

Chinese 'low-tar' cigarettes do not deliver lower levels of nicotine and carcinogens

Quan Gan,¹ Wei Lu,² Jiying Xu,² Xinjian Li,² Maciej Goniewicz,^{1,3} Neal L Benowitz,^{1,3} Stanton A Glantz^{1,4}

¹Center for Tobacco Control Research and Education, University of California, San Francisco, California, USA

²Shanghai Center for Disease Control and Prevention, Shanghai, China

³Division of Clinical Pharmacology and Experimental Therapeutics, Departments of Medicine and Biopharmaceutical Sciences, University of California, San Francisco, California, USA

⁴Department of Medicine and Cardiovascular Research Institute, UCSF Comprehensive Cancer Center, University of California, San Francisco, California, USA

Correspondence to

Stanton A Glantz, Center for Tobacco Control Research and Education, University of California, San Francisco, 530 Parnassus Avenue, Suite 366, San Francisco, California 94143-1390, USA; glantz@medicine.ucsf.edu

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ABSTRACT

Background Low-tar cigarette smoking is gaining popularity in China. The China National Tobacco Corporation (CNTC) promotes low-tar cigarettes as safer than regular cigarettes.

Methods A total of 543 male smokers smoking cigarettes with different tar yields (15 mg, regular cigarettes, 10–13 mg low-tar cigarettes and <10 mg low-tar cigarettes) were recruited in Shanghai, China, who then completed a questionnaire on smoking behaviour and provided a urine sample for analysis of the nicotine metabolites cotinine and trans-3'-hydroxycotinine. A total of 177 urine samples were selected at random for the analysis of the carcinogens polycyclic aromatic hydrocarbon metabolites (PAHs) (1-hydroxypyrene, naphthols, hydroxyfluorenes and hydroxyphenanthrenes) and the tobacco specific nitrosamine 4-(methylnitrosamino)-1-(3-pyridyl)-butanone (NNK) metabolites, 4-(methylnitrosamino)-1-(3-pyridyl)-butanol (NNAL) and NNAL-glucuronide. Values were normalised by creatinine to correct for possible distortions introduced by dilution or concentration of the urine.

Results Smokers of low-tar cigarettes smoked fewer cigarettes per day ($p=0.001$) compared to smokers of regular cigarettes. Despite this lower reported consumption, levels of cotinine, trans-3'-hydroxycotinine and PAHs in urine of people smoking low-tar cigarettes were not correlated with nominal tar delivery of the cigarettes they smoked. Urine concentrations of NNAL were higher in smokers of lower tar than higher tar cigarettes.

Conclusions Chinese low-tar cigarettes do not deliver lower doses of nicotine and carcinogens than regular cigarettes, therefore it is unlikely that there would be any reduction in harm. CNTC's promotion of low-tar cigarettes as 'less harmful' is a violation of the World Health Organization Framework Convention on Tobacco Control, which China ratified in 2005.

INTRODUCTION

Beginning in the 1950s, tobacco companies embarked on an effort to design cigarettes with lower yields of carcinogenic tar, with the hope that doing so would lead to less dangerous cigarettes.^{1–3} While this effort failed to produce less dangerous cigarettes, the companies discovered that cigarettes with lower tar yields (measured by a smoking machine) would appeal to health-concerned smokers even though the actual delivery of nicotine and carcinogens to people was not affected by the design changes to cigarettes.^{2 4 5} Low-yield cigarettes were designed to burn faster and to have

greater ventilation, (adding small ventilation holes to the filters that diluted the smoke delivered to the smoking machines). However, smokers easily compensated for these design changes by puffing more frequently and more intensively and blocking ventilation holes so as to maintain desired levels of nicotine in the body.²

Legal concerns forced the tobacco companies to be circumspect in making explicit health claims for so-called 'light' and 'mild' low (machine) delivery cigarettes, but the popularity of low-tar cigarette smoking increased dramatically.² The fact that the tobacco companies extensively researched the compensatory behaviours of low-tar cigarette smokers and engineered cigarette design to obtain low readings of nicotine and tar from smoking test machines while maintaining intake by smokers^{1 6–8} was a central element of Federal Judge Gladys Kessler's 2006 ruling⁹ that US tobacco companies violated the Racketeer Influenced and Corrupt Organizations (RICO) Act by systematically defrauding the public. As part of her remedy (under appeal as of April 2010), she ordered the companies to stop using the terms 'light' and 'mild'.^{9 10} For the same reasons, the World Health Organization Framework Convention on Tobacco Control (WHO FCTC), the global public health ratified by 168 countries (as of April 2010), requires parties to pass laws banning the use of terms 'light' and 'mild'.¹¹

The China National Tobacco Corporation (CNTC), which is part of the government as the State Tobacco Monopoly Agency (STMA), is the largest cigarette producer in the world and the dominant company in the Chinese market. CNTC initiated a nationwide effort in the mid 1980s to lower the machine-measured tar level of cigarettes produced in China.¹² Because of CNTC's tar reduction effort, the average machine-measured tar delivery of cigarettes sold in China dropped from 26.1 mg/cigarette in 1985 to 20 mg/cigarette in 1991 to 12.8 mg/cigarette in 2008 (figure 1). In 2004, CNTC set 15 mg as the maximum allowed limit of tar delivery for cigarettes sold in China.¹³ CNTC's tar reduction campaign has been accompanied with increasing popularity of lower-yield cigarettes among Chinese smokers. A 2007 survey found that nearly 20% of the cigarettes sold in China had tar levels below 12 mg,¹⁴ up from 5.6% in 2002.¹² In some areas such as Beijing, Shanghai, Dalian and Fujian, more than 2% of the cigarettes sold had a tar level at or below 8 mg.¹⁴ In 2006 CNTC stated that it put 'developing less harmful cigarettes' (including low-tar cigarettes) as one of the main focuses of its 'Research and Development Plan for 2006–2020'.¹⁵



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Figure 1 Average machine-measured tar content of cigarettes in the Chinese market has declined over 25 years (adapted from Lei *et al*¹²).



While the issue of smoking low-yield cigarettes has been thoroughly researched and has received considerable press attention in Western countries, this is not the case in China. Few published studies have examined the validity of the health claims related to Chinese low-tar cigarettes.^{16 17} The Chinese low-tar cigarettes are promoted by CNTC as ‘less harmful’ alternatives to regular cigarettes much more explicitly than they have been in the US and other Western countries (figure 2). A 2007 survey in eight major metropolitan areas in China found that 71% of respondents believed that ‘Low-tar cigarettes are less harmful to health’.¹⁴ As cigarettes are produced differently in different countries, it is important to examine the issue of low-tar cigarettes in China.

The present study tests the statement that Chinese low-tar cigarettes are less harmful than regular cigarettes by comparing the presence of nicotine metabolites and tobacco smoke carcinogens in urine from smokers of low-tar and regular cigarettes. As in the Western world, we found that people smoking cigarettes with lower machine-measured tar yields were not exposed to less nicotine or carcinogens than those smoking regular cigarettes.



Figure 2 A 2007 magazine advertisement of one of the leading low-tar cigarette brands in China ‘Zhongnanhai’. The print at the bottom of the figure reads: ‘A little lower means more loving care! Low-harm cigarettes give you more loving care! Cigarettes contain conflicting elements of pleasure and harm. Zhongnanhai has always focused on research and development of low-harm cigarette technology. Every product fuses the world’s most advanced low-harm cigarette technology, offering a guarantee of health for your smoking life’. (Photo courtesy of Susan Lawrence of the Tobacco Free Kids China Office.)

METHODS

Sampling protocol

Data for this study were collected in Shanghai, China from January to April 2008. All participants were Chinese smokers smoking Chinese brand cigarettes. A total of 543 participants were recruited at 4 driver physical examination centres in Shanghai, where drivers with local licenses are required to take physical exams every 1–6 years (depending on the type of the license). Participants were asked to show the interviewer the packaging of the cigarettes they smoked the most, and the tar reading on the package was recorded. Several inclusion and exclusion criteria were applied: (1) female smokers were excluded because few women smoke in China; (2) participants had to be between the ages of 18 and 65, with no diagnosis of cancer, heart disease or major respiratory diseases; (3) participants had to smoke on average at least five cigarettes per day; and (4) participants had to have been smoking their current brand for at least 3 months. Since brand mixing is common among smokers in China, a ‘main brand’ approach was used to determine the cigarette tar level of each participant. For each eligible participant, a consent form was signed and a questionnaire survey was administered. At the end of the survey, a 25 ml urine sample was collected from the participant.

The protocol was approved by the University of California San Francisco Committee on Human Research and the Shanghai Center for Disease Control and Prevention Committee on Human Subjects.

Analysis of tobacco smoke compounds in smokers’ urine

The urine samples were frozen and shipped to San Francisco General Hospital for analysis at the Tobacco Biomarker Core Facility of the UCSF Helen Diller Family Comprehensive Cancer Center. Cotinine and trans-3’-hydroxycotinine, both major metabolites of nicotine, 4-(methylnitrosamino)-1-(3-pyridyl)-butanol (NNAL) and NNAL-glucuronide, metabolites of nitrosamine 4-(methylnitrosamino)-1-(3-pyridyl)-butanol (NNK), a tobacco specific nitrosamine and one of the most potent carcinogens in tobacco smoke,¹⁸ and metabolites of polycyclic aromatic hydrocarbons (PAHs), which represent a class of combustion products that include a number of carcinogens, were measured. Cotinine and trans-3’-hydroxycotinine were measured using liquid chromatography by methods described previously.¹⁹ NNAL and NNAL-glucuronide were assayed by liquid chromatography–mass spectrometry and are reported as total NNAL.²⁰ Metabolites of the PAHs included 1-hydroxypyrene, naphthols, hydroxyfluorenes and hydroxyphenanthrenes, and

were measured by liquid chromatography–mass spectrometry and are reported as total PAHs.^{20 21} Concentrations of cotinine, trans-3'-hydroxycotinine, total PAHs and total NNALs were normalised by urine creatinine to correct for variations due to dilution or concentration of urine. Per cigarette levels were estimated by dividing creatinine-normalised cotinine, trans-3'-hydroxycotinine, total PAHs and total NNAL concentrations by the number of cigarettes the participant reported smoking per day.

All of the 543 participants with urine samples were tested for cotinine and trans-3'-hydroxycotinine levels. Because of cost considerations, a random sample of 180 was selected for the analysis of total PAHs and total NNAL. The subsample was not

different from the larger sample in cotinine, trans-3'-hydroxycotinine, cigarettes smoked per day, or demographic indices. In all, 22 participants were excluded from the study as a result of low cotinine levels typical of non-smokers (<50 µg/litre) and another 5 participants were excluded because of incomplete questionnaires. This process left a sample of 516 participants for the laboratory analysis of cotinine and trans-3'-hydroxycotinine and a sample of 177 participants for the analysis of total PAHs and total NNAL. There were no statistically significant differences in cotinine, trans-3'-hydroxycotinine, cigarettes per day or demographic indices between participants in the PAH and NNAL carcinogen sample and the full sample (data not shown).

Table 1 Metabolites of nicotine and carcinogen levels by nominal tar ratings

Nominal tar rating (per cigarette)*	15 mg	13 mg	12 mg	10 mg	8 mg	r _s	p Value†
Demographics							
Sample size	175	43	74	51	165		
Age in years, mean (SD)	44.5 (8.9)	46.9 (8.1)	42.2 (8.1)	43.3 (10.5)	43.3 (9.5)	0.075	0.089
Education, N (%)						-0.063	0.154
Junior high school and below	52 (30%)	26 (60%)	19 (26%)	19 (37%)	42 (25%)		
Secondary technical school	93 (53%)	13 (30%)	37 (50%)	27 (53%)	86 (52%)		
Junior college	21 (12%)	4 (9%)	11 (15%)	4 (8%)	27 (16%)		
College and above	9 (5%)	0 (0%)	7 (9%)	1 (2%)	10 (6%)		
Employment status, N (%)						0.022	0.617
Employed	164 (94%)	38 (88%)	69 (93%)	45 (88%)	152 (92%)		
Unemployed	11 (6%)	5 (12%)	5 (7%)	6 (12%)	13 (8%)		
Monthly income, N (%)						0.039	0.373
<500 yuan	7 (4%)	5 (12%)	4 (5%)	5 (10%)	8 (5%)		
500–999 yuan	1 (1%)	3 (7%)	0 (0%)	1 (2%)	6 (4%)		
1000–1999 yuan	30 (17%)	18 (42%)	9 (12%)	5 (10%)	32 (19%)		
2000–4999 yuan	107 (61%)	16 (37%)	47 (64%)	32 (63%)	100 (61%)		
≥5000 yuan	30 (17%)	1 (2%)	14 (19%)	8 (16%)	19 (12%)		
Change in daily consumption after switching from regular cigarettes (15 mg) to cigarettes with lower disclosed tar ratings						-0.052	0.398
Decreased daily consumption		11%	14%	14%	13%		
No change in daily consumption		56%	64%	57%	52%		
Increased daily consumption		33%	21%	28%	34%		
Cigarettes/day‡	20 (10–20)	18 (10–20)	11 (10–20)	20 (10–20)	15 (10–20)	0.152	0.001
Nicotine metabolites*							
Cotinine (µg/mg creatinine)	16.1 (8.9–27.0)	14.4 (7.2–32.7)	12.8 (7.1–20.4)	14.9 (7.6–28.0)	16.1 (8.2–25.4)	0.012	0.654
Cotinine/cigarette (µg/mg creatinine)	0.84 (0.56–1.50)	0.93 (0.56–2.12)	0.91 (0.60–1.66)	0.71 (0.42–1.75)	1.00 (0.56–1.85)	-0.068	0.123
Trans-3'-hydroxycotinine (µg/mg creatinine)	33.3 (16.4–63.4)	37.2 (19.3–74.4)	25.8 (10.9–48.0)	31.9 (19.2–64.9)	38.0 (16.9–62.6)	0.001	0.974
Trans-3'-hydroxycotinine/cigarette (µg/mg creatinine)	2.02 (0.92–3.36)	1.99 (1.00–4.51)	2.04 (0.76–4.14)	2.02 (1.06–3.51)	2.39 (1.26–4.11)	-0.071	0.109
Carcinogens*							
Sample size	60	14	28	18	56		
Total PAHs (pmol/mg creatinine)	153 (95–195)	159 (113–206)	142 (94–177)	152 (105–224)	121 (88–166)	0.125	0.099
Total PAHs/cigarette (pmol/mg creatinine)	8.46 (5.31–13.22)	8.33 (6.99–16.08)	9.66 (6.99–14.30)	10.4 (5.36–16.42)	6.72 (4.40–10.98)	0.109	0.149
NNAL (pmol/mg creatinine)	0.22 (0.16–0.37)	0.35 (0.22–0.41)	0.26 (0.20–0.36)	0.33 (0.22–0.45)	0.292 (0.190–0.479)	-0.148	0.050
NNAL/cigarette (pmol/mg creatinine)	0.0160 (0.00918–0.0220)	0.0217 (0.0118–0.0402)	0.0212 (0.0121–0.0406)	0.0198 (0.0146–0.0352)	0.0200 (0.0111–0.0324)	-0.146	0.053

*The tabulated results in this table do not include three participants who smoked 5 mg tar cigarettes, one who smoked 9 mg cigarettes, three who smoked 11 mg cigarettes and one who smoked 14 mg tar cigarettes because of small numbers. These data are, however, included in the calculation of the Spearman rank order correlations and associated p values.

†These are bivariate p values; there was no adjustment for any demographic variables.

‡Median (IQR).

NNAL, 4-(methylnitrosamino)-1-(3-pyridyl)-butanol; PAH, polycyclic aromatic hydrocarbon metabolites.

Statistical methods

The relationships between tar ratings and all variables were tested using Spearman rank order correlations with demographic variables recoded as ordinal variables. Performing the analysis using a non-parametric Spearman rank order correlation based on actual tar levels is a more sensitive method than treating the data as 'groups' in an analysis of variance for two reasons: first, treating the samples as groups disregards the fact that tar is measured on an interval scale, not a categorical scale; not taking advantage of this fact would reduce the power of the analysis. Second, grouping the data would increase the within-group variance and reduce the power of the analysis.

Role of the funding sources

The funding sources played no role in study design, the collection, analysis, interpretation of the data, the writing of the report, or in the decision to submit the paper for publication.

RESULTS

Demographic information for the participants is presented in table 1. There was no significant relationship between any of the demographic variables and the tar levels of the cigarettes they smoked. Reported number of cigarettes per day was positively correlated with tar level ($p < 0.001$); smokers of lower tar cigarettes tended to consume fewer cigarettes per day than smokers of higher tar cigarettes.

Cigarette switching

Among 353 smokers of low-tar cigarettes (< 14 mg), 276 had switched to their current brand from a previous brand with a median of 5 years ago (IQR: 2–7 years). In all, 230 switched from a higher yield brand to a lower yield brand, including 120 who switched from regular cigarettes. The most often cited reason for switching to brands with lower tar yields was 'better taste' (50%). Price was also one of the main reasons for switching to brands with lower tar yields (21%). Although generally low-tar cigarettes are more expensive than regular cigarettes in China, we observed two opposing concerns about price as reason for switching: some smokers switched because the current brand was more affordable (5%), while others switched because the current brand was more expensive and 'good for face' when offering cigarettes to others (16%), which is a common social etiquette in China. Health concern was reported as the third most popular reason for switching to lower-yield cigarettes (15%).

Urine levels of nicotine metabolites, total PAHs and total NNAL

There was no significant relationship between nominal tar rating and levels of the nicotine metabolites cotinine and trans-3'-hydroxycotinine in the smokers' urine (figure 3 and table 1) or levels per cigarette smoked (table 1). Total PAHs followed the same pattern as cotinine and trans-3'-hydroxycotinine, and showed no significant difference across different nominal tar ratings (figure 4 and table 1). A significant inverse ($p = 0.050$) relationship was detected between total NNAL in the smokers' urine and tar rating of the cigarettes (figure 4 and table 1), with the relationship remaining borderline significant ($p = 0.053$) after controlling for daily consumption of cigarettes (table 1).

DISCUSSION

The results of the current study do not support the Chinese tobacco industry's claims (figure 2) that low-tar cigarettes are safer products. As in the US,² we did not find that smoking

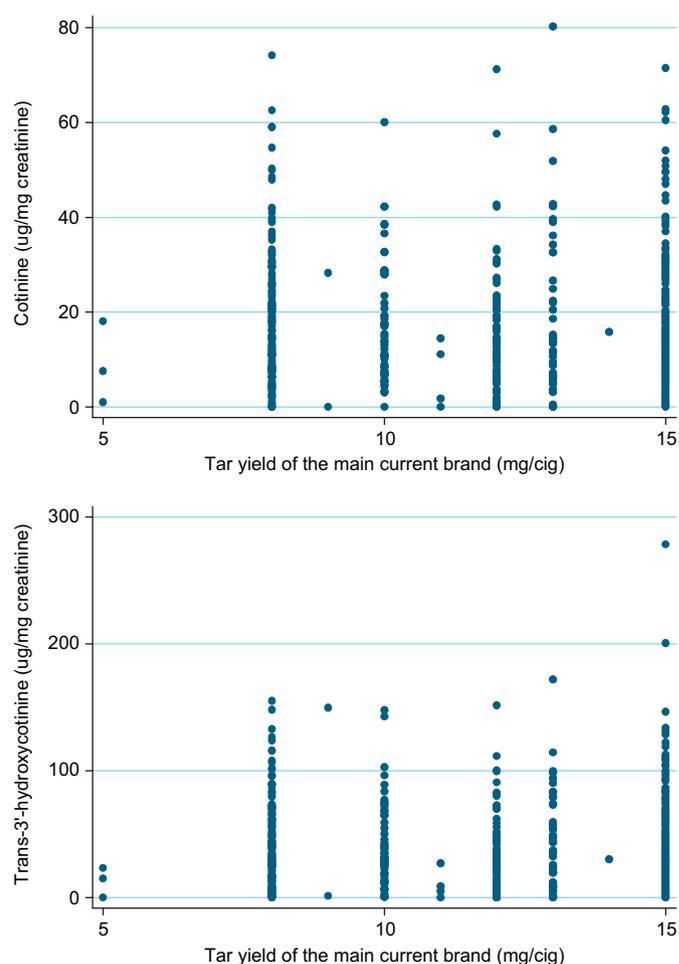


Figure 3 There is no significant correlation between the levels of cotinine ($r_s = 0.012$, $p = 0.782$) or trans-3'-hydroxycotinine ($r_s = 0.001$, $p = 0.974$) and the nominal tar yield of the main current brand.

cigarettes with lower machine yields of tar was associated with lower levels of nicotine metabolites or the carcinogen biomarker total PAHs in smokers' urine. In contrast to what might be expected (particularly since smokers on lower tar cigarettes reported lower levels of consumption), levels of the carcinogen NNAL in urine of smokers increased as the nominal tar level of the cigarettes fell. Thus, not only was there no evidence of reduced exposure per cigarette, but per cigarette exposure may actually be higher with low-yield compared to higher yield cigarettes.

Our findings indicate that the health claims associated with the marketing of Chinese low-tar cigarettes are misleading to the public. Smokers of low-yield cigarettes smoked fewer cigarettes daily compared with regular smokers, even though smokers of low-yield cigarettes reported increased daily consumption after switching from regular to low-yield cigarettes. This result suggests that these 'switchers' may tend to be more health conscious and may have been smoking fewer cigarettes per day than other smokers even before switching to low-tar cigarettes. Health concern is one of the most often cited reasons for switching to cigarettes with lower yields. Despite this lower reported consumption, however, levels of nicotine metabolites and carcinogens in the urine of people smoking low-yield cigarettes were not lower than in people smoking regular cigarettes. This result suggests that smokers of low-yield cigarettes have compensated for lower nominal nicotine yields by smoking

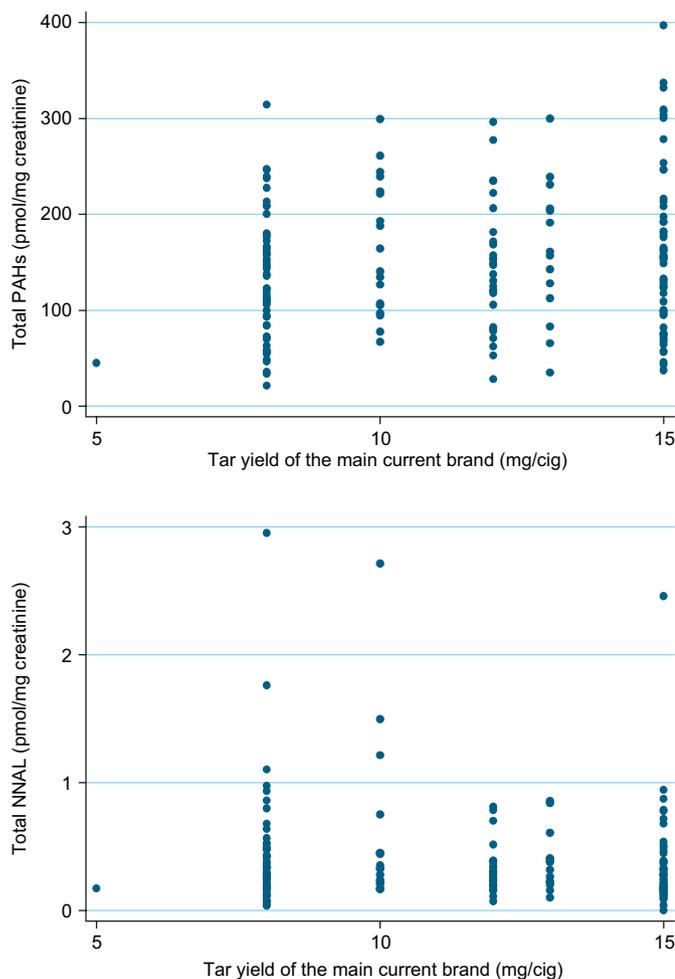


Figure 4 There is no significant correlation between level of polycyclic aromatic hydrocarbon metabolites (PAHs) ($r_s=0.109$, $p=0.149$) and the nominal tar level on cigarette packs. The relationship between level of 4-(methylnitrosamino)-1-(3-pyridyl)-butanol (NNAL) and the disclosed tar reading is significant ($r_s=-0.148$, $p=0.050$) and smokers of cigarettes with lower levels of disclosed tar reading have higher levels of NNALs in their urine.

low-yield cigarettes more intensively than smokers of regular cigarettes.^{1 2}

Since cigarette offering is a common social etiquette in China, smokers may smoke several brands of cigarettes at the same time. Fortunately, all the smokers who smoked regular (15 mg tar) cigarettes only smoked 15 mg tar cigarettes, even when they smoked several different brands. The same situation held for people smoking <10 mg tar cigarettes, all of whom smoked 8 mg tar cigarettes. For the 10–13 mg tar smokers, however, there was some variation in the levels of tar among the several brands that some of the people smoked, but all these brands fell in the 10–13 mg tar range. Our analysis of the relationship of nicotine metabolites and carcinogens with nominal tar levels was based on the tar level for the most-smoked brand among these people.

To examine the effect of brand mixing among the 10–13 mg tar smokers on the relationship between urine metabolites and tar yields, we tested indicators of nicotine intake and carcinogenic indicators (total PAHs, total NNAL), as well as the per cigarette levels of the four indicators, across the three tar levels (10 mg, 12 mg and 13 mg) and found no significant correlations between exposure and yield among these subgroups. The effect

What this paper adds

- ▶ While the truth about low-tar cigarette smoking is widely publicised in Western countries, the Chinese public has been exposed to little of such information. At the same time, the Chinese tobacco industry is heavily promoting low-tar cigarettes as reduced harm products.
- ▶ This paper, for the first time, examines the urine metabolites of nicotine and carcinogens from tobacco smoke among Chinese smokers of Chinese low-tar cigarettes and compares the levels with those among smokers of regular cigarettes.
- ▶ The study found no reduction in nicotine and carcinogens exposure from smoking Chinese low-tar cigarettes and thus the results do not support the health claims made by the Chinese tobacco industry.

of brand mixing among the 10–13 mg tar smokers on the relationship between levels of urine metabolites and tar yields among the entire sample (figures 3 and 4) should be minimal.

Our study supports the findings of previous studies that the cigarette consumption adjusted cotinine level was not lower among low-tar cigarette smokers than regular cigarette smokers.^{16 17}

Our study is the first to evaluate the safety claims of Chinese low-tar cigarettes through direct measurement of biomarkers of carcinogen exposure from tobacco smoke. There was no evidence of reduced exposure to tobacco smoke toxins and therefore it is unlikely that there would be any reduction in harm from smoking low-tar cigarettes. The results of our study support the evidence from other countries that low-tar cigarettes are not ‘less harmful’ alternatives to regular cigarettes. The WHO Framework Convention on Tobacco Control (FCTC) requires that parties enact legislation ending the use of terms such as ‘low-tar’, ‘light’, ‘ultra-light’ and ‘mild’ on cigarette packs because of their false health implications (Article 11.1).¹¹ China ratified the FCTC in 2005, but, as of April 2010 such terms still commonly appeared on many cigarette packs in China. Such promotion activity of CNTC is clearly a violation of the FCTC.

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Competing interests NLB serves as a paid consultant to pharmaceutical companies that are developing or that market smoking cessation medications. He also has been a paid expert witness in litigation against tobacco companies, including on issues related to light cigarettes. None of the other authors have any competing interests to declare.

Ethics approval This study was conducted with the approval of the UCSF and Shanghai CDC.

Provenance and peer review Not commissioned; externally peer reviewed.

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The lighter side

Speed Bump

