Effects of the grade/price of and thickness of cigarette on the PM2.5 concentration of smoke

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Abstract

Background: Due to lower tar and nicotine, high grade/price and slim cigarette are believed as “safe cigarette” and cause less tobacco smoke pollution (TSP) advocated by cigarette producers. However, cigarette smokes comprise thousands of harmful constituents, only two substances cannot represent TSP. Then in this study, we wanted to discover if the grade/price and thickness of cigarette affect TSP.

Methods: Slim (S) and regular (R) cigarette with different grades/prices were selected to investigate TSP *via* measurement PM2.5 in a closed chamber (1 m^3). Sidestream smoke was collected through cigarette combustion. Mainstream smoke was collected using piston-operated smoking machine.

Results: In sidestream smoke, cigarette grade/price did not affect PM2.5 of R or S cigarette. But in mainstream smoke, grade/price acted discrepancy roles in different thickness cigarette. In R cigarette, PM2.5 of lowest grade/price (R5) was lowest. While in S cigarette, PM2.5 of lowest grade/price (S5) was highest. Cigarette thickness obviously affected PM2.5. PM2.5 of R cigarette was 116% higher than S cigarette in sidestream. In mainstream smoke, magnification was down to 31%, despite PM2.5 of R cigarette was also higher.

Conclusions: Irrespective of sidestream or mainstream smoke, the grade/price of cigarette did not obviously affect PM2.5. But which was significantly influenced by cigarette thickness. Although S cigarette PM2.5 was significantly lower than R cigarette, it cannot mean that S cigarette was less harmful. Because harmfulness of smoke was not only affected by cigarette but also by smoker inhale habits. It needs further experiments to evaluate the harmfulness of slim cigarette.

Background

Tobacco smoke pollution (TSP), also known as “secondhand smoke” and “passive smoke”, in public places is a worldwide health problem. Tobacco smokes contain thousands of harmful constituents that come from cigarette combustion (“sidestream smoke”) and exhaled by the smoker (“mainstream smoke”) [1]. Accumulating evidence show that TSP may be the cause of many respiratory problems, acute cardiovascular effects, and lung cancer [2–4]. Due to the toxicity of TSP, > 600,000 people die every year worldwide [5].

The level of cigarette production and consumption in China is one of the highest in the world. Cigarette smoking has an important role in Chinese social customs, such as at weddings and funerals. Offering a cigarette to a friend or guest is regarded as a social courtesy. Nearly all these social courtesies happen in public places, and TSP is a serious problem [6].

In the past decade, the production and sales of cigarette in China has decreased, and this has been attributed to two main factors. The first is people’s awareness of the hazards of cigarette smoking. For

example, the percentage of people who were aware that cigarette smoking increases the risk of lung cancer increased from 36% in 1996 to 77.5% in 2010 [7]. The other reason is that the Chinese government promoted multiple policies to reduce cigarette smoking, such as curbing cigarette advertisements and increasing the price of cigarette [8, 9].

The decline in cigarette sales severely affected the profits of State Tobacco Monopoly Administration (STMA) and China National Tobacco Corporation (CNTC). (Actually, the STMA and CNTC is the same organization, the different names represent the separation between the government and tobacco industry.) STMA/CNTC exploited new marketing tools to maintain their profits [10], one of which was the “safe cigarette”, characterized by its low-tar and nicotine content. Some scientists attached to or funded by STMA/CNTC became engaged in reducing the harmfulness of smoking through improving cigarette-production technology or developing new types of cigarette.

New technologies were used to promote cigarette “safety”. For instance, filters made from new materials, high-permeability cigarette papers, and ways to improve combustion were reported to decrease the content of hazardous substances [11–13]. These new technologies led to increases in manufacturing costs, which were passed onto the consumer. This increase in price could be misconstrued by consumers as being correlated with increased safety. That is, a high price of cigarette denotes high safety, and low price corresponds with low safety. A “slim” (S) cigarette (circumference of 17 ± 1 mm) contains less tobacco than a “regular” (R) cigarette (25 ± 1 mm). As the result, S cigarette has been advocated to be a “safe cigarette” to increase the profits of STMA/CNTC [14]. Under the impetus of STMA/CNTC, sales of S cigarette have shown tremendous growth. In 2014, 2.9 million cartons of S cigarette were sold, but in 2018 sales increased to 347 million cartons [15]. Apart from developing new products, cigarette producers have propagated the “safe cigarette” through introducing the work of tobacco researchers. A typical case was the “Tobacco Academician” who promoted low-tar tobacco products and was elected to the Chinese Academy of Engineering (the highest honor for scientists in China) [16]. All the propagation and research conducted by the tobacco industry created an illusion to people that TSP from “safe cigarette” did not or reduced harm to their health.

Cigarette smokes comprise thousands of harmful compounds; low-tar and nicotine content cannot fully represent TSP. “PM2.5” refers to atmospheric particulate matter (PM) of diameter < 2.5 μm. The PM2.5 concentration is a suitable and reliable airborne marker to evaluate emission and exposure to TSP [17].

In the present study, we selected six types of cigarette to evaluate the effects of grade/price, cigarette thickness, and grade/price × thickness on the PM2.5 concentration after cigarette smoking.

Methods

STMA/CNTC divides cigarette into five grades according to price in China [18]. To clarify the relationship between cigarette price and PM2.5, we selected three grades/prices: 1 (≥ ¥100), 3 (¥30 ≤ and <¥70) and 5 (< ¥16.5). According to their thickness, there are two types of cigarette: R and S (Table 1).

Table 1
Materials selected in the present study

Thickness	Grade	Tar (mg)	Nicotine (mg)
Regular	1	8	0.6
	3	10	1.0
	5	12	1.1
Slim	1	6	0.6
	3	7	0.7
	5	8	0.8

Measurement of the PM2.5 concentration

Measurement of the PM2.5 concentration was undertaken according to the method developed by Sendzik and colleagues [19]. A Dustrak aerosol monitor 8532 (TSI, St. Paul, MN, U.S.A.) was placed in a closed chamber (1 m × 1 m × 1 m) to measure the PM2.5 concentration. The monitor was calibrated before each experimental session according to manufacturer specifications. A customized calibration factor of 0.32 was applied to the device, determined by calibrating the device in the present study with other light-scattering photometers measuring TSP [19, 20]. Sidestream smoke was collected in the chamber through cigarette combustion. Mainstream smoke was collected with a piston-operated smoking machine under the following conditions: puff volume of 40 mL, puff duration of 2 s, and interval between puffs of 10 s. According to this method, we could simulate the smoking of tobacco by a human [17]. Before data collection, we operated exhaust equipment to ventilate the PM2.5 of the chamber down to the air level.

Statistical analyses

Data were subjected to multivariate analysis of variance with general linear models. If thickness × grade/price had an interactive effect, further analyses were conducted. Data analysis were undertaken using SAS v8.0 (SAS, Cary, NC, USA).

Results

The cigarette grade/price had no significant effect on the PM2.5 concentration in either group (Fig. 1). However, the mean PM2.5 concentration for R cigarette was obviously higher than that for S cigarette (by 116%). Multivariate analysis of variance showed that cigarette thickness had main effect on the PM2.5 concentration of sidestream smoke (Table 2).

Table 2
Multivariate analyses of variance for PM2.5 in sidestream smoke

	df	F	P
Cigarette thickness	1	528.594	0.000
Grade/price	2	0.206	0.817
Thickness × grade/price	2	0.365	0.702

Table 3
Multivariate analyses of variance for PM2.5 in mainstream smoke

	df	F	P
Cigarette thickness	1	87.243	0.000
Grade/price	2	2.054	0.171
Thickness × grade/price	2	9.065	0.04

Just like for sidestream smoke, cigarette thickness had an effect on the PM2.5 concentration in mainstream smoke (Fig. 2). In addition, there was interaction effect between cigarette thickness and grade/price (Table 3). A simple effect analysis was conducted (Fig. 3). There was no obvious difference between R cigarette. The PM2.5 concentration of S1 and S3 were similar and lowest among all treatments. Interestingly, the PM2.5 concentration of S5 was significantly higher than that of S1 and S3, and close to that of R5.

Discussion

According to their annual report, STMA/CNTC had uninterrupted growth in recent years that reached ¥1155.6 billion ($168 billion) in 2018 [21]. This “brilliant achievement” was supported by millions of smokers. Due to customs and habits, smokers in China can be found in most public places. As a result, many nonsmokers are affected by TSP. TSP-induced health risks burden the government and families. It has been reported that the total healthcare cost of TSP exposure in rural China accounted for 0.3% of China’s national healthcare expenditure in 2011 [22]. Fortunately, thanks to government policies, cigarette-carton sales decreased gradually from 260.98 billion in 2014 to 233.58 billion in 2018 according to the National Bureau of Statistics [23].

[21][22][23]

The discrepancy between the decrease in cigarette sales and enhancement of profit is noteworthy. The reason was due to the new sales strategy of STMA/CNTC. To align with the requirements for tobacco control from the government and society, STMA/CNTC decreased the output of low grade/price cigarette but slightly increased the output of high grade/price cigarette. Studies from several research institutions attached to or funded by STMA/CNTC indicated that high grade/price cigarette was likely to be much safer than low grade/price cigarette. The filters of cigarette made in China are composed of cellulose acetate (CA) or polypropylene (PP), of which CA has a higher filtration efficiency (by 6%) compared with PP [24]. PP filters are used in low grade/price cigarette [13]. Good-quality tobacco leaves in high grade/price cigarette have excellent flame properties, which can reduce the toxicity due to decrease tar and nicotine content [25]. In addition, some studies have indicated high-combustion cigarette papers and safer additive materials can decrease the toxicity of cigarette. However, these new technologies lead to much higher manufacturing costs and, consequently, price increases [11, 26]. Studies have created an illusion for smokers that high grade/price cigarette are harmless to health. However, we found that the PM2.5 concentration was not affected by the grade/price of cigarette in sidestream or mainstream smoke. The conflicting results between our study and previous studies may be due to different research objectives. Several studies investigate a constituent of smoke (e.g., tar, nicotine, tobacco-specific nitrosamines) but we investigated the PM2.5 concentration. Tobacco smoke contains > 5000 constituents [27]. Smoke toxicity cannot be measured through investigating a few substances even if they have high toxicity. Conversely, PM2.5 almost contains all the constituents of tobacco smoke.

S cigarette is a relatively new type of cigarette, and attracts smokers rapidly upon their introduction. Their carton sales increased from 2.9 million to 347 million within 5 years. One of the important reasons for this massive increase in sales was that STMA/CNTC and their research institute transmitted a simple message: S cigarette can decrease harm to your health [28]. In the Chinese cigarette market, the tar and nicotine content of S cigarette annotated on cartons is 6–8 mg and 0.6–0.8 mg respectively, which is lower than that for R cigarette (Table 1). Ge and colleagues compared the components in mainstream smoke between S cigarette and R cigarette, and found that S cigarette released less nicotine, tar and carbon monoxide than R cigarette [29]. In the present study, the PM2.5 concentration was significantly lower in S cigarette in sidestream smoke and mainstream smoke. The mean PM2.5 concentration of sidestream smoke in S cigarette was lower by 54% compared with that in R cigarette whereas, in mainstream smoke, it was lower by 24%. These results seemed suggested that S cigarette was safer than R cigarette. In fact, the harmfulness of S cigarette cannot be reflected by the tar and nicotine content labeled on the carton, a hypothesis supported in the present study. The PM2.5 concentration of S5 was similar to that of R cigarette (Fig. 2, 3). And more important should to be noted that experiment results merely represented one cigarette differences between two types. But for one smoker, the objective of tobacco smoking is the satisfaction elicited by nicotine. If smokers changed from R cigarette to S cigarette, to maintain the desired intake of nicotine, they could change the way they smoked (e.g., deeply inhale each draw of the cigarette, increase the number of cigarettes smoked) [30]. Thus, their exposure to tobacco may be higher or at least equal to that of R cigarette.

To our knowledge, this was the first study to investigate the effects of grade/price and thickness of cigarette on the PM2.5 concentration. We found no significant difference between lower and higher grade/price of cigarette. S cigarette produced lower concentrations of PM2.5 compared with that of R cigarette. However, this result does not demonstrate that S cigarette is safer than R cigarette because the harmfulness of smoking is determined not only by the cigarette but also by inhalation habits. This was theoretical research undertaken using a closed chamber, and indoor studies are needed to verify our data.

Consent for publication

No application

Availability of data and materials

All data generated or analysed during this study are included in this published article

Declarations

Consent for publication

No application

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Competing interests

The authors declare that they have no competing interests

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Authors' contributions

L.Z. and L.P. designed the experiment and produced the draft. J.S., S.Y. and W.Y. collected the data. W.Q. analyzed the data.

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Figures

Figure 1

The cigarette grade/price had no significant effect on the PM2.5 concentration in either group

Figure 2

Multivariate analysis of variance showed that cigarette thickness had main effect on the PM2.5 concentration of sidestream smoke

Figure 3

In addition, there was interaction effect between cigarette thickness and grade/price (Table 3). A simple effect analysis was conducted