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Relationship between cigarette format and mouth-level exposure to tar and nicotine in smokers of Russian king-size cigarettes

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ABSTRACT

Differences in length and circumference of cigarettes may influence smoker behaviour and exposure to smoke constituents. Superslim king-size (KSSS) cigarettes (17 mm circumference versus 25 mm circumference of conventional king-size [KS] cigarettes), have gained popularity in several countries, including Russia. Some smoke constituents are lower in machine-smoked KSSS versus KS cigarettes, but few data exist on actual exposure in smokers. We investigated mouth-level exposure (MLE) to tar and nicotine in Russian smokers of KSSS versus KS cigarettes and measured smoke constituents under machine-smoking conditions. MLE to tar was similar for smokers of 1 mg ISO tar yield products, but lower for smokers of 4 mg and 7 mg KSSS versus KS cigarettes. MLE to nicotine was lower in smokers of 4 mg KSSS versus KS cigarettes, but not for other tar bands. No gender differences were observed for nicotine or tar MLE. Under International Organization for Standardization, Health Canada Intense and Massachusetts regimes, KSSS cigarettes tended to yield less carbon monoxide, acetaldehyde, nitric oxide, acrylonitrile, benzene, 1,3-butadiene and tobacco-specific nitrosamines, but more formaldehyde, than KS cigarettes. In summary, differences in MLE were observed between cigarette formats, but not systematically across pack tar bands.

1. Introduction

Differences in the length and circumference of cigarettes may influence smoker behaviour and exposure to cigarette smoke constituents. It has been shown that smokers of 100 mm length cigarettes demonstrated a higher mouth-level exposure (MLE) to tar and nicotine than smokers of similar machine-derived yield king-size (83–85 mm length) cigarettes (St Charles et al., 2010; Nelson et al., 2011). Additionally, higher tar and nicotine MLE was observed in smokers of Canadian king-size (84 mm length) cigarettes than in smokers of similar machine-derived yield Canadian regular (72 mm length) cigarettes (Côté et al., 2011).

Two studies have reported on the effect of cigarette circumference on the exposure of smokers to cigarette smoke constituents. St Charles et al. measured MLE to tar and nicotine in smokers of different US cigarettes. They reported a marginally lower mean MLE to tar for smokers of a 17 mm circumference, 100 mm length cigarette compared with that seen in smokers of a similar machine yield 24 mm circumference, 100 mm length cigarette (St Charles et al., 2010). In contrast, a study conducted among Romanian smokers reported no significant differences in MLE to tar and nicotine between smokers of conventional (25 mm circumference) and superslim (17 mm circumference) cigarettes of similar length and International Organization for Standardization (ISO) tar and nicotine yields (Ashley et al., 2011).

The mainstream machine-smoke emissions of six superslim (17 mm circumference) Canadian cigarette brands were compared with predicted emission data obtained from the Canadian Benchmark (Siu et al., 2013). The Canadian Benchmark is produced annually and is based on regression equations between the tar yields and the yields of a range of smoke analytes obtained from a minimum of 28 conventional circumference cigarettes from the Canadian market. This study reported lower mainstream smoke emissions per cigarette of carbon monoxide, carbonyls, volatiles and aromatic amines, but higher emissions of some smoke constituents such as formaldehyde, for the superslim products compared with the Canadian Benchmark. A subsequent study by the same group examined toxicological endpoints in response to exposure to cigarette smoke from superslim cigarettes (Mladjenovic et al., 2014) and noted reductions in the toxicity per mg total particulate matter (TPM) and per mg nicotine of the derived smoke, potentially as a consequence of the lower toxicant levels in these cigarettes. As a result, the authors of these two papers have expressed a concern that superslim cigarettes may be considered

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by consumers as being 'less harmful' than conventional circumference cigarettes. Although the superslim cigarettes generated lower machine-derived emissions, lower emission levels are not necessarily linked to a reduction in smokers' exposure to cigarette smoke constituents or to a reduced health risk. Therefore it is important to examine the exposure of smokers to mainstream smoke constituents from superslim cigarettes.

The primary aim of this study was to determine the effect of cigarette circumference (17 mm versus 25 mm) on smokers' MLE to tar and nicotine. We also measured smoke constituents under ISO, Health Canada Intense (HCI) and Massachusetts machine-smoking regimes. A further aim of the study was to measure smokers' puffing topography, in order to determine whether different physical parameters of cigarettes, such as cigarette pressure drop or draw resistance resulting from the reduction in cigarette circumference, influence puffing behaviour. The study was carried out in a Russian population due to the popularity of the superslim cigarette in this market.

2. Methods

2.1. Study products

We compared a king-size superslim (17 mm diameter; KSSS) with a conventional king-size product (25 mm diameter; KS) within the ISO pack tar bands of 1 mg, 4 mg and 7 mg. All products included in the study were commercially available and conformed to British American Tobacco standard manufacturing specifications. Each product was sourced from a single batch.

2.2. Study participants

A market research agency recruited a target of 60 healthy male and female smokers in approximately equal numbers to each of the six product groups described in Section 2.1. Full inclusion/exclusion criteria are provided in the Supplementary Information. In brief, participants eligible for inclusion in the study were aged between 21 and 50 years, had a self-reported average cigarette consumption of at least ten cigarettes per day of one of the study products and were required to have been smoking their usual brand for at least 6 months. Women were excluded if they reported that there was any possibility that they were pregnant. All participants were screened using a written questionnaire and provided written informed consent prior to the study.

2.3. Study protocol

Participants were required to attend three visits at a study site in Moscow over a 12 day period. At visit 1 (Day 1), all participants who met the inclusion criteria were briefed on the study protocol. Participants were provided with diaries in which to record daily cigarette consumption of cigarettes purchased themselves. Diaries covered consecutive days, labelled from Monday to Sunday (Days 2–8) and participants were provided with instructions on how to record the number of cigarettes they smoked each day. On Day 9, participants returned for visit 2 with the completed cigarette consumption diaries and each participant was provided with a filter cutter, training and instructions for cigarette-filter collection and sufficient cigarettes of their usual product to smoke on Days 10 and 11. Participants were asked to smoke the supplied cigarettes in their normal manner and environment, and to collect a minimum of 15 filters from the spent cigarettes. They were instructed only to collect filter tips from the cigarettes supplied. On Day 12, participants attended visit 3 to assess puffing topography and to provide the collected filters, which were then stored at 4 °C prior to part-filter analysis.

2.4. Analytical methods

2.4.1. Mouth-level exposure to tar and nicotine

Part-filter analysis was used to estimate smokers' MLE to tar and nicotine, as previously described (St Charles et al., 2009). In brief, the estimation of MLE relies on the relationship between the amount of tar and nicotine delivered to the smoker and the amount retained within the filter of the cigarette, as defined by calibration smoking.

Each participant's spent filters collected in the filter cutters were split randomly into three replicates each containing five tips, which were analysed independently on different days. The length of each filter tip was measured (±0.1 mm), and recorded before being extracted in methanol containing n-heptadecane as an internal standard (Ashley et al., 2011). The extracts were analysed for tip nicotine and tar using gas chromatography and ultraviolet (UV) absorbance (using a variable wavelength detector set at 310 nm as described previously (St Charles et al., 2009)), respectively. Calibration data were produced by machine smoking each product over a wide range of typical human smoking behaviour parameters.

MLE to nicotine was estimated for each replicate using the tip nicotine values measured from the smoker's spent filters and the linear regression equation obtained by plotting mainstream smoke nicotine yield versus tip nicotine data obtained during calibration smoking. Similarly, MLE to tar was estimated using the UV absorbance per tip data from the smoker's spent filters and the linear regression equation derived by plotting mainstream smoke nicotine-free dry particulate matter (NFDPM [tar]) yield versus UV absorbance per tip during calibration smoking.

2.4.2. Smoke constituent yields

Mainstream smoke yields of NFDPM (tar), nicotine, carbon monoxide and selected Hoffmann analytes were measured using ISO, Massachusetts and HCI machine-smoking regimes. These regimes, along with descriptions of the analytical methods used to measure smoke constituents in the present study, have been described in detail previously (McAdam et al., 2011, 2012) and on the British American Tobacco science website (www.bat-science.com).

2.4.3. Puffing topography

Puffing topography (puff volumes, intervals between puffs and number of puffs) was analysed by providing each participant with two cigarettes of their usual product which they were requested to smoke through a smoking analyser, with an interval between each cigarette of at least 20 min. Puffing topography data were recorded using a proprietary portable smoking analyser (SA7; developed in collaboration with C-Matic Limited, Crowborough, UK). The SA7 consists of a cigarette holder, with a unidirectional pressure transducer. The pressure transducer detects a pressure change across an orifice (2 mm), which is proportional to the flow rate (Slayford et al., 2012).

2.5. Data analysis

Minitab 16 statistical software (Minitab Inc., PA, USA) was used to conduct statistical analysis. MLE data are presented as mean ± standard deviation (SD). The physical characteristics of cigarettes and smoke toxicant data from machine-smoking regimes are presented as mean values. Analysis of variance general linear model (ANOVA GLM) was used to compare smokers' MLE and puffing topography data by smoker group. Where a significant differ-