limited to only 1-mg tar Ultra-light brands. In contrast to both the 1- and 2-mg tar Ultra-light brands, there was no added CO exposure due to vent blocking for the Virginia Slims Ultra-lights, a 5-mg tar brand that is approximately 56% ventilated.

And finally, some may question whether the exclusive use of female smokers influenced the results of this study. Virginia Slims, one of the brands used in this study, are marketed towards women. To have men smoke this "feminine" brand could serve as a potential source of error. Also, the use of female smokers is justified given that female smokers are more likely to smoke lower yield brands than men (5). Previous vent-blocking studies conducted in our laboratory, including Study 1, did employ both male and female cigarette smokers. Analyses of data from each of these studies failed to reveal any gender differences for the dependent variables of interest, suggesting that restricting the study to female smokers likely had no biasing effects on the results.

GENERAL DISCUSSION

To date, six different brands of ventilated-filter cigarettes have been studied for the effects of behavioral vent blocking. Degree of filter ventilation, rather than its designation as "Ultra-light" or "Light," appears to determine whether a brand is susceptible to increased CO yields as a result of vent blocking (although there is a high correlation between standard yields and percentage filter ventilation). Although blocking the filter vents of brands with ventilation levels of at least 66% led to significant increases in CO exposure, the same manipulation on brands with filter ventilation levels of 56% or lower appeared to have negligible consequences for CO exposure. Marlboro Lights are, therefore, not alone in being a Light brand that shows no effects of vent blocking on CO exposure. Rickert et al. (16) have shown that 50% vent blocking of Light cigarettes in smoking-machine simulations causes significant increases in tar, nicotine, and carbon monoxide yields. We have no explanation for this discrepancy between the effects of vent blocking for human smokers vs. smoking machines, but, whatever the reason, it points to another failure of the smoking-machine test as a simulation of human smoking behavior.

By current practice, cigarette brands yielding between 1 and 5 or 6 mg tar in standardized smoking machine tests are called "Ultra-light." Studies have shown, however, that all Ultra-light brands do not necessarily deliver the same amounts of harmful smoke constituents to smokers. Levels of exposure from some so-called "Ultra-light" brands have been found to be no different from the levels produced by many "Light" brands, and 1-mg tar brands seem to be different from other Ultra-light brands (2,20).

Recently released documents from British American Tobacco Company, the world's largest cigarette manufacturer, indicate that the industry acknowledges the importance of filter ventilation for designing products to be "compensatible" or "elastic" (i.e., so that a product with a low machine-smoked yield would give much higher yields to the smoker). For example, in one document the question is asked, "Which product/design properties influence elasticity?" The answer: "1. Tip ventilation: bigger effects at higher degree of ventilation. . . . 2. Delivery of the blend." (15).

The current practice of classifying cigarette brands as "Ultra-light," "Light," or "Regular" based on standard yields derived from smoking machine tests is misleading. Terms such as "Ultra-light" and "Light" are tantamount to health claims. A recent study found that many smokers believe that when used in cigarette brand names, such terms indicate that those brands deliver reduced amount of tar, nicotine, and ultimately, risk of disease (8).

We examined the effects of vent blocking on only one biomarker of smoke exposure—expired-air CO. Future studies should investigate how other smoke constituents such as nicotine, and hydrogen cyanide (HCN), for example, are influenced by vent blocking. Although we do not have direct data on tar and nicotine exposures from our studies, ratings of perceived harshness, which may be assumed to be positively related to tar and nicotine yields, were significantly greater for blocked cigarettes than for the unblocked cigarettes in both Studies 1 and 2. Perhaps measures of other smoke toxins will reveal effects of vent blocking for Light cigarettes [cf. (17,20)].

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