A comparison of German smokers' exposure to tar and nicotine using analysis of smoked cigarette filters with yields from a range of machine smoking regimes

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Introduction

The International Organization for Standardization (ISO) regime for machine smoking cigarettes underestimates the yields of smoke obtained from cigarettes by smokers[1]. Although more intense regimes have been adopted in Canada[2] and the Commonwealth of Massachusetts, USA, these were introduced prior to the international ratification of the Framework Convention on Tobacco Control (FCTC). Despite the inclusion of provisions for testing and regulating cigarette emissions in the FCTC, the public health community have not yet reached consensus about an intense regime that could be recommended to the Conference of the Parties (COP) to the FCTC, however both COP and ISO continue to work on the subject.

In 2006 Hammond *et al* [3] reported that none of the proposed machine smoking regimes were significantly associated with saliva cotinine as a measure of nicotine uptake, nor with machine regimes based on mean measured human smoking behaviour. Also in 2006, St.Charles *et al* [4] reported a comparison between the analysis of smoked cigarette filters and nicotine biomarkers, where the best correlation was observed between filter analysis and urinary nicotine equivalents. Filter analysis estimates the maximum mouth-level of smoke constituents to which the smoker was exposed from the actual cigarettes smoked, in the smoker's normal environment, regardless of how or where smoked. It is also minimally invasive and enables sample collection from large numbers of subjects. The estimates of mouth-level exposure are reported as Yields In-Use (YIU).

A study has been undertaken to compare mouth-level exposure to tar and nicotine from cigarettes covering the ISO yields available in the German market with yields from the same cigarettes when smoked on a smoking machine using ISO and a range of current and potential regulatory intense smoking regimes.

Methods

At least 50 current smokers of each of 5 BAT cigarette products from the German market (ISO tar yields 1-10mg, and with approx. 10% market share) were recruited from several German cities to represent the age and gender distribution of consumers of the products. The details of the study were explained and participating subjects gave their informed consent. They were given 2 packets of their normal cigarettes and asked to collect a 10mm section of the mouth end (downstream of any ventilation holes) of at least 15 filters of their own smoked cigarettes using a special filter cutter/collector (Figure 1) over the subsequent 48 hours. No stipend was offered. The tar and nicotine contents of 3 replicates of 5 filter sections were determined using HPLC with UV detection (310nm) and GC with FID detection respectively after methanol extraction[4]. The yields of tar and nicotine delivered to the smoker were estimated using calibrations from cigarettes machine smoked using puffing regimes that encompass the normal volumes and flows generated by smokers[5].

The cigarettes were also smoked to the ISO regime[6], ISO TC126 WG9 Option B, Canadian and Massachusetts Intense regimes[1] and using the Kozlowski and O'Connor compensating regime[7] (Table 1). Tar and nicotine yields were determined using ISO methods[8-10]. Five replicates of 5 cigarettes were smoked per mainstream pad for each regime except the Canadian regime where only 3 cigarettes were smoked per pad to avoid 'breakthrough' of smoke through the collection pad. The machine smoking regimes used for calibration of the smoked filter analysis were different from the intense/compensating regimes.

Figure 1: Filter cutter/collector

Table 1: Machine smoking regimes

Regime	Puff Volume (mL)	Puff Duration (s)	Interval (s)	Vent Blocking (%)
ISO	35	2	60	0
Massachusetts	45	2	30	50
ISO TC126 WG9 Option B	60	2	30	50
Canadian Intense	55	2	30	100
Compensating	40*	2	60*	50

*Values for 1mg/cig ISO products; for each 0.1mg/cig nicotine below 1mg/cig at ISO, puff volume is increased by 4mL and puff interval is decreased by 4s[7].

References

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Results

Human and machine tar and nicotine data for each product were compared graphically and using ANOVA (general linear model) and Tukey's pairwise comparisons (Figures 2/3 and Tables 2/3). Yields labelled with the same letter are not significantly different ($p>0.05$); however, this analysis should be interpreted with caution since some assumptions for ANOVA are not met, namely the number of values and variances are unequal.

Table 2: Tar yields from human and machine smoking
(mg/cig; Mean ± 1sd, with Tukey's groupings)

Product	Human Tar in-use	Machine Regimes				
		ISO	Massachusetts	ISO TC126 WG9 Option B	Canadian Intense	Compensating
A	8.5 ± 3.5b	1.1 ± 0.1a	6.7 ± 0.5ab	9.2 ± 1.3bc	15.2 ± 2.5d	13.8 ± 0.2cd
B	15.9 ± 4.6b	6.1 ± 0.1a	15.7 ± 0.7b	19.1 ± 0.8b	20.6 ± 1.7b	14.6 ± 0.9b
C	15.3 ± 4.1b	7.0 ± 0.3a	15.9 ± 0.4bc	18.4 ± 0.6bc	20.3 ± 2.2c	14.3 ± 0.5bc
D	17.7 ± 5.5b	10.1 ± 0.5a	22.0 ± 1.5bc	25.8 ± 1.0c	27.1 ± 1.4c	14.6 ± 0.8ab
E	17.0 ± 5.4b	10.0 ± 0.4a	22.0 ± 0.9bc	25.9 ± 0.5c	27.3 ± 1.8c	15.3 ± 0.8ab
N	51 – 57	5	5	5	5	5

Figures 2 and 3: Mean tar and nicotine yields from human and machine smoking

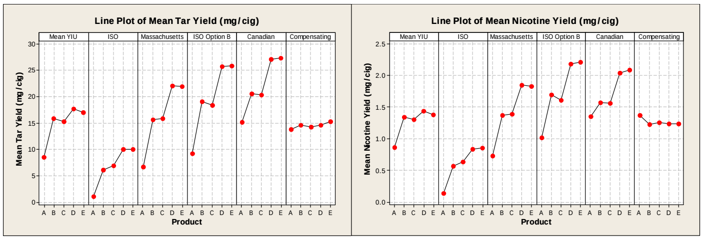

Table 3: Nicotine yields from human and machine smoking
(mg/cig; Mean ± 1sd, with Tukey's groupings)

Product	Human Nicotine in-use	Machine Regimes				
		ISO	Massachusetts	ISO TC126 WG9 Option B	Canadian Intense	Compensating
A	0.86 ± 0.35b	0.14 ± 0.01a	0.73 ± 0.04b	1.01 ± 0.06bc	1.35 ± 0.11c	1.37 ± 0.09c
B	1.34 ± 0.38b	0.57 ± 0.03a	1.37 ± 0.02b	1.69 ± 0.05b	1.57 ± 0.14b	1.22 ± 0.10b
C	1.30 ± 0.35b	0.64 ± 0.04a	1.39 ± 0.06b	1.61 ± 0.06b	1.56 ± 0.11b	1.26 ± 0.06b
D	1.44 ± 0.40b	0.84 ± 0.05a	1.84 ± 0.07bc	2.18 ± 0.14c	2.04 ± 0.14c	1.24 ± 0.10ab
E	1.38 ± 0.43b	0.85 ± 0.04a	1.83 ± 0.05bc	2.21 ± 0.05c	2.09 ± 0.21c	1.24 ± 0.07ab
N	51 - 57	5	5	5	5	5

Conclusions

- Human in-use yields of tar and nicotine show very wide variation due to differences in individuals' smoking behaviour.

- For Product A (the 1mg ISO product), the tar and nicotine yields from the Massachusetts and ISO TC126 WG9 Option B machine regimes are closest to the mean in-use yields, but the Canadian and Compensating regimes substantially overestimate in-use yields. For Product B (the 6mg ISO product) all intense machine regimes were similar to the human in-use yields. For Product C (the 7mg product) the nicotine yields from all machine regimes were similar to human in-use yields, but the tar yield from the Canadian intense regime was substantially higher. For Products D and E (the 10mg products), the Massachusetts and compensating regimes were similar to human in-use yields, but the ISO TC126 WG9 Option B and Canadian machine regimes were substantially higher than human in-use yields.

- The Massachusetts regime provided data that were most similar to human in-use yields for these products smoked by German smokers. The Compensating and ISO TC126 WG9 Option B regimes provided data that were similar to human in-use yields for some products but the Canadian regime over-estimated most human in-use yields. The Compensating regime was found to be impractical for routine use in a testing laboratory because of the number of smoking machine changes and checks required, as recognised by the WHO Tobacco Laboratory Network[11].

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