Impact of menthol delivery methods on smoker sensory perceptions

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ABSTRACT

INTRODUCTION Menthol can be added to cigarettes in several ways; these different delivery methods of menthol may lead to changes in sensory attributes, as well as perceived risk and appeal of these products.

METHODS Using a randomized, controlled study design, 18 current, established menthol smokers were asked to sample Camel Crush and Camel Menthol cigarette products, crushed and uncrushed. Smoking behavior, exhaled carbon monoxide, subjective ratings, and perceived risk measures were assessed for each product.

RESULTS Cigarette Evaluation Scale relief of craving scores for participants' preferred brand (mean: 5.3, SE: 0.3) were significantly higher (p=0.012) than Camel Menthol crushed (mean: 4.6, SE: 0.3) as were the Sensory Scale satisfaction scores (preferred brand mean: 6.9, SE: 0.7 compared to Camel Menthol crushed mean: 5.1, SE: 0.6; p=0.004). In addition, the average Sensory Scale smoke strength scores for participants' preferred brand (mean: 6.9, SE: 0.5) was also significantly higher than Camel Crush crushed (mean: 5.0, SE: 0.5; p=0.022). There were no significant differences in smoking topography measures, CO boosts, or perceived risk between Camel Crush or Camel Menthol products.

CONCLUSIONS The delivery method and amount of menthol present in cigarettes did not appear to affect short-term smoking behavior, sensory perceptions, or perceived product risk among a small sample of current established adult menthol smokers. It is possible that consumers of cigarette products may be attracted to the innovative technology of the crushable filter capsule as opposed to the taste experience, however, further research is needed.

INTRODUCTION

The addition of menthol to cigarettes creates a minty taste and aroma that also has anesthetic and mild irritant effects[1]. These characteristics of menthol affect the smoking experience (e.g. reduce perceived strength, create a minty taste, and reduce harshness), which may contribute to smoking initiation by youth and young adults and continuation of use by established smokers[1,2]. Whereas the use of non-mentholated cigarettes has declined over time, the use of mentholated cigarettes has remained steady[3]. Following the Family Smoking Prevention and Tobacco Control Act (FSPTCA) of 2009, menthol is the only characterizing flavor allowed to be marketed in cigarettes sold in the US[4]. Menthol can be added to cigarettes in the tobacco, via a crushable capsule in the filter, or the combination of the above methods[1]. Different delivery methods of menthol may lead to changes in sensory attributes, as well as perceived risk and appeal of these products.

The crushable capsule allows a greater concentration of menthol to be transferred into the smoke as the menthol is not burned with the tobacco[5]. In addition, as the menthol flavoring is

housed within the capsule, the migration of the menthol flavor may be limited and prevent the flavor from dissipating over time or after the pack is opened[5]. Knowledge of consumers' sensory perceptions, perceived risk, and perceived appeal could provide information to help develop tobacco control policies regulating the delivery method of menthol in cigarettes to reduce smoking.

A previous study used Camel Crush cigarettes to assess the effects of menthol on smoking behavior, biomarkers of exposure, and subjective responses[6]. Although they found that menthol had little to no impact on consumers' smoking behavior, biomarkers of exposure, and subjective responses[6], Camel Crush only delivers menthol via a crushable filter capsule. Menthol may be found in the tobacco, or in the tobacco and a capsule in other products. Using a randomized controlled study design, the current pilot study aimed to explore the effects of two primary delivery methods of menthol flavoring in cigarettes on sensory attributes, perceived health risk and appeal, and short-term smoking behavior among regular smokers.

METHODS
Study population
Participants were eligible if they were 18–65 years of age, currently smoked at least 5 cigarettes per day, primarily preferred mentholated cigarettes, were not trying to quit smoking, were able to provide consent, and had no medical contraindications (e.g. pregnancy, asthma, diabetes). Recruitment was conducted via advertisements in local community and college newspapers, flyers on community boards in local shops, advertisements on Craigslist.com, and respondent driven sampling. A maximum incentive of $110 was offered to participants who completed their participation. This study was approved by the Roswell Park Comprehensive Cancer Center's Institutional Review Board (MOD00002780), and informed consent was obtained from participants.

Cigarette products
The cigarettes used in this intervention were Camel Crush and Camel Menthol cigarettes (R.J. Reynolds, Winston-Salem, NC), which are commercially available. Analysis of cigarette physical features was done at Roswell Park following the International

Organization for Standardization 3402:1999 and noted no statistically significant differences between the physical features of Camel Menthol and Camel Crush cigarettes. Both products contain a menthol capsule in the filter that can be crushed to release menthol into the cigarette. However, Camel Crush cigarettes do not contain menthol as a characterizing flavor without crushing the capsule while Camel Menthol cigarettes contain menthol in the tobacco as a characterizing flavor prior to crushing. Therefore, the Camel Menthol cigarette has a dual menthol delivery method while Camel Crush only has a single menthol delivery system. Menthol concentrations were measured at Roswell Park following an adapted form of the CORESTA N°62 MTBE method. Camel Menthol with the capsule crushed contained 6.2 mg menthol/cigarette, and 3.6 mg menthol/cigarette without crushing the capsule. The Camel Crush with the capsule crushed contained 5.3 mg menthol/cigarette, and 0.16 mg menthol/cigarette without crushing the capsule[7]. All cigarettes were purchased from retail outlets in Western New York State during September 2017.

Study design
This pilot study used a randomized controlled design to assess the effects of delivery methods of menthol flavoring in the cigarette on consumers' sensory perceptions, perceived health risk and appeal, and short-term smoking behavior. The study was conducted at Roswell Park from December 2017 to February 2019. Once determined eligible for the study, a participant was randomly assigned to one of four sampling groups, which varied in the sequence of the cigarette products that were smoked (Camel Crush crushed, Camel Crush uncrushed, Camel Menthol crushed, and Camel Menthol uncrushed) (Table 1). All participants (N=18) smoked all available cigarette products. At the baseline session, all participants smoked their preferred brand, which allowed them to serve as their own control.

A total of five 2-hour laboratory sessions occurred over about two weeks with at least 24 hours between consecutive sessions. Participants were asked not to smoke 45 minutes before coming to the laboratory to ensure that they were ready for a cigarette. At the start of each session, the participants completed the Questionnaire of Smoking Urges[8] and Minnesota

Table 1. Experimental sequences to which participants (N=18) were randomly assigned, 2017–2019

Sampling group	Order of product by session				
	1 (Baseline)	2	3	4	5
1	Preferred cigarette brand	Camel Crush crushed	Camel Crush uncrushed	Camel Menthol crushed	Camel Menthol uncrushed
2	Preferred cigarette brand	Camel Crush uncrushed	Camel Crush crushed	Camel Menthol uncrushed	Camel Menthol crushed
3	Preferred cigarette brand	Camel Menthol crushed	Camel Menthol uncrushed	Camel Crush crushed	Camel Crush uncrushed
4	Preferred cigarette brand	Camel Menthol uncrushed	Camel Menthol crushed	Camel Crush uncrushed	Camel Crush crushed

Nicotine Withdrawal scale[9]. These measures were used to ensure that the craving for a cigarette, which could affect smoking behavior, did not differ between sessions. At each session, two cigarettes of the product assigned for that session were smoked with a 45-minute interval between cigarettes. The participant's exhaled carbon monoxide (CO) levels were measured using a Micro+ Smokerlyzer (CoVita, Santa Barbara, CA) prior to smoking, following standard procedure. Participants then smoked a cigarette that was inserted into a Clinical Research Support System for Laboratories smoking topography device (CReSS; Borgwaldt, Richmond, VA). During the washout period, various questionnaires related to the product's sensory attributes were completed. Ten minutes after the last puff, exhaled CO levels were reassessed. This procedure was repeated for the cigarette replicate after 45 min. At the end of each session, the perceived risk of the cigarette product smoked at that session was assessed.

Sensory attribute measures

After smoking each cigarette provided during this study, the Cigarette Evaluation Scale and the Sensory Scale were used to assess the overall sensory attributes of each product[6,10-12]. The Cigarette Evaluation Scale evaluates 21-items that can be broken down into the following subscales: satisfaction, psychological reward, aversion, and relief of craving[10,11]; items were rated on a scale of 1 (not at all) to 7 (extremely), and item scores for each subscale were averaged[10,11]. The Sensory Scale is a linear scale (from 0 to 10) with descriptive anchors6. Participants were asked to mark along the scale to indicate their rating for the following items: strength, harshness, heat, draw, taste, satisfaction, burn rate, mildness, aftertaste, staleness, and smoke harshness, strength and smell. These items have been used by the tobacco industry and elsewhere[6,12].

Smoking behavior and biomarker measures

Exhaled CO boosts were calculated by taking the difference between the pre- and post-smoking CO level for each cigarette smoked during this study. In addition, the smoking topography measures (total smoke volume, average puff volume, puff duration, inter-puff interval, and puffs per cigarette) were obtained from the CReSS device for each cigarette smoked during this study.

Perceived risk measures

At the end of each session, a 10-rung risk ladder was used to assess perceived health risk of the cigarette product after smoking the cigarette replicates assigned for that session. The top of the ladder represented a greater health risk and the bottom was no or little health risk[13].

Data analysis

Basic descriptive statistics and analysis of variance (ANOVA) were used to compare demographic and smoking behavior characteristics of study participants. Within-subject differences in smoking urges and withdrawal measures at the start of each session, sensory perception measures (Cigarette Evaluation Scale and Sensory Scale), CO boost, smoking topography (total smoke volume, average puff volume, puff duration, inter-puff interval, and puffs per cigarette), and the risk perception measures at the end of each session were assessed using repeated

measures ANOVA with Bonferroni *post hoc* tests; a p<0.05 was considered to be statistically significant. The sensory perception measures, CO boost, and smoking topography were measured for each cigarette administered. Differences were evaluated between the cigarette products and between the two cigarette replicates smoked at each session. Data analyses were completed using Statistical Package for the Social Sciences Version 21.0 (IBM, Armonk, NY).

RESULTS

Study participants

Eighteen participants completed the study (Figure 1). A prototypical participant was non-Hispanic White (88.9%), male (55.6%), on average 42.3 years old (SE=2.8) with some college and/or technical schooling (44.4%), had a yearly household income of $60001 or more (38.9%), felt that they were slightly better off than the rest of their community according to the MacArthur Ladder of Socioeconomic Status

(6.7, SE=0.24), and had little to no physical symptoms and some emotional symptoms according to the Memorial Symptom Assessment Scale (Physical: 0.37, SE=0.09; Emotional: 1.6, SE=0.15). Most smoked Seneca brand mentholated cigarettes (55.6%), chose their brand because of the price (38.9%), smoked about 13 cigarettes per day (SE=1.0), with an average Fagerström Test for Nicotine Dependence (FTND) score of 2.3 (SE=0.33). There were no significant differences between sampling groups for demographic and smoking behavior characteristics (all p>0.1). One participant was excluded from the remainder of the analyses because he/she received the wrong product condition at the last session.

Smoking sessions

Sensory perception ratings

The Cigarette Evaluation subscales were compared between cigarette products as well as cigarette replicates. No significant differences were seen for

Figure 1. Flow diagram of enrollment and randomization of study participants, 2017–2019
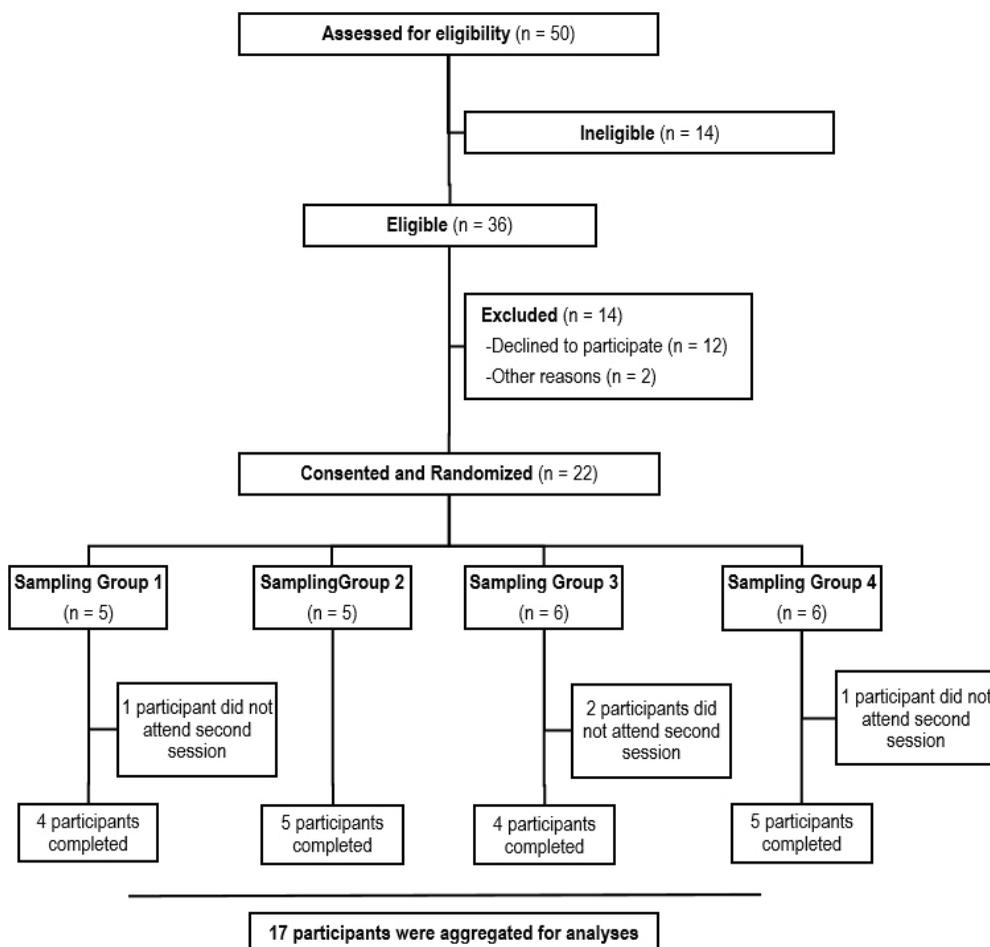
mean scores of the Cigarette Evaluation subscales between the cigarette replicates. In addition, no significant differences were seen between cigarette products for mean scores for the satisfaction, psychological, and aversion subscales. On the other hand, a significant association was seen in mean scores of the relief of craving subscale between cigarette products [F(4,64)=4.7; p=0.008]. The *post hoc* test showed that the mean relief of craving score of participant's preferred brand was significantly higher than that of Camel Menthol crushed (p=0.012); Camel Crush crushed and Camel Crush uncrushed were not found to be significantly different in the *post hoc* test (p=0.08 and p=0.09, respectively) (Figure 2).

All of the sensory scale items mean scores were compared between cigarette products as well as cigarette replicates. There were significant associations between cigarette products for mean scores of satisfaction [F(4,64)=5.8; p=0.004], too mild [F(4,64)=3.8; p=0.027], strength [F(4,64)=3.7; p=0.030], and smoke strength [F(4,64)=5.3; p=0.010]. The *post hoc* test showed that the mean satisfaction score of the participants' preferred brand was significantly higher than mean satisfaction score for Camel Menthol crushed (p=0.004). In addition, the mean smoke strength scores of participants' preferred brand was also significantly higher than Camel Crush crushed (p=0.022). Furthermore, mean smoke strength scores of Camel Menthol crushed was significantly higher than Camel Crush crushed (p=0.033). Significant associations were

also seen between cigarette replicates for mean scores of too mild [F(1,16)=11.1; p=0.004] and strength [F(1,16)=5.7; p=0.030] with high scores for the first cigarette replicate. Finally, a significant interaction was noted between cigarette brand and cigarette replicate for the mean score of smoke harshness [F(4,64)=3.8; p=0.021] (Table 2).

Smoking behavior and biomarkers
Three participants were excluded from the smoking topography analyses due to CReSS device equipment failures. There were no significant differences in any of the smoking topography measures between cigarette products or between the cigarette replicates (Table 3). In addition, there were no significant differences in mean CO boosts between cigarette brand or between the cigarette replicates (data not shown).

Risk perception
The risk perception of each cigarette product was assessed at the end of each session. Scores were averaged and compared across cigarette products. There were no significant differences in mean risk perception scores according to cigarette product [F(4,64)=0.77; p=0.448]. Scores showed that most participants felt that all cigarette products where harmful to their health.

Smoking urges and withdrawal
A significant difference in mean smoking urges scores was observed between cigarette products

Figure 2. Average scores of Cigarette Evaluation subscales by cigarette product, 2017–2019
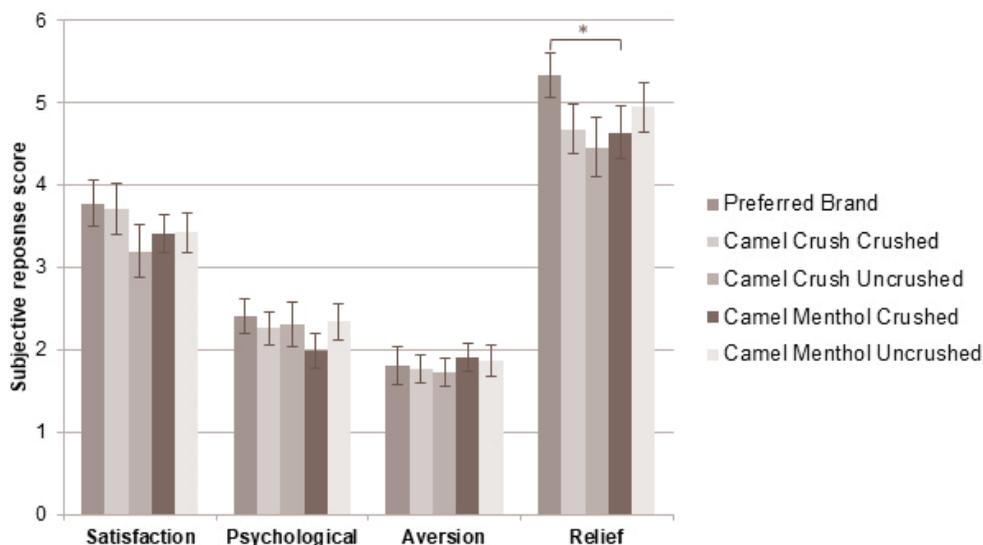
Eighteen items rated on a scale of 1 (not at all) to 7 (extremely); item scores for each subscale were averaged for 17 participants. Relief refers to relief of craving.
*Significance at p<0.05 using repeated measures ANOVA with Bonferroni post hoc tests.

Table 2. Average scores* of Sensory Scale items by cigarette product and cigarette replicate (1 and 2), 2017–2019

Sensory Scale items	Preferred Brand		Camel Crush crushed		Camel Crush uncrushed		Camel Menthol crushed		Camel Menthol uncrushed	
	1	2	1	2	1	2	1	2	1	2
Harshness	4.8 (0.77)	4.8 (0.61)	3.9 (0.43)	4.8 (0.49)	5.3 (0.53)	5.0 (0.56)	6.1 (0.55)	5.5 (0.52)	5.0 (0.62)	5.9 (0.39)
Heat	2.0 (0.63)	2.4 (0.58)	2.9 (0.54)	2.9 (0.53)	3.0 (0.67)	3.2 (0.68)	3.3 (0.70)	3.6 (0.69)	3.4 (0.67)	3.4 (0.65)
Draw	3.7 (0.82)	3.5 (0.74)	3.4 (0.73)	3.2 (0.58)	3.2 (0.76)	3.2 (0.63)	3.4 (0.60)	3.6 (0.61)	3.8 (0.68)	4.2 (0.56)
Taste	5.6 (0.67)	4.8 (0.60)	4.7 (0.63)	4.2 (0.52)	3.9 (0.60)	3.5 (0.52)	4.2 (0.57)	4.5 (0.49)	4.6 (0.47)	4.6 (0.48)
Satisfaction[a]	6.9 (0.70)	6.9 (0.65)	5.2 (0.66)	4.5 (0.62)	4.9 (0.61)	4.2 (0.64)	4.9 (0.67)	5.4 (0.47)	5.3 (0.62)	5.6 (0.49)
Burn rate	5.1 (0.42)	5.2 (0.44)	4.8 (0.47)	4.8 (0.32)	4.7 (0.44)	4.6 (0.47)	4.6 (0.28)	4.8 (0.29)	4.7 (0.40)	4.4 (0.34)
Mildness of taste	5.5 (0.50)	4.6 (0.45)	4.8 (0.46)	5.3 (0.56)	5.1 (0.58)	5.2 (0.51)	6.1 (0.48)	5.5 (0.45)	5.6 (0.48)	5.6 (0.42)
Too mild[a,b]	8.5 (0.58)	6.9 (0.44)	6.2 (0.63)	5.4 (0.61)	6.1 (0.55)	5.4 (0.65)	7.1 (0.52)	6.3 (0.48)	6.5 (0.52)	6.2 (0.45)
Strength[a,b]	7.1 (0.43)	6.2 (0.36)	5.5 (0.45)	5.2 (0.46)	5.3 (0.56)	5.4 (0.56)	6.7 (0.48)	6.2 (0.40)	6.1 (0.50)	5.9 (0.34)
Smoke harshness[c]	6.6 (0.86)	5.4 (0.70)	5.7 (0.62)	4.6 (0.51)	4.5 (0.68)	5.4 (0.65)	5.4 (0.61)	4.8 (0.47)	3.9 (0.57)	5.1 (0.51)
Aftertaste	3.8 (0.74)	3.6 (0.65)	4.0 (0.63)	3.6 (0.51)	3.5 (0.59)	3.8 (0.65)	4.2 (0.50)	4.3 (0.44)	3.9 (0.45)	4.2 (0.46)
Stale	8.4 (0.68)	6.1 (0.93)	6.5 (0.87)	6.2 (0.80)	6.2 (0.79)	5.0 (0.82)	7.0 (0.85)	7.5 (0.68)	9.9 (2.9)	7.4 (0.68)
Smoke strength[a]	7.4 (0.51)	6.5 (0.42)	5.2 (0.54)	4.8 (0.41)	5.6 (0.46)	5.8 (0.53)	7.1 (0.37)	6.3 (0.37)	6.1 (0.41)	6.3 (0.41)
Smoke smell	5.1 (0.86)	4.6 (0.72)	4.4 (0.59)	3.9 (0.55)	4.1 (0.46)	4.3 (0.51)	3.8 (0.56)	4.7 (0.53)	4.6 (0.58)	3.8 (0.49)

* Items were rated on a scale of 0 to 10; item scores were averaged, based on data for 17 participants; numbers in parentheses are mean standard errors (SE). a Significant brand effects. b Significant cigarette replicate effect. c Significant interaction between cigarette brand and replicate. Bolded items indicate statistical significance at p<0.05 using repeated measures ANOVA with Bonferroni post hoc tests.

Table 3. Summary of smoking topography measures[a] by cigarette product, 2017–2019

Measures	Preferred Brand	Camel Crush crushed	Camel Crush uncrushed	Camel Menthol crushed	Camel Menthol uncrushed	p[b]
Average number of puffs	12.9 (1.2)	12.0 (0.81)	12.8 (0.79)	11.3 (0.75)	11.0 (0.77)	0.103
Average puff volume in mL	52.4 (5.4)	49.3 (4.8)	50.8 (4.6)	47.9 (4.5)	49.1 (4.4)	0.333
Average total smoke volume in mL	644.7 (63.8)	565.0 (48.7)	618.3 (46.5)	521.2 (45.7)	522.8 (47.1)	0.124
Average puff duration in seconds	1.8 (0.13)	1.6 (0.10)	1.7 (0.11)	1.6 (0.10)	1.7 (0.13)	0.051
Average inter-puff interval in seconds	22.6 (2.0)	22.8 (2.3)	21.6 (2.3)	24.7 (3.5)	24.3 (3.1)	0.357

a Mean scores are presented based on data for 14 participants; numbers in parentheses are mean standard errors (SE). b Statistical significance was assessed using repeated measures ANOVA with Bonferroni post hoc tests.

$[F_{(4,64)}=2.6; p=0.045]$. Smoking urges scores were lowest prior to the participants smoking their preferred brand (PB: 3.2, SE=0.17), followed by scores prior to smoking Camel Crush crushed (CCC: 3.3, SE=0.19), Camel Menthol uncrushed (CMU: 3.5, SE=0.18), Camel Crush uncrushed (CCU: 3.6, SE=0.19), and Camel Menthol crushed (CMC: 3.6, SE=0.13). However, there were no significant differences between cigarette products when looking at the *post hoc* test comparisons. No significant differences were observed in mean nicotine withdrawal scores between cigarette products $[F_{(4,64)}=0.14; p=0.898]$.

DISCUSSION

This study assessed the effects of two primary delivery methods of menthol flavoring in cigarettes on sensory attributes, perceived health risk and appeal, and short-term smoking behavior between the participants' preferred brand, Camel Crush (crushed and uncrushed) and Camel Menthol (crushed and uncrushed). Differences in items from the Cigarette Evaluation Scale and Sensory Scale were seen, but primarily between the participants' preferred brand and one of the Camel cigarette products. The participants' preferred brand seemed to provide the

most relief of craving and satisfaction, and scored the highest on the smoke strength and harshness scale. This could be attributed to participants' familiarity with their own product. In addition, the first cigarette smoked at the session was rated higher on the too mild and strength scale than the second cigarette smoked, which was rated more neutral for these two items likely consistent with adjustment to the cigarette product and/or a regression to the mean phenomenon. However, despite the various concentrations of menthol and various delivery methods of menthol, these established menthol smokers did not demonstrate differences in smoking behavior or CO boost for Camel Crush and Camel Menthol products, crushed or uncrushed.

These findings are consistent and build upon findings from a study by Strasser et al.[6], which used Camel Crush (menthol in a filter capsule only) to assess the effect of menthol on smokers' sensory perceptions and short-term smoking behavior, and found that the total puff volume significantly increased when the participants switched from mentholated (crushed) to non-mentholated (uncrushed). However, this change in total puff volume did not translate to differences in biomarker levels. In the current study, total puff volumes for Camel Crush crushed and Camel Crush uncrushed were not significant. Furthermore, the total puff volumes for use of the Camel Crush crushed and the Camel Crush uncrushed in the current study were comparable to the study by Strasser et al.[6] Also, subjective ratings were comparable between the two studies when looking at the Camel Crush products. However, the study by Strasser et al.[6] noted significant differences in subjective ratings associated with taste and flavor (e.g. taste, mildness, aftertaste, and smoke smell). The current study found differences in similar subjective ratings, including overall taste and aftertaste, but there were also significant differences associated with relief of craving (e.g. craving, withdrawal symptoms, and enough nicotine) and sensation (e.g. irritation, strength, harshness, smoke harshness).

Strengths and limitations

This study is the first, to our knowledge, to examine two primary delivery methods of menthol available in the US (menthol added to the tobacco and menthol in a crushable capsule in the filter) and their effect on consumer sensory perceptions, perceived risk and appeal, and smoking behavior and biomarkers. Although this study allowed for participants to serve as their own controls, which eliminates the potential for confounding by demographic and smoking behavior characteristics, there are some limitations to this study. This study included current smokers and did not assess the effect of menthol on smoking initiation. In addition, the participants showed low nicotine dependence and our findings may not be generalizable to all smokers of menthol products. This study was designed as a pilot study with a limited sample size. We had to lower our targeted accrual from 24 to 18 due to recruitment challenges, but still had 85% power to detect a mean difference in sensory perceptions scores of 5.5. The CReSS Topography device malfunctioned during some study sessions, and one participant was given the wrong cigarette product during one study session, which resulted in missing data for some subjects, further depleting our sample. Finally, the integrity of the crushable filter capsule may have deteriorated over time and affected by storage in a freezer at -20°C. In the future, the shelf-life of the filter capsule should be assessed to better understand any potential changes or degradation of the filter capsule that occurs over time and at various temperatures.

CONCLUSIONS

In 2016, menthol cigarettes accounted for more than 30% of cigarettes in the United States[14]. Furthermore, while tobacco control efforts have mitigated overall smoking rates in the US, the prevalence of menthol cigarette use is decreasing at a slower rate than that of non-menthol cigarettes[1,15]. Smokers experience menthol as a minty taste and aroma that also produces anesthetic effects in the airways, which reduces the harshness of the cigarette smoke and may contribute to the slower decline in the prevalence of menthol cigarette use[1,2]. Although the crushable filter capsule allows greater concentration of menthol to be transferred into the smoke and may limit migration and dissipation of the menthol flavor over time or after the pack is opened[5], the delivery method and amount of menthol present did not seem to affect short-term smoking behavior, sensory perceptions, or perceived risk among a small sample of current,

established adult menthol smokers in the present study. In addition, despite a non-mentholated condition among menthol smokers, participants did not seem to perceive differences in delivery method of menthol or perceived risk ratings. It is possible that consumers of cigarette products may be attracted to the innovative technology of the crushable filter capsule as opposed to the taste experience, however, additional research is needed.

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