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Smoking Behavior and Smoke Constituents from Cigarillos and Little Cigars

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Abstract

Objective—Although most cigarillos and little cigars smokers also smoke cigarettes (dual use), there are few studies comparing toxicant exposure and smoking behavior in cigars and cigarettes.

Methods—Two groups of dual users smoked their usual brand of cigarette and either a Winchester unflavored little cigar (N = 21) or a Black & Mild cigarillo (N = 23). Acute exposure of nicotine and exhaled carbon monoxide (CO) and puffing topography parameters were collected. Individual cigar puffing data were used to machine-replicate smoking for analysis of volatile organic compounds (VOC) and semi-volatile organic compounds (SVOC) in mainstream smoke.

Results—There were significant differences in puff topography, plasma nicotine and exhaled CO after cigarettes, little cigars, and cigarillos. Puff topography differences between cigarillos and cigarettes were due to the difference in the size of the article. Mainstream cigar and cigarette smoke was qualitatively similar; the yield was dependent on the smoking behavior. When smoke yield was adjusted for weight of tobacco burned or puff volume, exposure differences decreased.

Conclusions—There is a wide range of delivery of both SVOC and VOC components of cigar and cigarillo smoke. The difference in exposure is largely dependent on the article size and the amount consumed.

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Human Subjects Statement

The study was approved by Battelle's Institutional Review Board.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Keywords

mainstream smoke; constituents; VOC; SVOC; topography; cigar; cigarillo

Few laboratory studies have characterized how current cigar consumers smoke the products. The most comprehensive review of cigar smoking was the 1998 NIH Monograph #9 “Cigars: Health Effects and Trends.”¹ Except in that monograph and in the relatively few subsequent publications, there has been little written about the smoking topography of cigars and the toxicant delivery from mainstream cigar smoke. Part of this gap in knowledge is that cigar smoking prevalence - relative to cigarette smoking - is relatively small.^{2,3} Another impediment has been that off-the-shelf commercial smoking topography instrumentation and hardware is designed for cigarette research and must be modified to accommodate cigar products.

A further challenge is that cigars (unlike cigarettes) come in a wide variety of sizes - from articles the size of cigarettes containing less than 1g of tobacco to large cigars that may contain 30g of tobacco filler.⁴ Furthermore, there are idiomatic use patterns associated with some cigar smoking that are not seen in cigarette smoking. For example, partial smoking and re-lighting is common among cigarillo smokers⁵ but almost never seen among cigarette smokers. Other studies⁶⁻⁸ and the Internet document the practice of “hying” - removing the tobacco filler and the paper liner and repacking the filler before smoking some cigarillo brands; chewing on the tip; and using cigars to deliver marijuana.^{9,10} Also, little cigar and cigarillo consumers typically use both a cigar product and a conventional cigarette (dual users).^{2,5,11-13}

Although there are practical challenges to research and some questions on the generalizability of results, the use of laboratory smoking studies provide an estimate of the use behavior and toxicant exposure. We have adopted puff topography methods and measures of acute toxicant exposure developed and used in cigarette studies^{14,15} to investigate cigarillo and little cigar smoking in our laboratory. Replicated human puffing measures were used to drive machine smoking of cigarillos and little cigars for post hoc analyses of mainstream smoke components in the gas (volatile organic compounds, VOCs) and the solid (semi-volatile organic compounds, SVOCs) phases of cigar smoke.

METHODS

Participants

Twenty-one adult dual users of little cigars and cigarettes and 23 dual users of cigarillos and cigarettes were recruited through newspapers, Craigslist, word-of-mouth, and from our database of former research participants. Eligibility was determined with a telephone interview. An experienced recruiting specialist gathered basic demographic, health, and product use information to determine if inclusion criteria were met. The inclusion criteria of the study were: (1) adult men and women aged 18–65; (2) ability to provide study consent, attend all laboratory sessions lasting approximately 2 hours each and complete all study procedures; (3) smoke both a minimum of 10 cigarettes per day for at least 2 years and a

minimum of one little cigar per week; (4) absence of smoking related-illness or disease; and (5) not actively trying to quit smoking. Participants were compensated \$70 for each of the 2 study visits, plus an additional \$25 completion bonus at the end of visit 2. Data from this study were collected between March 2013 and November 2014.

Procedure

At the initial laboratory visit, participants read and signed a Battelle IRB-approved consent form. They answered questions on their personal smoking history, cigarette, and little cigar use patterns. Their self-reported height and weight were recorded and they provided a urine sample. Participants were randomized to smoke either an unflavored Winchester little cigar (85 mm, filtered, filter-ventilated) or unflavored Black & Mild cigarillo or their own brand of cigarette in the first group at that session; at their next visit, they smoked the other tobacco product. The little cigar product was chosen because it has been a market-leading brand in sales (#8 with 3.2% of that market in 2012¹⁶) and was designed to be as close to a cigarette as possible.¹⁷ The cigarillo chosen is also a recognized product and has a leading market share. The 2 laboratory sessions were separated by at least 24 hours.

The procedures at the second visit were identical to the first but the participant consumed the other product. The little cigar, cigarillo, and cigarette were weighed before and after smoking to determine the amount of tobacco smoked. The amount of tobacco consumed and total puff volume were used to adjust mainstream smoke VOCs and SVOCs per gram of tobacco consumed and per 1000 mL of total puff volume.

Dependent Measures

Puff measures—Measures of topography included: the number of puffs, puff volume (PV), puff duration (PD), puff velocity (PVeI), interpuff interval (IPI), and time to smoke (TTS). Smoking topography was measured using a SPA/D Puff Analyzer (Sodim Instruments, Mebane, NC). A cigarette or cigar (little cigar or cigarillo) was inserted into the topography mouthpiece. The product was smoked and the puff topography data from each puff were saved to a computer. Smoking topography was collected from participants as they sat in a comfortable chair in a well-ventilated room while under observation by laboratory personnel through a one-way mirror. The cigar (or cigarette) was lit by the study staff to ensure accurate measurement of smoking onset time. Participants were observed continually during smoking; at the end of the last puff they provided a specific visual cue to signal the end of smoking.

Mainstream smoke generation and chemical analysis—The individual smoking topography data collected from each participant in the clinic were used to replicate mainstream smoke from little cigars and cigarillos smoking by a contractor (Enthalpy Inc. Richmond, VA). Mainstream smoke was generated for chemical analysis using a 20-port linear smoking machine (Cerulean SM450RH) fitted with 210 mL volume stepper driven aluminum bore puff engines (Cerulean, UK). The participant-specific puff profile was replicated in its entirety through the use of a conversion program (HPP software), developed specifically for the topography data we collected from participants. Thus, the machines

smoked the cigars in the same way that the participant smoked them, allowing for the mainstream smoke replication and analysis.

As a standard, the machine was fully programmable for a series of different individual puff shapes that could be selected for volume, duration, and interval between puffs. The capture of particulate matter was conducted using a glass fiber pad and holder as described in ISO standards (the Cambridge filter pad holder). A series of impinger devices with the puff engine also was connected to the smoking machine to collect and trap vapor and gas phase components of the smoke. The capture of particulate matter was conducted using a glass fiber pad and holder (the Cambridge filter pad holder). Vapor and gas phase components were collected using impinger devices (with immobilizing liquids) in series with the puff engine for offline analysis. Table 1 presents the limit of quantification (LOQ) and the method of collection for each VOC and SVOC compound. All chemical analyses were performed according to Enthalpy's internal Standard Operating Procedures (SOPs). For each analytical run, a calibration curve was analyzed with each batch of samples. The final analysis report was reviewed and certified by Enthalpy's Quality Control and Quality Assurance Officer before submission to Battelle. Enthalpy's tobacco smoke laboratory is ISO-17025 Certificate No. 3198.01 accredited.

Selection of smoke toxins to be measured in mainstream smoke—Previous work has identified particle-bound SVOCs and vapor phase VOCs as highly relevant lung carcinogens.^{18–20} Ten target compounds from cigar smoke were selected according to the following criteria: (1) compounds cover a wide range of vapor pressures; (2) prevalence in mainstream smoke; (3) toxicity (potential adverse effects on health); or (4) role as tobacco smoke markers (Table 1). There are well over 8000 recognized components of the mainstream smoke from cigarette^{21–23} and cigar¹ consumption. Mainstream tobacco smoke is an aerosol composed of particles, SVOCs suspended in a gaseous phase that contains, among other substances, VOCs. Among the compounds identified, 93 are known to be harmful or potentially harmful, and many are known carcinogens and/or have been identified as involved in cardiovascular non-carcinogenic pulmonary pathology (chronic obstructive pulmonary disease; COPD or airway irritation).²⁴ Table 1 shows the chemicals selected for analysis, the levels of quantification, and the recognized pathology.

RESULTS

Puff topography

Research in our laboratory has added to an understanding of the health consequences of cigar smoking through studies that investigate smoking behavior (topography) and toxicant exposure. Acute toxicant exposure was directly measured from changes in exhaled CO and plasma nicotine levels before and immediately after cigar smoking.^{5,11} We have further estimated delivery of other smoke constituents from replicated human puffing by machine smoking and measurement of representative constituents of mainstream smoke. In other studies, mainstream cigar smoke using puff topography parameters from participant profiles and using puff parameters the International Organization for Standardization (ISO) regimen

for measuring cigarette smoke constituents were generated and analyzed (data not reported here).

The data show that cigarette smoking was similar in both groups of dual users but that there were differences between cigarette smoking and cigarillo smoking and cigarette smoking and little cigar smoking (Table 2; Figure 1). Specifically puff volume, average puff volume, puff velocity and duration were similar in cigarette smoking but there were significant differences when cigarette smoking was compared with cigar smoking. For example time to smoke, number of puffs, and total puff volume in cigarillo smoking differed from those parameters in cigarette smoking. Some of the differences between cigarette and cigarillo smoking may be due to differences in the size of a cigarillo (tobacco weight = 3.1 g) and the cigarette (~0.84 g) – for example, time to smoke and number of puffs. Among cigarillo smokers there are clearly differences between the amounts smoked as a percentage of the article. However, the topography differences in cigarette and little cigar (weight 0.75 g) smoking could not be attributed to difference in the weight of the product. Furthermore, few participants smoked the entire cigarillo, whereas nearly all participants smoked the entire cigarette or the little cigars. The difference in the amount consumed is evident in Figure 2. As the right panel shows, tobacco consumed in the lab ranged from 0.48 to 2.4 g when cigarillos were smoked but the tobacco consumed with little cigar ranged from 0.4 to 0.7 g.

Precision of Human Smoking Replication on the Smoking Machine

The ability of the machine smoking to replicate the human laboratory smoking is illustrated in the correlation plots in Figure 2. Both the total puff volume and the amount of tobacco consumed after both laboratory and machine smoking were highly correlated. Furthermore, time to smoke and number of puffs (data not shown) were identical after human smoking and laboratory replication. These data indicate the machine smoking faithfully replicated human smoking over a wide range of smoking behaviors and in both cigar articles.

In the present study we have quantified components of mainstream smoke generated from a representative cigarillo – Black & Mild – and a representative little cigar, Winchester. The puff topography recordings (air flow) from each of the participants was measured with SPA/D Puff Analyzer, digitized, and stored. In the laboratory time to smoke, mass of tobacco consumed and number of puffs in the smoking session were recorded. These data were later used to verify the fidelity of the machine-generated smoking compared to the laboratory smoking (Figure 2).

In the laboratory a computer interface was developed that read the digitized smoking topography data from each participant on a puff-by-puff basis and “drove” the linear smoking machine to puff the article identically to how the participant smoked the article in the lab. The articles (Black & Mild cigarillo or Winchester Little Cigar) were inserted into the ports of the linear smoking machine (Cerulean).

VOCs and SVOCs in Mainstream Smoke

Figure 3 presents the results from 2 representative VOCs and SVOCs. The 3 panels illustrate the puff exposure for each participant in the cigarillo and little cigar smoking groups. The left panel (A) shows the total exposure; the center panel (B) shows the exposure per 1000

mL puff volume; and panel (C) shows the exposure adjusted for 1g of tobacco consumed. Also illustrated is the average toxicant exposure from 5 US domestic cigarettes machine smoked using puff parameters that were the average of the puff parameters for cigarette smoking sessions of the little cigar and cigarillo group (PV=51mL; PD=2.2sec.; IPI=21sec). The mainstream cigarette smoke was analyzed using procedures identical to those of the cigar products.

It can be seen in Panel A of each toxicant (both VOCs and SVOCs) that cigarillos delivered more toxicants than little cigars. Furthermore, little cigars delivered about the same amount of toxicants as cigarettes. The range of exposure in the cigarillo group was much larger than the range in the little cigar group. This pattern was evident for all of the VOCs and SVOCs tested. For example, mainstream smoke emissions of benzene, a VOC, ranged between 110 and 490 μg (average 315 μg) after ad lib smoking of the cigarillo and between 50 and 200 μg (average 105 μg) from little cigar smoking. After the yield of the mainstream smoke was adjusted for weight of tobacco consumed or for puff volume, the average delivery was essentially equal after each product (250 $\mu\text{g/g}$ or 225 $\mu\text{g}/1000\text{ mL}$) and the range of exposure across the groups was similar. These data illustrate that when one considers toxicant exposure from the whole article there is a wide range of values and that the variation between smokers and articles is diminished when the exposure is adjusted for weight of tobacco consumed or puff volume.

Also note that the exposure to 2,5-dimethylfuran is much higher in cigarillo smoking than little cigar smoking. This compound has been proposed as a marker of cigar smoke.²⁵

When the mainstream toxicant emissions data were adjusted by the grams of tobacco consumed (Panel B) or puff volume (Panel C), differences between the cigarillos and little cigars diminished. Although there was still a considerable range of emissions among the participants of the 2 groups, the difference was less than the range in Panel A.

DISCUSSION

Overall these data indicate that both cigarillos and little cigars deliver toxicants in mainstream smoke. Little cigars deliver nicotine in levels similar to those of cigarettes whereas cigarillos deliver more nicotine and other toxicants. The differences in emissions between cigarillos and little cigars are largely due to differences in their size; when adjustments are made for the tobacco consumed and the puff volume the differences largely disappear.

The range of smoking behavior – even in this small selected sample – was large. Puff parameters of most participants exceeded those of the ISO and International Committee for Cigar Smoke Study (ICCSS) standards²⁶ that are available for cigar smoking. As indicated above, there is a wide range of use behavior in cigar consumption. Unlike cigarette consumption where smokers typically light, rather consistently puff and finish a cigarette in a single session, cigar smokers, particularly cigarillo and large cigar smokers, puff differently, take much longer to consume the product and may not smoke all of the article in a single session. Subsequently, the article is relit and more of it is consumed. The practical

consequence of the wide variations in smoking behavior among cigar smokers renders standardized machine smoking paradigms (eg, ISO, Massachusetts or Canada Intense^{27,28}) potentially inappropriate for replication of cigar smoke for analysis of mainstream smoke constituents.

The results of our study illustrate the complex relation between the product and its user in the determination of toxicant exposure. There was a wide range of use behavior that was especially evident in cigarillo smoking; some people smoked nearly all of the cigarillo whereas others smoked only a portion of the cigarillo. Findings from cigarette machine smoking research indicate that standard puffing protocols with fixed puff volumes, constant interpuff interval, and constant velocity are not reflective of human smoking. The results of the present study show that cigar smoking is also associated with a wide range of behavior in puffing and in the amount of a cigarillo consumed in a single session.

Limitations

There were limitations of the study. The smoking behavior was studied in only one cigarillo and one little cigar brand but there are hundreds of cigars products on the market. Flavoring in cigarillo and little cigars is important for marketing and consumer appeal²⁹ but we only measured smoking in unflavored cigar products. Our sample was largely middle-aged men, but little cigar and cigarillo smoking is especially popular among younger smokers.¹ Quantification of mainstream cigar smoke is challenged by variations in products, variations in smoking behavior within and between people.

In spite of the limitations, our results indicate that both little cigars and cigarillos deliver addictive amounts of nicotine and other toxicant components of tobacco smoke. On a puff basis, there is a qualitative and quantitative similarity between cigars and cigarettes but the overall toxicant exposure from tobacco products must consider the extent of use and the overall consumption.

Conclusions

There is a wide range of delivery of both SVOC and VOC components of cigar and cigarillo smoke. Without adjustments that take into account the size of the article, it would seem that cigarillos deliver more toxicant per article than little cigars or cigarettes. However, when the mainstream smoke exposure is adjusted to take into account the mass of tobacco consumed or the puff volume is adjusted, the yields of most toxicants are quite similar to each other. The difference in exposure is largely dependent on the size of the article and the amount consumed. After adjusting for consumption variables, the SVOC and VOC components of little cigar and cigarillo smoke were quite similar.

IMPLICATIONS FOR TOBACCO REGULATION

This study was an initial attempt to quantify mainstream smoke toxicant exposure from cigarillo and little cigars smoking in dual users of these cigar products and cigarettes. There are a number of variables that have not been studied that may influence toxicant exposure from cigar smoke. As mentioned above cigar flavoring appears to be an important factor in cigar selection.^{29,30} About 50% of cigar sales are for flavored cigar products. Menthol

flavoring has been shown to modestly affect cigarette smoking topography and also appears to have an effect on smoking acceptance and initiation.^{31,32} A further understanding of the quantitative and qualitative effects of flavoring on smoke topography, toxicant exposure and subjective effects of cigar is warranted.

Others¹⁰ also have found evidence of filter ventilation in some products. It is known that filter ventilation changes the composition of mainstream cigarette smoke²¹ but behavioral compensation by blocking vent holes, changing puff topography, and smoking more cigarettes^{33–35} overcome the effects of ventilation to reduce nicotine delivery. It is uncertain how these compensatory changes affect the delivery of other smoke components. For example, smokers take larger puffs, smoke more cigarettes per day, and block ventilation holes in cigarettes to achieve familiar levels of nicotine and presumably other toxicants. There are no such data available for cigar smoking. This seems especially relevant because the characteristics of the mainstream smoke could be changed by filter ventilation and further altered by efforts to compensate.

Early studies^{36,37} noted that as a cigar is smoked the pH of the smoke becomes more alkaline as the rod is consumed. This was observed in smoke from large cigars but the pH of cigarette and little cigars did not change. Because the bioavailability of nicotine is strongly associated with the free base nicotine that increases in an alkaline environment, it is important to measure product and smoke pH from products in the current marketplace. Finally, there is increasing evidence that the cigar market and the delivery of marijuana smoke are inexorably linked.^{9,38} Studies are needed to determine whether blunt smoking and cigarillo smoking have the same topography. Nicotine delivery from the cigar wrapper in blunt smoking after the filler has been replaced with marijuana has not been studied thoroughly. Whereas additional research is needed, our results support the notion that regulation of little cigars and cigarillos is appropriate in light of public health considerations.

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Figure 1.
Distribution of Puff Topography Measures for Cigarettes, Little Cigars, and Cigarillos
Note. The line through the center of the box represents the median; the lower and upper ends of the box represent the 25th and 75th percentiles, respectively; the ends of the whiskers mark 1.5 times the interquartile range (IQR) below and above the 25th and 75th percentiles, respectively; value outside of 1.5 times the IQR is an outlier and represented by a dot on the graph.

Figure 2.

Correlation between Machine Smoking and Human Lab Smoking

Note. Slopes of a curves were as follows: Total Puff Volume $0.8177x+130.07$ (Winchester little cigar); $1.0984x+47.642$ (Black & Mild cigarillo); Tobacco consumed $0.7358x+0.1897$ (Winchester little cigar); $0.8591x+0.2179$ (Black & Mild cigarillo).

Figure 3.

Results from Representative VOC (Acrylonitrile) and SVOCs (Nicotine, B[a]P and 2,5-dimethylfuran)

Note. The 3 panels illustrate the exposure for each participant in the cigarillo and little cigar smoking groups. Panel (A) shows the total exposure per smoking session; panel (B) shows the exposure per 1000 mL puff volume; and panel (C) shows the exposure adjusted for 1 g of tobacco consumed. Also illustrated is the average toxicant exposure from 5 US domestic cigarettes machine smoked using puff parameters that were the average of the own-cigarette smoking puff parameters of the little cigar and cigarillo group.

Table 1

Mainstream Smoke Collection and Chemical Analysis

	LOQ	Collection method	Characteristics	Mainstream Smoke Yield from Cigarette Smoking ⁴⁰⁻⁴²
Gas Phase VOC				
Acetaldehyde	0.034 µg/mL	2 Impingers	Carcinogen	600 – 2,100 µg
Benzene	0.460 µg/mL	44 mm CFP + 1 impinger	Carcinogen	28 – 106 µg
Acetonitrile	1.2 µg/mL	44 mm CFP + 1 impinger	Irritant	2,975 ppb
Acrylonitrile	0.320 µg/mL	44 mm CFP + 1 impinger	Carcinogen	8 – 39 µg
1,3 – Butadiene	0.54 µg/mL	44 mm CFP + 1 impinger	Carcinogen	24 – 123 µg
2,5 – Dimethylfuran	0.8 µg/mL	44 mm CFP + 1 impinger	Tobacco smoke marker	2,141 ppb
Particle-Bound SVOC				
Nicotine	1.000 µg/mL	44 mm CFP	Addictive	0.61 – 3.23 mg
NNK^a	0.180 ng/mL	44 mm CFP	Carcinogen	55 – 221 ng
NNN^b	0.580 ng/mL	44 mm CFP	Carcinogen	100 – 317 ng
B[a]P	1.390 ng/mL	44 mm CFP	Carcinogen	<1 – 42 ng

Note.

^aNNK = 4(methylnitrosoamino)-1-(3-pyridyl)-1-butanone;

^bNNN = N-Nitrososonornicotine; LOQ – limit of quantification; CFP - Cambridge filter pad

Table 2

Average Puff Topography Measures for Cigarettes, Little Cigars, and Cigarillos

Smoking Topography Parameter	Cigarette Smoking ^a		p	Cigarillo Smoking ^b		p	Cigarette Smoking ^d		p	Little Cigar Smoking ^c		p
	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)	
Number of puffs	15 (6)	24 (9)	<.001	14 (4)	10 (3)	<.001	710 (158)	399 (147)	<.001	239 (109)	41.5 (14.4)	<.001
Total Puff Volume (mL)	698 (215)	1267 (476)	<.001	52.4 (12.3)	22.0 (6.2)	<.001	20.7 (7.0)	20.8 (8.7)	NS	20.7 (7.0)	20.8 (8.7)	NS
Time to Smoke (s)	315 (79)	620 (350)	<.001	23.2 (6.1)	2.8 (1.1)	NS	26.7 (7.3)	2.2 (0.6)	NS	26.7 (7.3)	2.2 (0.6)	NS
Puff Volume (mL)	50.3 (15.4)	56.2 (16.0)	NS	2.3 (0.8)	22.0 (8.1)	NS	2.3 (0.8)	22.0 (8.1)	NS	2.3 (0.8)	22.0 (8.1)	NS
Puff Velocity (mL/s)	24.5 (6.1)	23.2 (6.1)	NS	2.3 (0.8)	22.0 (8.1)	NS	2.3 (0.8)	22.0 (8.1)	NS	2.3 (0.8)	22.0 (8.1)	NS
Puff Duration (s)	2.3 (0.8)	2.8 (1.1)	NS	2.3 (0.8)	22.0 (8.1)	NS	2.3 (0.8)	22.0 (8.1)	NS	2.3 (0.8)	22.0 (8.1)	NS
Interpuff Interval (s)	22.0 (8.1)	24.4 (11.0)	NS	24.4 (11.0)	24.4 (11.0)	NS	24.4 (11.0)	24.4 (11.0)	NS	24.4 (11.0)	24.4 (11.0)	NS

Note.

^a = Own Cigarette,^b = Black & Mild tipped,^c = Winchster filtered