RESEARCH PAPER

Marlboro UltraSmooth: a potentially reduced exposure cigarette?

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Aim: To compare relative toxic emissions scores (RTE) of the carbon filter cigarette Marlboro UltraSmooth (MUS), against regular Marlboro, Holiday, and British Columbian brands.
Method: MUS cigarettes were purchased in Tampa, Florida; Marlboro regular and Holiday were purchased in Auckland, New Zealand, and all emissions tested by Labstat International Inc, Kitchener, Ontario under Health Canada Intensive (HCI) machine-smoking conditions (55 ml puff per 30 seconds, filter ventilation holes blocked) against: (1) previous same brand emissions tested under ISO (International Organization for Standardization) conditions; (2) ISO and HCI average emissions for 16 regular brands sold in British Columbia (BC), the reference standard. Toxicants, selected by toxicological risk assessment, enabled estimation of an RTE per brand, and RTE per mg of nicotine.
Results: The BC standard for RTE in both ISO and HCI test modes, including metals and nitrosamines, was set at 100. Hereafter excluding them, RTE in ISO mode for BC was 97, MUS 4, Marlboro 102, and Holiday regular 99; and in HCI test mode BC was 97, MUS 42, Marlboro regular 107, and Holiday 95. From ISO to HCI, MUS total puff volume increased 50%, from 252 ml to 380 ml; nicotine yield increased 2.6 fold. Normalising for nicotine (RTE per mg nicotine), in ISO test mode, the BC standard was 97, MUS 10, Marlboro regular 124, and Holiday regular 107. In HCI mode, however, MUS/nicotine at 104 exceeded the average BC standard of 97; Marlboro regular was 137, and Holiday regular 97; MUS ranked sixth highest among 18 regular brands. MUS contained 103 mg of carbon in its 304 mg filter, which was 55% ventilated.
Conclusion: The combined acetate-carbon filter of MUS performed best at low smoke volumes on ISO testing. Under more smoker-realistic intensive machine testing, and correcting for relative nicotine concentration and compensatory smoking, MUS increased the RTE, for all toxicants combined, for carcinogens, and for cardiovascular toxicants, compared with most regular brands. MUS was not a potentially reduced-exposure product (PREP) under smoker-realistic test conditions, and thus would not be expected to reduce overall harm. It is unrealistic to expect that even major design changes, as seen in MUS, or a regulatory framework to enforce such changes, could reduce cigarette smoking mortality risks to acceptable levels.

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Consensus is lacking on which smoke chemicals cause most harm. Pryor[1] focused on free radicals as cancer initiators, but these are not routinely measured; Hecht emphasised the importance of particulate matter, particularly for lung cancer.[2]

Toxicological risk assessment approaches[3–7] emphasised volatile organic compounds (VOCs) and included non-carcinogenic toxicants in assessing the overall total toxicity of smoke. Using this method, and using published potencies and threshold values, we found VOCs contributed more toxicity than tar for carcinogens, respiratory and cardiovascular toxicants. When toxicities were combined on the basis of their share of cigarette deaths, VOCs provided up to four-fifths of the potential emission toxicity.[7 8]

The ability of smoke particulates, painted on mice, to induce cancer, led to the use of cellulose acetate (CA) filters, which could capture smoke particles by adhesion and let gases and volatiles pass through. If, however, VOCs are the dominant toxicants in smoke, then activated charcoal filters which adsorb gases on to their large surface area provide the best chance of lowering smoke toxicity.

Cigarette company chemists had shown since 1965 that charcoal filters could reduce overall toxicity of cigarette smoke by up to 40% under ISO (International Organization for Standardization) conditions.[9] In 2002 we tested two variants of charcoal filter Mild Seven cigarettes, the world's top selling charcoal filter brand. The token amount of carbon in the CA filter failed to reduce emissions compared with a CA filter brand of similar tar yield.[9]

Still seeking a cigarette with reduced emissions, we selected Marlboro UltraSmooth (MUS), with a combined CA and carbon filter. It was in other respects a conventional filter cigarette, carrying the Marlboro brand name; and unlike previous attempts at safer cigarettes, might just become popular in its three test markets in the United States. If MUS was eventually sold in New Zealand and internationally, we wanted to know in advance how its emissions would compare with those of established popular brands (New Zealand Holiday and Marlboro, respectively).

The research design relied on differences in smoke emissions according to brand and smoke machine test mode, to allow us to infer whether smokers, in switching from popular regular brands to MUS, would reduce overall exposure to smoke toxicants. Using two test conditions

Abbreviations: BC, British Columbia; CA, cellulose acetate; Cd, cadmium; CRI, cancer risk index; HCI, Health Canada Intensive; HCN, hydrogen cyanide; ISO, International Organization for Standardization; MUS, Marlboro UltraSmooth; NNK, 4-(N-nitrosomethylamino)-1-(3-pyridyl)-1-butanone); NCRI, non-cancer risk index; NNN, N-nitrosonornicotine; PREP, potentially reduced exposure product; REL, reference exposure levels; RTE, relative toxic emissions; VOCs, volatile organic compounds

(ISO and Health Canada Intensive (HCI)) we compared MUS, Marlboro regular, Holiday regular, against a fourth, from 16 BC reference brands averaged. The toxicants studied were those contributing most toxicity on risk assessment. Emissions were incorporated into a single overall toxicity emissions score per brand for each test condition. We did not, however, test any human volunteers, or perform any switching study or clinical trial of MUS versus other brands.

This study investigates whether MUS qualifies as a potential reduced exposure product (PREP), the first step to qualifying as a safer cigarette. If the smoke machine found no reduction in emissions, however, the smoker's exposure to, and future harm from, those emissions would not be reduced.

METHOD

A carton of 200 MUS cigarettes purchased at retail in Tampa, Florida, was tested by Labstat International Inc, Kitchener, Ontario under Health Canada intensive machine smoking (HCI), and compared with emissions from: (1) one carton each of Marlboro regular and New Zealand regular Holiday brands purchased in Auckland, New Zealand, tested at Labstat under HCI; (2) Tampa-type MUS cigarettes, tested by Philip Morris under ISO conditions[10]; (3) published averaged of 16 British Columbia (BC) brands in 2001 as the reference standard; (4) Marlboro regular brand in ISO and HCI test modes.

Selection of test brand variant

Manufacturer Philip Morris test marketed three variants of the MUS cigarette brand in 2005. Avoiding one variant with a novel filter, and another containing only 45 mg carbon, we selected the 120 mg carbon-on-tow variant test marketed in Tampa.[10]

Comparison and reference cigarettes

Marlboro is the leading international brand, and its Australian-made regular variant is sold widely in New Zealand. The nitrosamines and metals tested refer to this variant, and to the BC brands. In 2004 in New Zealand, Holiday was the most popular manufactured cigarette brand sold (29% volume share) and its regular variant the most popular (17% of all cigarettes sold).[11] Reference brands were 16 BC brands yielding over 0.9 mg nicotine (ISO), comprising all such brands sold in BC in 2001, and tested by Labstat in ISO and HCI modes.[12] All cigarettes tested were king-size, of 83 mm in length.

Selection of smoke machine testing method

Mainstream smoke was analysed by the HCI method (55 ml puffs lasting 2 seconds each, every 30 seconds, 100% of holes covered (55,2,30,100)) to represent the behaviour of intensive smokers, who are most at risk of subsequent disease.[13 14] Many smokers today take puffs of 50 ml, two to three times a minute.[15] The puffs taken by a machine smoking Marlboro regular cigarettes[16] under HCI test modes implies a total machine puff volume per cigarette of 583 ml (all vents blocked), as against the smoke inhaled from ventilated popular low nicotine (615 ml) and medium nicotine (523 ml) brands.[15] For all brands tested, data from previous testing under the ISO method of testing (35,2,60,0) were available for comparison. For MUS, instead of ISO, Philip Morris used the virtually identical Federal Trade Commission method, and for simplicity, ISO test mode is used to describe either method in this paper.

Toxicant testing

Three observations per brand were obtained for cresols, and for tar, nicotine and other analytes, five observations per brand (table 1). Labstat's test methods, as specified by Health

Table 1 Cancer potency factors and non-cancer reference exposure levels; and smoke emissions of Marlboro UltraSmooth and 18 other cigarette brands in two smoking machine test modes

	Puff count	Tar	CO	HCN	Acetaldehyde	Formaldehyde	Butadiene	Acrylonitrile	Benzene	Acrolein	m, p, o-Cresols
Cancer potency factors[6] $(\mu g/m^3)^{-1}$					0.0000027	0.000006	0.00017	0.00029	0.000029		
REL[6] $\mu g/m^3$			10000, CV	9.00, CV	9.00, R	3.00, R		5.00, R	60.00, CV	0.06, R	600, CV
Puff number, emissions/cigarette	**n**	**mg**	**mg**	**µg**	**µg**	**µg**	**µg**	**µg**	**µg**	**µg**	**µg**
ISO smoking machine condition											
Marlboro UltraSmooth 2004[10] (SD)	8.1 (0.3)	4.47 (0.11)	5.9 (0.24)	4.06 (0.4)	21.8 (6.5)	3.6 (0.3)	0.80 BLQ	0.14 BLQ	0.43 (0.12)	<0.45 BLQ	3.7* NM
Marlboro Regular 2004[16] (SD)	8.3 (0.3)	13.1 (0.6)	12.3 (0.9)	166.7 (11.2)	517 (45)	26.2 (0.8)	43.3 (2.8)	10.5 (0.7)	42.3 (2.4)	47.4 (3.6)	27.0 (1.5)
Holiday Regular 2003	7.6 (0.3)	14.3 (0.4)	13.6 (0.6)	138.0 (4)	545 (59)	72.5 (10.9)	46.9 (1.0)	8.5 (0.45)	40.6 (2.4)	68.5 (6.7)	NM
Mean, of 16 BC brands 2001 (SD)	NK	12.5 (1.4)	13.4 (1.7)	114.9 (21.2)	579.3 (80.9)	62.6 (17.6)	48.3 (6.2)	8.7 (1.1)	49.5 (5.0)	77.2 (12.9)	17.1 (2.1)
HCI smoking machine condition											
Marlboro UltraSmooth 2005 (SD)	6.9 (0.3)	19.4 (0.8)	22.5 (1.2)	124.0 (18)	742.0 (54)	34.3 (4.1)	55.9 (7.7	5.6 (1.0)	14.3 (2.3)	48.6 (10.3)	7.5 (0.7)
Marlboro Regular 2005 (SD)	10.1 (0.3)	35.4 (2.7)	27.8 (1.0)	337.0 (7)	1318.0 (48)	137.0 (8)	98.1 (7.8)	19.0 (0.9)	86.1 (7.8)	162.0 (3)	23.4 (1.9)
Holiday Regular 2005 (SD)	10.0 (0.4)	35.0 (2.4)	25.8 (1.7)	310.0 (25)	1195.0 (49)	150.0 (6)	81.7 (4.4)	16.8 (2.4)	72.2 (5.4)	141.0 (9)	33.1 (3.0)
Mean of 16 BC brands 2001 (SD)	NK	32.5 (2.5)	29.4 (2.9)	268 (34)	1081 (85)	131.2 (30.7)	102.9 (11.5)	18.9 (3.0)	91.7 (8.7)	149.2 (20.5)	31.1 (3.1)

Cancer potency factors and REL from Fowles and Dybing's table 1.[6] http://tc.bmjjournals.com/cgi/data/12/4/424/DC1/1
All data from Labstat Canada except for Philip Morris.[10]
*No data; taken as half the HCI value.
BLQ, one or more values below limit of quantification; CO, carbon monoxide; CV, cardiovascular; HCI, Health Canada Intensive; HCN, hydrogen cyanide; NK, not known; NM, not measured; R, respiratory effect; REL, reference exposure levels; SD, standard deviation.

Canada under Canadian Tobacco Reporting Regulations,[17] may have differed a little from the methods used by Philip Morris to test MUS in ISO mode.[10]

Toxicant selection

Toxicants were selected by toxicological risk assessment—method and limitations previously described.[4 6] Californian Environmental Protection Agency databases,[4 6] accessed in January 2006, listed carcinogens and toxicants recognised by the state of California. Toxicants known to be present in cigarette smoke and which had known cancer potency factors and reference exposure levels, were included, and observed emissions used to estimate cancer (CRI) and non-cancer (NCRI) risk indices for each toxicant, and each test mode, as described.[4 6 7] The selected 16 toxicants had previously accounted for 81% of the known carcinogenic relative toxic emissions (RTE), and over 99% of cardiovascular and of respiratory RTE in a low-yield Holiday brand in ISO test mode.[7] Not testing heavy metals (cadmium, arsenic, lead) and nitrosamines (NNN, (N-nitrosonornicotine) and NNK (4-(N-nitrosomethylamino)-1-(3-pyridyl)-1-butanone)) across BC brands[12] diminished overall RTE by a only a few percentage points, and as their testing was particularly expensive, they were omitted, leaving 11 toxicants to be tested, as listed in table 1. Tar, which can vary in carcinogenicity, was not used to estimate RTE.[6]

Estimation of toxicity by cause-of-death grouping

Toxicants were rated for potency and dose in each brand's smoke, and by their main target organs (vascular, respiratory, cancer). The California Environmental Protection Agency database lists each toxicant's target organ/disease groupings.[6] Based on the toxicant emissions in each brand's smoke, the cancer (CRI), cardiovascular, and respiratory non-cancer risk indices (NCRI)[6] were calculated for each brand, separately for ISO and HCI modes. The RTE for each disease group was weighted according to each disease group's contribution to the 1.94 million (16.9% of all) deaths attributed to cigarette smoking in 45 developed countries in 2000. Of these cigarette deaths, 37.0% were attributed to cancer, 33.2% to cardiovascular, and 17.8% to respiratory diseases. Other medical diseases not assigned to specific toxicants were attributed with 12.0% of cigarette deaths.[8]

Estimation of overall brand toxicity

We produced four RTE scores for each brand—two each for ISO and intensive modes, with each mode scored before, and then after normalising for nicotine, as shown in fig 1. The RTE was the sum of risks for cancer, cardiovascular and non-cancer respiratory disease in table 2, dividing this sum by 0.88 to adjust for the 12% of deaths not assigned to specific toxicants. For each brand and disease group or target organ system, when nitrosamines and metals emissions were included, the RTE for the mean for 16 regular BC reference brands tested under HCI was standardised to 100. These low-ventilation BC brands constituted a suitable standard because their emissions were not distorted by dilution of smoke, and included all brands sold in BC in 2001.

RESULTS

Physical characteristics

MUS, as sold in Tampa, Florida, contained an estimated 104 mg of coconut-shell activated carbon in its 34 mm, 304 mg carbon-on-CA filter. Marlboro regular, Holiday regular, and the 16 BC brands contained CA-only filters. Tobacco per cigarette was 543 mg for MUS,[10] 750 mg for Marlboro regular,[16] and 702 mg for Holiday regular.[18] All brands were 83 mm in length, with the tobacco rod 49 mm for MUS,[10] and for Holiday and Marlboro, each 58 mm, with CA filter of 25 mm.[19]

MUS contained a total of 10 mg nicotine per cigarette,[10] though its packet displayed no tar or nicotine yield labels. On ISO results, MUS's nicotine yield (0.4 mg) and tar (4 mg) were both low (tables 1 and 2).

In table 1, for the regular brands, acrolein, with its very low threshold to adverse respiratory effects, and appreciable smoke yield, was the main respiratory toxicant. Butadiene had the highest cancer risk index, due to a high cancer potency factor, and appreciable yield in smoke. In ISO test mode, especially before adjusting for nicotine, MUS toxicant emissions were very low, and in HCI test mode, were under half the values for Marlboro regular and Holiday regular, but were not so greatly reduced in the case of carbon monoxide, butadiene, and acetaldehyde.

Marlboro regular had substantially higher emissions than Holiday and the BC brands, whereas Holiday regular emissions were similar to those of the BC brands.

The charcoal filter was highly efficient for small smoke volumes; however, at the smoke volumes typically inhaled by smokers, this ability of the MUS cigarette to filter out harmful VOCs was greatly reduced. After normalising for nicotine (result 4 in fig 1) to allow for the compensatory over-smoking expected from this low-yield cigarette, the apparent advantage of the MUS cigarette over regular unventilated cigarettes disappeared.

Emissions

As the second to last column of table 2 shows, RTE for MUS, before normalising for nicotine, was the lowest for any brand under both ISO and HCI test modes.

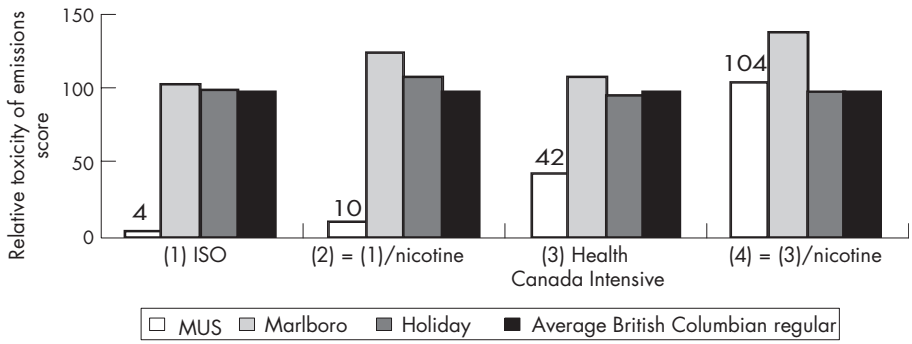

Figure 1 Relative emissions toxicity scores for Marlboro UltraSmooth (MUS), Marlboro regular and New Zealand Holiday regular, standardised against British Columbia regular brands, in ISO (International Organization for Standardization) and Health Canada Intensive machine test modes. With and without normalisation for nicotine yield.

Table 2 Relative toxicity emissions scores for Marlboro Ultrasmooth and selected conventional brands. Standardised against British Columbian regular brands, in ISO and HCI test modes, with and without adjustment for nicotine yield

Brand	Test year	Test mode	Nicotine yield (SD) mg	Toxicity of emissions relative to those of 16 BC regular brands weighted by each disease group's attributable mortality: Carcinogens	CV toxicants	Resp toxicants	RTE score, all disease groups: RTE	RTE / nicotine ratio¶
Fraction of mortality attributable to disease group*				0.370	0.332	0.178	1.000	1.000
Excluding metals and nitrosamines								
Marlboro UltraSmooth†	2005	ISO	0.42(0.009)	0.006	0.023	0.001	3.6	10.1
Marlboro regular‡	2004	ISO	0.98 (0.05)	0.336	0.455	0.110	104.3	126.0
Holiday regular NZ	2003	ISO	1.10 (0.04)	0.331	0.386	0.158	101.3	109.0
16 BC regular§	2001	ISO	1.18 (0.10)	0.344	0.332	0.177	97.0	97.1
Marlboro UltraSmooth	2005	HCI	1.09 (0.04)	0.153	0.158	0.060	42.1	104.2
Marlboro regular	2005	HCI	2.11 (0.13)	0.343	0.404	0.193	106.8	136.5
Holiday regular	2005	HCI	2.64 (0.17)	0.296	0.371	0.169	94.8	97.0
16 BC regular***	2001	HCI	2.71 (0.23)	0.345	0.332	0.177	97.0	97.0
Including metals and nitrosamines								
Marlboro regular‡	2005	HCI	2.11(0.13)	0.382	0.407	0.194	111.6	142.8
Marlboro regular‡	2004	HCI	2.38 (0.19)	0.405	0.568	0.169	129.8	147.1
16 BC regular§	2001	HCI	2.71 (0.23)	0.370	0.332	0.178	100.0	100.0

*Peto *et al.* Cigarette mortality by disease group for 45 developed countries.[8] www.ctsu.ox.ac.uk
†Marlboro UltraSmooth was tested in Federal Trade Commission (virtually the same as ISO) test mode by Philip Morris. All other data from Labstat Canada.
‡Metals and nitrosamine values for 2005 (and all values dated 2004): Counts 2004.[16]
§Mean values, Government of British Columbia.[11]
¶RTE was divided by nicotine, then standardised to BC = 100.
BC, British Columbia; CV, cardiovascular; HCI, Health Canada Intensive; ISO, International Organization for Standardization; Resp, respiratory, RTE, relative toxic emissions; SD, standard deviation.

Including metals and nitrosamines

(1) RTE and RTE/nicotine for BC brands were standardised to average 100 in both ISO and HCI test modes. (2) In HCI mode RTE increased by 5 percentage points for Marlboro regular (NNN 318 ng, NNK 232 ng, cadmium (Cd) 136 ng per cigarette),[15] and by 3 percentage points for the BC regular brands (NNN 59 ng, NNK 120 ng, Cd 191 ng)[16] per cigarette (table 2).

RTE excluding nitrosamines and metals

(1) In ISO test mode, BC was 97, MUS 4, Marlboro 102, and Holiday regular 99. (2) In HCI mode, BC was 97, MUS 42, Marlboro regular 107, and Holiday 95.

RTE per mg of nicotine, excluding nitrosamines and metals

(1) In ISO test mode, BC was 97, MUS 10, Marlboro regular 124, and Holiday regular 107. (2) In HCI mode, BC was 97, MUS was 104, Marlboro regular 137, and Holiday regular 97. Among BC brands MUS ranked fifth highest for RTE/nicotine, fourth highest for CRI/nicotine, second highest for cardiovascular NCRI/nicotine, and lowest for respiratory NCRI /nicotine.

Correlation of RTE with component toxicants

In HCI test mode, mean RTE across 19 brands tested ($n = 19$) correlated most highly with acrolein ($r = 0.94$), HCN ($r = 0.94$) and acrylonitrile ($r = 0.90$), butadiene ($r = 0.87$), carbon monoxide ($r = 0.83$), and tar ($r = 0.78$, $p < 0.0001$). RTE/nicotine was correlated with HCN ($r = 0.49$, $p = 0.03$) but not significantly with RTE ($r = 0.32$). The overall RTE was highly correlated with the RTE for carcinogens ($r = 0.95$), and with the RTEs for cardiovascular and respiratory toxicants, respectively ($r = 0.94$, $r = 0.95$, $p < 0.0001$).

Ventilation, puff count, total puff volume, and elasticity

The filter tip of MUS was 55% ventilated. Puff counts for MUS were 30% lower than for the other two brands, partly explained by MUS's shorter tobacco rod. In moving from ISO to HCI: (1) total puff volume for MUS increased by one-half (ISO: 7.2 puffs*35 ml/puff = 252 ml per cigarette; HCI: 6.9 puffs*55 ml = 380 ml per cigarette) but doubled for Marlboro regular and Holiday regular brands; (2) MUS nicotine yield increased 2.6-fold, and toxicants also increased disproportionately to the total puff volume of smoke, whereas the increase in nicotine for the two other brands was proportionate.

DISCUSSION

Principal findings

MUS does not qualify as a PREP in this study. The carbon filter removed toxicants from 250 ml of smoke in ISO mode; however, in HCI test mode, from 380 ml smoke, closer to smoking behaviour, it removed half the toxicants, but after adjustment for nicotine MUS's RTE was sixth highest out of 18 regular brands. On the smoke data available, MUS implies reduced potential exposure to toxicants in the smoke of filter cigarettes, but only if most smokers smoked like a machine in ISO test mode, which they do not.

Labelling and claims

Cigarette tar labels are usually based on ISO readings, and this cigarette could claim 96% reduction of emissions, communicating a most welcome reduced-risk message to the health-conscious smoker, while denying elsewhere on the packet onsert any claim of reduced risk. This would be grossly misleading, as in HCI mode, the RTE per mg of nicotine for MUS was higher than for Holiday, the most popular New Zealand brand (fig 1, result 4).

Machine and human smoking

The ISO smoke machine results are one thing; but how MUS is actually smoked by the average individual and the range of individuals could be very different. MUS offers each smoker great flexibility and variability in smoking it, due to high elasticity, and substantial filter ventilation.

The reference standard

The BC regular brands denote market-wide average cigarette toxicity before filters were highly ventilated, and provide a

What this paper adds

The Marlboro UltraSmooth (MUS) cigarette, test marketed in the United States in 2005, with combined acetate and carbon filter, is arguably ''state of the art'', designed to reduce smoke emissions. It removes almost all emissions if the machine inhales 250 ml of smoke, and removes half from 380 ml of smoke, but on a per milligram of nicotine basis, implying a doubling of smoke inhaled to obtain the same amount of nicotine, MUS smoke per cigarette was estimated to be potentially more toxic than for 13 out of 18 regular brands tested (Marlboro, Holiday and 16 from British Columbia). On this basis, MUS does not qualify as a potentially reduced-exposure product (PREP).

logical standard, rather than other Marlboro brands already in the test market. In HCI test mode, for example, RTE for Marlboro regular in table 2 was 12% higher, and its RTE/nicotine 43% higher, than the reference standard (BC = 100).

Limitations and strengths

The RTE estimates are relative only, comparing only the identifiable, measurable toxicants in mainstream smoke entering the smoke machine. The RTE score assumes that each toxicant's effect is additive, and not multiplied or subtracted, or otherwise interactive. No allowance is made for the unmeasured effects of free radicals as toxicants, and other as yet unrecognised or uncharacterised toxicants.

All results were from Labstat, except the MUS ISO results from Philip Morris' own laboratories. Findings are limited to the brands studied, and to the time of purchase. In 2005, MUS cigarettes for ISO testing came direct from the manufacturer: those HCI tested were purchased at retail. For Holiday and Marlboro regular, ISO results date from 2003 and 2004, respectively, while HCI tests refer to 2005. Inter-batch variation was a possibility. The weight of carbon sprinkled on the tow in the MUS filter proved difficult for Labstat to estimate precisely.

Compensatory smoking

We expressed RTE per mg of nicotine, conveniently if crudely, to adjust for compensatory smoking. Future studies may use smoking topography to measure total puff volume and the smoking machine can be set to those puff volumes. MUS could be expected to behave like other low-yield ventilated cigarettes studied this way,[14 20] and found to have high puff volumes, and high toxicant emissions.

Findings in relation to other studies

In a recent study of ventilated-filter low tar cigarettes (mean 8.5 mg tar, 0.7 mg nicotine ISO), 56 US smokers averaged a total puff volume per cigarette of 615 ml,[15] producing nicotine, tar and carbon monoxide emissions at least twice the ISO values. In another study of low tar smokers of (4 mg tar, 0.8 mg nicotine yield ISO) cigarettes recorded an average total puff volume of 779 ml per cigarette.[20] Either way, the low yield MUS cigarette could be expected to result in smokers inhaling much more smoke per cigarette than the smoke machine in ISO or HCI mode.

Unanswered questions and future research

An RTE score based on smoke machine testing is not enough for regulation. Puffing and other data[15] are needed to supplement the HCI smoke machine RTE score, and inform regulators whether a lower RTE score also means less smoke and toxicants in the mouth (delivery), reduced lung exposure (inhalation), or reduced toxicants entering body fluids (absorption). A full range of analytical chemistry and a modernised suite of toxicological test results of the toxicants as delivered, exhaled, and absorbed, would be needed for each cigarette brand variant.

No matter how adequate the testing, however, this study questions whether any filter technology can detoxify smoke adequately after combustion. Even if the current one in two risk estimate of early death from cigarette smoking[21] could be most improbably reduced by cigarette redesign to a one in four risk, the modified cigarette would remain unacceptably dangerous. In contrast, low nitrosamine smokeless tobacco products, while still providing addictive nicotine, can reduce smoking risks by at least 90%.[22]

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Authors' competing interests: Both authors have conducted contract research for health agencies but not for tobacco industry groups. The first author chairs a tobacco policy trust (www.smokeless.org.nz)

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The Lighter Side