NIH Public Access
Author Manuscript
Public Health. Author manuscript; available in PMC 2011 December 1.

Published in final edited form as:
Public Health. 2010 December ; 124(12): 667–674. doi:10.1016/j.puhe.2010.08.018.

Cigarette characteristic and emission variations across high-, middle- and low-income countries

R.J. O'Connor[a,*], **K.J. Wilkins**[a], **R.V. Caruso**[a], **K.M. Cummings**[a], and **L.T. Kozlowski**[b]

[a] Department of Health Behavior, Division of Cancer Prevention and Population Sciences, Roswell Park Cancer Institute, Elm and Carlton Streets, Buffalo, NY 14263, USA

[b] School of Public Health and Health Professions, University at Buffalo, SUNY, Buffalo, NY, USA

SUMMARY

Objectives—The public health burden of tobacco use is shifting to the developing world, and the tobacco industry may apply some of its successful marketing tactics, such as allaying health concerns with product modifications. This study used standard smoking machine tests to examine the extent to which the industry is introducing engineering features that reduce tar and nicotine to cigarettes sold in middle- and low-income countries.

Study design—Multicountry observational study.

Methods—Cigarettes from 10 different countries were purchased in 2005 and 2007 with low-, middle- and high-income countries identified using the World Bank's per-capita gross national income metric. Physical measurements of each brand were tested, and tobacco moisture and weight, paper porosity, filter ventilation and pressure drop were analysed. Tar, nicotine and carbon monoxide emission levels were determined for each brand using International Organization for Standardization and Canadian Intensive methods. Statistical analyses were performed using Statistical Package for the Social Sciences.

Results—Among cigarette brands with filters, more brands were ventilated in high-income countries compared with middle- and low-income countries [$\chi^2(4)=25.92$, $P<0.001$]. Low-income brands differed from high- and middle-income brands in engineering features such as filter density, ventilation and paper porosity, while tobacco weight and density measures separated the middle- and high-income groups. Smoke emissions differed across income groups, but these differences were largely negated when one accounted for design features.

Conclusions—This study showed that as a country's income level increases, cigarettes become more highly engineered and the emissions levels decrease. In order to reduce the burden of tobacco-related disease and further effective product regulation, health officials must understand cigarette design and function within and between countries.

[*]Corresponding author. Tel.: +1 716 845 4517., Richard.Oconnor@roswellpark.org (R.O'Connor).

Ethical approval
None sought.

Competing interests
KMC has provided expert testimony in court cases involving the tobacco industry.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

NIH-PA Author Manuscript
NIH-PA Author Manuscript
NIH-PA Author Manuscript

Keywords

Tobacco; Emissions; Regulation

Introduction

The public health burden of tobacco use is shifting towards the developing world, such that by 2030, more than 80% of the world's tobacco-related deaths will be in developing countries.[1] This change is occurring, in part, because the tobacco manufacturers appear to be applying some of the same marketing tactics that made them successful in recruiting and retaining customers in high-income countries in middle- and low-income countries. One can anticipate that cigarette manufacturers will, as a matter of course, continually update their product lines to adapt to shifting markets and consumer needs.[2] As public awareness of the health risks of smoking gradually increased over the past 50 years, tobacco manufacturers responded by introducing filtered and so-called 'low tar and nicotine' brands into the marketplace. Trends towards lower tar brands worldwide are likely in response to consumers' growing awareness of the negative health effects of smoking.[3,4] The marketing of lower tar cigarettes is unfortunately aided by well-meaning government regulations that include International Organization for Standardization (ISO)/Federal Trade Commission tar, nicotine and carbon monoxide (TNCO) yields on packs, which merely draws attention to meaningless distinctions among brands.[5] Labelling packages with this information is troublesome because TNCO emission numbers are misleading to consumers, who do not realize that these numbers are not related to the level of risk for a particular product.

Cigarette design plays a major role in determining TNCO yields in tests using machine smoking. Cigarette filters, usually made from cellulose acetate filaments, are able to reduce the machine yields of tar and nicotine by 40–50%.[6] In high-income countries, such as the USA, filtered cigarettes became popular in the early 1950s as the demand for lower smoke yields grew, following the initial reports of lung cancer associated with smoking, and now represent the majority of the market.[6] The addition of filter ventilation to cigarettes is a method widely used by cigarette manufacturers to achieve lower machine-measured TNCO yields, able to achieve lower smoke yields than filters, paper permeability and tobacco processing would be able to achieve alone.[6] Ventilation holes appear as a ring of tiny perforations that circle the filter end of the cigarette. This design feature allows air to enter the holes when a puff is taken, which reduces the amount of tobacco which is consumed, and dilutes the tobacco smoke coming from the mouth end.[6] Filter ventilation is successful in lowering TNCO yields when cigarettes are smoked by machines for testing, but they are not as successful for people. People knowingly and unknowingly subvert this design feature by blocking the ring of holes by a number of different methods. The holes are blocked by smokers' fingers, lips and, in some cases, even tape.[7] Smokers may also defeat ventilation by taking larger, more frequent puffs or smoking to a shorter butt length to compensate.[7] Internal documents available as a result of litigation reveal that the tobacco industry capitalized on the limitations of the smoking machine protocol used to report TNCO yields to consumers and regulators; cigarettes were promoted as 'low yield' when they only produced low yield under unrealistic smoking conditions.[8]

Given the growth of tobacco use in the developing world and the history of tobacco product design in developed countries, the purpose of the current study is to examine whether the design of cigarettes varies by country development level. It was hypothesized that countries in different stages of the tobacco epidemic and awareness of the health risks of smoking would have cigarettes that differ in their design features.

NIH-PA Author Manuscript NIH-PA Author Manuscript NIH-PA Author Manuscript

NIH-PA Author Manuscript
NIH-PA Author Manuscript
NIH-PA Author Manuscript

Methods

Cigarette acquisition and storage

The cigarettes analysed in this project originated in 10 different countries (Table 1). Prior research had focused almost exclusively on cigarettes from the USA, Canada, the UK and Australia,[9,10] so cigarettes from these markets were not considered in the current study. Field teams in each country purchased 18 packs each of popular brands of cigarettes in that market from three distinct retail locations. Packs were purchased in the Czech Republic and Greece in 2005, and packs from the remaining countries were purchased in 2007. The packs were shipped via common courier to Roswell Park Cancer Institute, where they were catalogued and stored at −20°C until analysis. In accordance with ISO 3402:1999, the packs were conditioned for a minimum of 48 h at 22±2.0°C and 60±2.0% relative humidity in an environmental chamber prior to testing.

Income categories

The World Bank divides national economies according to gross national income (GNI) per capita, expressed in US dollars[a]. The countries chosen for comparison were divided into low-income (up to $3595), middle-income ($3596–11,115) and high-income ($11,116 or more) categories on this basis.

Physical measurements

Five cigarettes were selected from each pack after conditioning for physical analysis. Digital calipers were used to measure the length of the entire cigarette, the length and diameter of the tobacco rod, and the length and diameter of the filter. Filter weight measurements were made gravimetrically using an analytical balance. The tipping paper was removed from each filter, and measurements of its length and the presence of any vent holes were performed using a transparent ruler and a light box.

Tobacco moisture and tobacco weight

Tobacco moisture and tobacco weight were analysed using a HR83 Moisture Analyzer (Mettler-Toledo, Columbus, OH, USA), and procedures were adapted from the Mettler-Toledo Application Data Sheet[b]. The moisture content was determined as the percentage change in weight after heating the tobacco from five cigarettes with a halogen bulb at 125°C.

Paper porosity

The level of porosity of the cigarette paper was measured using a PPM1000M paper porosity device (Cerulean, Milton Keynes, UK). Five cigarette papers were tested for each brand, with five readings taken for each paper, and the 25 total measurements were averaged.

Filter ventilation and pressure drop

Measurements of the cigarette filter ventilation and pressure drop were taken using a KC3 combined dilution/pressure drop instrument (Borgwaldt-KC, Richmond, VA, USA). The average was taken from five cigarettes tested with this device.

---

[a]http://data.worldbank.org/about/country-classifications/world-bank-atlas-method.
[b]http://us.mt.com/global/en/home/supportive_content/application_methods/CigaretteTobacco.rxHgAwXLuMvM.MediaFileComponent.html/CigaretteTobacco_en.pdf (last accessed 10/09/2009).

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Tar, nicotine and CO emissions

The determination of TNCO emissions levels was performed by an independent laboratory (Labstat, Kitchener, ON, Canada) using both ISO and Canadian Intensive (CI) methods. The international standard method, ISO 3308, requires a puff volume of 35 ml, a puff duration of 2.0 s and a puff frequency of one per 60 s. Butt length is specified as 23 mm for non-filter cigarettes and the length of filter overwrap plus 3 mm for filtered cigarettes. A modified protocol is used to test the cigarette under 'intense' smoking conditions. According to Health Canada's intense smoking protocol, 100% of the filter vents are blocked by a single layer of tape covering the filter and tipping paper. The puff volume is 55 ml and the puff frequency is 30 s, but other parameters are identical to ISO 3308.

Statistical analysis

Data analysis was completed using Statistical Package for the Social Sciences Version 14.0 (SPSS Inc., Chicago, IL, USA). Pearson correlations were used to identify univariate associations between physical and design measurements and TNCO emissions under both the ISO and CI regimens, and for high-, middle- and low-income countries. Discriminant function analysis was used to determine design features that best discriminated among the three development levels, with Wilks' lambda used to test for significance. Multivariate repeated-measures analysis of variance was used to examine associations between development level and TNCO emissions, including adjustment for design features. Here, Hotelling's trace F-test for multivariate significance was used, with the Greenhouse–Geisser correction for violations of the sphericity assumption applied in univariate tests.

Results

Table 2 shows the mean values for design features on cigarettes across countries. Initial analysis revealed that all of the brands from high-income countries had filters, compared with 95% of the middle-income brands and 86% of the low-income brands with filters. If one breaks this out further into whether those filters are ventilated, a pattern emerges where 95% of cigarettes in high-income countries had vented filters, compared with 87.5% in middle-income countries and 44.4% in low-income countries; this difference was statistically significant [$\chi^2(4)=25.92$, $P<0.001$]. The majority of products popular in Indonesia were kreteks, which differed significantly in terms of several characteristics (higher tobacco rod length, weight, density and filter density, all $P<0.001$) from other products purchased in the other low-income countries. For subsequent multivariate analyses, only filtered, standard diameter cigarettes were considered. This reduced the overall sample size to 99 varieties.

Multivariate analysis

To determine whether some combination of design features could be used to distinguish between filtered cigarettes sold in countries of differing income levels, a discriminant function analysis was conducted. Two discriminant functions were derived, with a Wilks' Lambda value of 0.275 [$\chi^2(24)=108.99$, $P<0.001$]. A significant association between putative groups and predictors was seen [$\lambda=0.615$, $\chi^2(11)=41.145$, $P<0.001$]. The first discriminant function (comprised of filter density, ventilation, moisture, filter weight, paper porosity, tipping paper length, rod density, filter diameter, filter length) maximally separates the low-income products from the remaining groups, while the second function (rod diameter, tobacco length, tobacco weight) separates middle- from high-income products, with low-income products falling in between. The two functions accounted for 66.3% and 33.7% of the variance, respectively. Classification statistics indicated an overall accuracy of 78.5%, with 71.4% of low-income, 80.6% of middle-income and 80.6% of high-income cases correctly classified.

NIH-PA Author Manuscript NIH-PA Author Manuscript NIH-PA Author Manuscript

A second approach examined whether brands made by the three largest multinational producers (Philip Morris, British-American Tobacco, Japan Tobacco International; *n*=57), available in countries at all income levels, were systematically different from brands produced by other manufacturers (*n*=36). A two-way multivariate analysis of variance examined the effects of income level and manufacturer on the set of cigarette design variables. Overall, a significant multivariate interaction effect of manufacturer*income level was observed [$F(24,150)=3.428$, $P<0.001$, partial $\eta^2=0.354$], along with main effects of both manufacturer [$F(12,76)=4.754$, $P<0.001$, partial $\eta^2=0.429$] and income level [$F(24,150)=5.496$, $P<0.001$, partial $\eta^2=0.468$]. Drilling down to univariate effects, the interaction was statistically significant for ventilation, filter density, filter weight and moisture (Table 3). The brands from the major manufacturers were observed to be, on average, largely identical across countries with different income levels, while the other brands showed greater variation.

Examination of tar, nicotine and CO yields

Emissions for all brands were compared under the ISO and CI smoking regimens; results of these basic comparisons are shown in Table 4. In general, cigarettes in the low-income countries were found to have significantly higher puff counts compared with products from middle- and high-income markets regardless of regimen. To account for this difference, yields were indexed per litre of smoke for subsequent analysis, following a recommendation of Rickert et al.[11]

A multivariate repeated-measures analysis of variance was used to examine the change in TNCO emissions per litre of smoke simultaneously among the three income levels. (As above, unfiltered cigarettes, kreteks and superslims were omitted from the analysis.) A significant multivariate difference in yields by development level was found [$F(6,176)=11.166$, $P<0.001$, partial $\eta^2=0.276$], along with a main effect of testing method (ISO vs CI) [$F(3,89)=136.596$, $P<0.001$, partial $\eta^2=0.822$] and a significant interaction [$F(6,176)=9.286$, $P<0.001$, partial $\eta^2=0.240$]. Univariate results showed that TNCO yields increased from ISO to CI methods, as expected, but the patterns of change depended on income level to differing extents.

To examine the impact of design features on these relative differences between ISO and CI yields adjusted for smoke volume, the design features were entered into the model as covariates. A backward elimination approach was taken to remove those design features that did not contribute explanatory power from the model, with a criterion of $P>0.10$ for removal. The final model included tobacco length, tipping paper length, paper porosity, ventilation, tobacco weight and filter density. Even with the inclusion of these covariates, development level remained significantly associated with emissions per litre (Table 5). However, accounting for the cigarette design variables eliminates most of the differences observed between ISO and CI TNCO levels between high-, middle- and low-income countries.

As a secondary approach to the question of how design influences emissions, the study examined whether income levels differed in terms of average design features at a given tar yield; the 9–11 mg range was chosen given the European Union upper limit. For this tar level, significant differences were observed by income level in filter density and pressure drop, both of which increased with higher income (data not shown).

Discussion

This study set out to compare the physical design characteristics and smoke emissions of cigarettes from high-, middle- and low-income countries, and found that cigarette design

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

does differ between countries with low, middle and high levels of income. The general trend is that as the country's income level increases, cigarettes become more highly engineered and the emissions levels decrease. This was confirmed by discriminant analysis, where a cluster of engineering elements best distinguished cigarettes from low-income countries from those in middle- and high-income countries.

Multivariate analysis showed that when TNCO were adjusted for the amount of smoke produced (i.e. expressed per litre), income level differences persisted, although they were minimized by adjustment for a cluster of cigarette engineering features, the key being filter ventilation. This is consistent with results observed in other studies.[12–15] Increased filter ventilation decreases emissions levels in ISO machine testing, albeit in an illusory way, and lower emissions levels are desirable in areas under pressure from health concerns (and, in some cases, government regulations) to produce 'less harmful' cigarettes.[6,16] Even after these adjustments, cigarettes from lower-income countries still emitted more nicotine. This may be a further marker of design, as the cigarettes from lower-income countries, particularly those made by local manufacturers, may be less likely to contain engineered tobaccos such as reconstituted sheet and expanded tobacco, with which rod nicotine content can be altered.[17]

Clearly, a wide range of cigarette characteristics exists, and the constellations of characteristics appear to differ across country income levels. The design features appear to explain most of the difference in TNCO yields observed. This reinforces the point that cigarettes can be manipulated by manufacturers to conform to local tastes and product regulatory policies. The World Health Organization Framework Convention on Tobacco Control calls for future regulation of the contents and emissions of products under Article 9,[8] and a firm scientific basis is needed to support such regulation. It is clear that the requirements of any regulatory scheme for tobacco products needs to encompass product design as well as toxicant emissions. At the Third Conference of Parties (2008), the working group charged with developing guidelines for Articles 9 and 10 noted that design features of products should be included in any disclosure and testing requirements. In particular, they identified product dimensions, tipping paper length, ventilation, paper porosity, moisture content, packing density, and filter length and density as key metric for which reliable measures exist.[18] In addition, the TobReg proposalfor upper limits on specific harmful constituents addresses issues of variable cigarette design in part by adopting a machine smoking regimen that occludes vents and using nicotine-normalized emissions.[19] However, other researchers have gone further to call for proscriptions on the use of certain design features, primarily filter vents, by manufacturers.[16,20,21] These approaches are not necessarily in conflict. Where deliberate efforts are proposed to reduce toxicants, regulators ought to have some say over what methods for compliance are or are not legitimate. Indeed, it is reasonable to question why, in the case of cigarettes, which are exceedingly dangerous with no accompanying societal benefit, manufacturers should be permitted to continue designing their products without restriction.

Given the growing concentration of the cigarette market in a relatively small number of transnational corporations,[22] it is likely that engineered cigarettes which provide an illusion of safety will only become more and more common in low- and middle-income countries unless regulators intercede. Indeed, this study found that products made by the major transnationals were practically identical across income levels. Inaction could leave smokers there vulnerable to the same marketing tactics used in Western markets since the 1970s.[6,21,23] Indeed, there is evidence that pack colours, for example, can signal product strength to smokers,[24,25] even if actual design differences between products are minimal.[26]

This research may be limited by the sample of cigarette brands used for the study. It would be unreasonable to test every brand of cigarettes available in each country that participated, so the brands selected may not be a perfectly representative sample. Some brands were chosen according to popularity and market share, as determined by the representative sending the brands to the laboratory. This could affect the results if cigarettes with particular characteristics were over- or under-represented in the sample. Also, the current study did not examine other aspects of design, such as the use of additives, which are also believed to impact smokers' perceptions of products.[27]

Innovations in product design are motivated by a variety of factors, including increasing health concerns, public health regulations and manufacturing cost. In order to continue making progress in the improvement of public health by reducing the burden of tobacco-related disease, health officials must possess strong scientific understanding of cigarette design and function, and the ways in which products in different markets are similar and divergent. This way, effective, relevant and enforceable regulations may be placed on tobacco products.

Acknowledgments

The authors thank the research teams in each country for procuring the cigarettes used in this research project.

Funding

This work was supported by the US National Cancer Institute via the Roswell Park Cancer Institute Transdisciplinary Tobacco Use Research Center (P50CA111236) and by P01CA138389. The study sponsor had no role in study design, collection, analysis and interpretation of data, writing of the manuscript, nor the decision to submit the manuscript for publication.

References

1. World Health Organization. WHO Report on the global tobacco epidemic, 2008 – the MPOWER package. [last accessed 16/06/2010]. Available at: http://www.who.int/tobacco/mpower/2008/en/index.html
2. Wayne GF, Connolly GN. Regulatory assessment of brand changes in the commercial tobacco product market. Tob Control 2009;18:302–9. [PubMed: 19528042]
3. Euromonitor International. The world market for tobacco. Chicago: Euromonitor International; 2006.
4. Euromonitor International. Tobacco – world. Chicago: Euromonitor International; 2007.
5. Hammond D, Wiebel F, Kozlowski LT, Borland R, Cummings KM, O'Connor RJ, McNeill A, Connolly GN, Arnott D, Fong GT. Revising the machine smoking regime for cigarette emissions: implications for tobacco control policy. Tob Control 2007;16:8–14. [PubMed: 17297067]
6. Kozlowski LT, O'Connor R. Cigarette filter ventilation is a defective design because of misleading taste, bigger puffs, and blocked vents. Tob Control 2002;11:40–50.
7. Hammond D, Collishaw NE, Callard C. Secret science: tobacco industry research on smoking behavior and cigarette toxicity. Lancet 2006;367:781–7. [PubMed: 16517278]
8. World Health Organization. WHO Framework convention on tobacco control. 2005 [last accessed 16/06/2010]. Available at: http://www.who.int/tobacco/framework/WHO_FCTC_english.pdf
9. O'Connor RJ, Hammond D, McNeill A, King B, Kozlowski LT, Giovino GA, Cummings KM. How do different cigarette design features influence the standard tar yields of popular cigarette brands sold in different countries? Tob Control 2008;17(Suppl 1):i1–5. [PubMed: 18768453]
10. Kozlowski LT, Mehta NY, Sweeney CT, Schwartz SS, Vogler GP, Jarvis MJ, West RJ. Filter ventilation and nicotine content of tobacco in cigarettes from Canada, the United Kingdom, and the United States. Tob Control 1998;7:369–75. [PubMed: 10093170]

NIH-PA Author Manuscript NIH-PA Author Manuscript NIH-PA Author Manuscript

NIH-PA Author Manuscript
NIH-PA Author Manuscript
NIH-PA Author Manuscript

11. Rickert WS, Collishaw NE, Bray DF, Robinson JC. Estimates of maximum or average cigarette tar, nicotine, and carbon monoxide yields can be obtained from yields under standard conditions. Prev Med 1986;15:82–91. [PubMed: 3714662]
12. Counts ME, Hsu FS, Laffoon SW, Dwyer RW, Cox RH. Mainstream smoke constituent yields and predicting relationships from a worldwide market sample of cigarette brands: ISO smoking conditions. Regul Toxicol Pharmacol 2004;39:111–34. [PubMed: 15041144]
13. Calafat AM, Polzin GM, Saylor J, Richter P, Ashley DL, Watson CH. Determination of tar, nicotine, and carbon monoxide yields in the mainstream smoke of selected interrnational cigarettes. Tob Control 2004;13:45–51. [PubMed: 14985595]
14. Stephens WE. Dependence of tar, nicotine and carbon monoxide yields on physical parameters: implications for exposure, emissions control and monitoring. Tob Control 2007;16:170–6. [PubMed: 17565136]
15. O'Connor RJ, Li Q, Stephens WE, Hammond D, Elton-Marshall T, Cummings KM, Giovino G, Fong GT. Cigarettes sold in China: design, emissions, and metals. Tob Control. in press.
16. Kozlowski LT, O'Connor RJ, Giovino GA, Whetzel CA, Pauly J, Cummings KM. Maximum yields might improve public health if filter vents were banned: a lesson from the history of vented filters. Tob Control 2006;15:262–6. [PubMed: 16728759]
17. Hoffmann D, Hoffmann I. The changing cigarette, 1950–1995. J Toxicol Environ Health 1997;50:307–64. [PubMed: 9120872]
18. Elaboration of guidelines for implementation of Articles 9 and 10 of the WHO Framework Convention on Tobacco Control: progress report of the working group. Conference of the Parties to the WHO Framework Convention on Tobacco Control, Third session; Durban, South Africa. 17–22 November 2008; [last accessed 16/06/2010]. Available at: http://apps.who.int/gb/fctc/PDF/cop3/FCTC_COP3_6-en.pdf
19. Burns DM, Dybing E, Gray N, Hecht S, Anderson C, Sanner T, O'Connor R, Djordjevic M, Dresler C, Hainaut P, Jarvis M, Opperhuizen A, Straif K. Mandated lowering of toxicants in cigarette smoke: a description of the World Health Organization TobReg proposal. Tob Control 2008;17:132–41. [PubMed: 18375736]
20. King B, Borland R. The 'low-tar' strategy and the changing construction of Australian cigarettes. Nicotine Tob Res 2004;6:85–94. [PubMed: 14982692]
21. Borland R, Fong GT, Yong HH, Cummings KM, Hammond D, King B, Siahpush M, McNeill A, Hastings G, O'Connor RJ, Elton-Marshall T, Zanna MP. What happened to smokers' beliefs about light cigarettes when 'light/mild' brand descriptors were banned in the UK? Findings from the International Tobacco Control (ITC) Four Country Survey. Tob Control 2008;17:256–62. [PubMed: 18426868]
22. World Health Organization. Tobacco industry interference with tobacco control. Geneva: WHO Press; 2008.
23. Elton-Marshall T, Fong GT, Zanna MP, Jiang Y, Hammond D, O'Connor RJ, Yong H-H, Li L, King B, Li Q, Borland R, Cummings KM, Driezen P. Beliefs about the relative harm of 'light' and 'low tar' cigarettes: findings from the International Tobacco Control (ITC) China survey. Tob Control. (in press).
24. Hammond D, Parkinson C. The impact of cigarette package design on perceptions of risk. J Public Health (Oxf) 2009;31:345–53. [PubMed: 19636066]
25. Hammond D, Dockrell M, Arnott D, Lee A, McNeill A. Cigarette pack design and perceptions of risk among UK adults and youth. Eur J Public Health 2009;19:631–7. [PubMed: 19726589]
26. King B, Borland R, Abdul-Salaam S, Polzin G, Ashley D, Watson C, O'Connor RJ. Divergence between strength indicators in packaging and cigarette engineering: a case study of Marlboro varieties in Australia and the USA. Tob Control. (in press).
27. Rabinoff M, Caskey N, Rissling A, Park C. Pharmacological and chemical effects of cigarette additives. Am J Public Health 2007;97:1981–91. [PubMed: 17666709]

NIH-PA Author Manuscript NIH-PA Author Manuscript NIH-PA Author Manuscript

Table 1

Summary of countries, income levels and brands studied

Country	Income level	Number of brands	FCTC Status	Leading manufacturer[a]	Emissions, content and design regulations
New Zealand	High	11	Party	BAT	None
Cyprus	High	12	Party	BAT	Subject to EU 10:1:10 limits on tar, nicotine and CO emissions; yields displayed on packs
Greece	High	10	Party	Philip Morris	Subject to EU 10:1:10 limits on tar, nicotine and CO emissions; yields displayed on packs
Czech Republic	High	9	Signatory	Philip Morris	Subject to EU 10:1:10 limits on tar, nicotine and CO emissions; yields displayed on packs
Mexico	Middle	15	Party	Philip Morris	Yields displayed on packs[b]
Turkey	Middle	15	Party	Philip Morris	Yields displayed on packs
Romania	Middle	10	Party	BAT	Subject to EU 10:1:10 limits on tar, nicotine and CO emissions; yields displayed on packs
Nepal	Low	15	Party	Local	None
Indonesia	Low	15	Not signed or ratified	Philip Morris	Yields displayed on packs
India	Low	6	Party	Local	Authority exists to set maximum limits and require reporting
Total		118			

FCTC, Framework Convention on Tobacco Control; BAT, British-American Tobacco; EU, European Union; CO, carbon monoxide.

[a]Data from Shafley O, Eriksen M, Ross H, Mackay J. *Tobacco atlas*. 3rd edn. Atlanta: American Cancer Society; 2009.

[b]At time of study. Per regulations introduced in 2009, yields are no longer displayed on packs.

NIH-PA Author Manuscript
NIH-PA Author Manuscript
NIH-PA Author Manuscript

Table 2

Basic differences in physical parameters by income level

		Mean	SE	Minimum	Maximum	ANOVA	*P*
Cigarette length (mm)	Low	81.02	1.27	68.33	90.30	F(2,115)=4.060	0.020
	Middle	85.20	1.32	68.86	99.72		
	High	84.52	0.58	79.36	98.61		
Rod diameter (mm)	Low	7.75	0.09	6.71	9.93	F(2,115)=3.747	0.027
	Middle	7.92	0.04	7.57	9.92		
	High	7.64	0.08	5.41	8.07		
Tobacco length (mm)	Low	64.76	1.00	56.90	81.69	F(2,115)=4.515	0.013
	Middle	62.94	0.98	54.93	73.20		
	High	61.12	0.55	56.02	70.13		
Length of tipping paper (mm)	Low	25.61	0.80	17.56	32.31	F(2,108) =6.109	0.003
	Middle	28.54	0.69	18.09	35.86		
	High	28.60	0.53	20.21	34.78		
Filter length (mm)	Low	18.98	0.79	11.06	27.10	F(2,103)=5.434	0.006
	middle	21.38	0.87	9.22	27.12		
	High	22.61	0.66	6.85	30.21		
Filter weight (g)	Low	0.10	0.01	0.05	0.16	F(2,102)=6.791	0.002
	middle	0.12	0.01	0.05	0.16		
	High	0.12	0.00	0.04	0.16		
Number of vent rows	Low	0.75	0.23	0.00	6.00	F(2,6781)=8.0212.966	0.00
	Middle	1.26	0.22	0.00	4.00		
	High	2.64	0.56	0.00	6.00		
Distance (mm) – mouth end to nearest row of vents	Low	13.15	0.47	11.00	15.70	F(2,55)=4.928	0.011
	Middle	12.09	0.24	10.30	14.55		
	High	11.73	0.25	10.20	15.00		
Per-cigarette tobacco weight (g)	Low	0.84	0.05	0.64	1.86	F(2,115)=12.71	0.00
	Middle	0.69	0.01	0.59	0.90		
	High	0.65	0.01	0.37	0.80		

NIH-PA Author Manuscript
NIH-PA Author Manuscript
NIH-PA Author Manuscript

		Mean	**SE**	**Minimum**	**Maximum**	**ANOVA**	***P***
Ventilation (%)	Low	11.52	2.51	0.00	47.04	F(2,99)=19.188	0.00
	Middle	25.95	1.68	1.30	40.70		
	High	36.94	3.46	1.56	81.94		
Paper porosity (CORESTA)	Low	36.40	2.07	11.42	60.21	$\chi^2(3)=11.07$	0.004[a]
	Middle	56.87	7.88	22.70	334.31		
	High	45.17	2.48	21.05	72.45		

SE, standard error; ANOVA, analysis of variance.

[a]By Kuskal-Wallis test.

NIH-PA Author Manuscript
NIH-PA Author Manuscript
NIH-PA Author Manuscript

Table 3

Mean values for selected design parameters by income level and manufacturer type

Dependent variable	Manufacturer	Income level	Mean	SE	F(2,93)	*P*	η^2
Ventilation	Other	Low	7.724	3.562	14.803	<0.001	0.254
		Middle	23.238	4.215			
		High	49.187	3.848			
	PM/BAT/JTI	Low	24.751	5.038			
		Middle	26.945	2.614			
		High	26.582	2.721			
Filter density	Other	Low	97.648	2.219	10.869	<0.001	0.200
		Middle	115.402	2.625			
		High	121.274	2.397			
	PM/BAT/JTI	Low	112.361	3.138			
		Middle	113.674	1.628			
		High	113.628	1.695			
Filter weight (g)	Other	Low	0.078	0.007	4.937	0.009	0.102
		Middle	0.119	0.009			
		High	0.117	0.008			
	PM/BAT/JTI	Low	0.126	0.010			
		Middle	0.117	0.005			
		High	0.126	0.006			
% Moisture	Other	Low	14.461	0.242	4.465	0.014	0.093
		Middle	14.718	0.286			
		High	15.780	0.261			
	PM/BAT/JTI	Low	15.194	0.342			
		Middle	16.144	0.177			
		High	15.819	0.185			

PM, Philip Morris; BAT, British-American Tobacco; JTI, Japan Tobacco International; SE, standard error.

NIH-PA Author Manuscript
NIH-PA Author Manuscript
NIH-PA Author Manuscript

Table 4

Differences in International Organization for Standardization (ISO) and Health Canada puff counts and yields by country income level

		Mean	SE	Minimum	Maximum	ANOVA	*P*
ISO Puff count	Low	10.12	0.64	6.49	21.53	F(2,110)=13.17	0.00
	Middle	7.70	0.21	5.05	10.76		
	High	7.75	0.11	6.31	9.90		
ISO Tar	Low	22.27	2.18	6.56	60.03	F(2,110)=36.79	0.00
	Middle	10.69	0.25	8.04	13.78		
	High	7.62	0.62	0.46	13.82		
ISO Nicotine	Low	1.33	0.09	0.62	2.81	F(2,110)=33.18	0.00
	Middle	0.85	0.03	0.45	1.16		
	High	0.81	0.07	0.12	1.18		
ISO CO	Low	13.23	0.70	7.05	23.21	F(2,91)=20.33	0.00
	Middle	9.44	0.27	5.16	12.38		
	High	7.15	0.54	0.64	12.90		
Canadian puff count	Low	13.37	0.84	8.35	27.06	F(2,110)=18.17	0.00
	Middle	9.89	0.28	7.42	14.46		
	High	9.32	0.23	6.50	13.30		
Canadian Intense tar	Low	47.18	3.44	28.09	110.07	F(2,110)=28.78	0.00
	Middle	31.34	0.57	23.06	38.47		
	High	27.02	0.68	18.09	34.80		
Canadian Intense nicotine	Low	2.75	0.15	1.60	5.94	F(2,110)=17.87	0.00
	Middle	2.13	0.08	0.95	2.98		
	High	1.92	0.06	1.22	2.54		
Canadian Intense CO	Low	28.47	1.24	19.57	51.41	F(2,110)=5.83	0.00
	Middle	25.32	0.56	11.96	30.74		
	High	24.99	0.39	19.09	30.20		

CO, carbon monoxide; SE, standard error; ANOVA, analysis of variance.

NIH-PA Author Manuscript NIH-PA Author Manuscript NIH-PA Author Manuscript

Table 5

Multivariate between- and within-subject tests for development level and cigarette design parameters with respect to tar, nicotine and carbon monoxide per litre of smoke under International Organization for Standardization (ISO) and Canadian Intense (CI) testing conditions

Variable	Hotelling's trace	F	Test df	Error df	Sig.	Partial η^2
Intercept	2.921	75.940	3	78	<0.001	0.745
Income group	0.379	4.858	6	154	<0.001	0.159
Ventilation	1.063	27.649	3	78	<0.001	0.515
Tobacco weight	0.402	10.462	3	78	<0.001	0.287
Tipping paper length	0.374	9.713	3	78	<0.001	0.272
Tobacco rod length	0.258	6.715	3	78	<0.001	0.205
Paper porosity	0.239	6.222	3	78	0.001	0.193
Filter density	0.2	5.204	3	78	0.002	0.167
Smoking method (CI vs ISO)	0.231	6.017	3	78	0.001	0.188
Method * income group	0.503	6.452	6	154	<0.001	0.201
Method * vent	9.037	234.954	3	78	<0.001	0.900
Method * tobacco weight	0.343	8.917	3	78	<0.001	0.255
Method * porosity	0.272	7.062	3	78	<0.001	0.214
Method * rod length	0.23	5.979	3	78	0.001	0.187
Method * tipping	0.134	3.497	3	78	0.019	0.119
Method * filter density	0.107	2.772	3	78	0.047	0.096