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Observation and Measurement of Smokers' Ash Removal Behavior in China*

by

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SUMMARY

In order to investigate the main factors behind hot coal fallout during cigarette smoking, an in-use behavior survey among smokers was conducted in three locations (Guiyang, Shijiazhuang and Nanchang) in China. In addition, a measuring device was designed to record whether a flicking or tapping force was exerted to remove ash and to record the force applied as well as their characteristic parameters. We found that there was no significant difference among the behavior characteristic parameters of the users in the three locations. The proportion of consumers who applied flicking was higher than the proportion of consumers tapping. There were some differences in the in-use behavior when smoking King Size and Superslim cigarettes. The work could help to develop a suitable hot coal fallout test method. [Beitr. Tabakforsch. Int. 28 (2018) 42–50]

KEY WORDS: Hot coal; fallout propensity; behavior survey; characteristic parameters

ZUSAMMENFASSUNG

Zur Untersuchung der Hauptfaktoren für den Fallout heißer Glut beim Zigarettenrauchen wurde an drei Standorten in China (Guiyang, Shijiazhuang und Nanchang) unter Rauchern eine Befragung zum Konsumverhalten durchgeführt. Des Weiteren wurde ein Messgerät entworfen, mit dem aufgezeichnet werden kann, ob eine schnippende oder klopfende Bewegung ausgeübt wird, um die Asche zu entfernen, und mit dem die angewendete Kraft sowie charakteristische Parameter aufgezeichnet werden können. Es wurde festgestellt, dass zwischen den das Verhalten charakterisierenden Parametern der Verbraucher an den drei Standorten kein signifikanter Unterschied bestand. Der Anteil von Verbrauchern, die schnippten, war höher als der Anteil derjenigen, die klopften. Es gab gewisse Unterschiede im Konsumverhalten beim Rauchen von King Size Zigaretten und Superslim Zigaretten. Die vorliegende Arbeit könnte dabei helfen, eine geeignete Testmethode für den Fallout heißer Glut zu entwickeln. [Beitr. Tabakforsch. Int. 28 (2018) 42–50]

RESUME

Dans le souci d'analyser les principaux facteurs influençant la retombée des braises durant le fumage d'une cigarette, une étude comportementale des fumeurs durant la consommation fut menée dans trois villes chinoises (Guiyang, Shijiazhuang et Nanchang). En outre, un dispositif de mesure fut conçu pour distinguer si une chiquenaude était donnée ou si un tapotement était utilisé pour détacher les cendres ainsi que pour enregistrer la force exercée et les paramètres caractéristiques de ce mouvement. Nous n'observâmes aucune différence significative distinguant les paramètres caractéristiques du comportement des fumeurs dans les trois villes. La proportion de consommateurs qui donnent une chiquenaude dépassa la proportion de fumeurs qui tapotent leur cigarette. Certaines différences émergèrent dans le comportement de consommation lors du fumage de cigarettes Superslim et King Size. Ce travail pourrait contribuer au développement d'une méthode adéquate de test de la retombée des braises.
[Beitr. Tabakforsch. Int. 28 (2018) 42–50]

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1. INTRODUCTION

Hot coal fallout during cigarette smoking has been an issue for consumers. Such incidences are normally reported as consumer complaints, which not merely represent unsatisfactory experiences but may also constitute fire hazard (1–3). In order to solve this problem, objective investigations of smoker's cigarette-handling behaviors during smoking are the first step. The information gained could help reaching technical solutions for cigarette design and manufacturing.

Possible reasons behind the cigarette hot coal fallout are diverse. For instance, one hypothesis is that the cigarette paper smoldering speed does not match the burning rate of the tobacco rod. In addition, during cigarette making there may be mechanical factors resulting in poor tobacco rod quality, contributing to a higher incidence of hot coal fallout. So far most technological solutions to hot coal fallout are based on the measurement of lit cigarette ash-flicking behavior under laboratory conditions. For example, LI *et al.* built a laboratory instrument based on the measurement of a constant rotational force to study the cigarette ash stability in order to predict hot coal fallout propensity of cigarettes (4). In practice this method is inefficient due to lack of in-use data and the repeatability is not satisfactory as compared to user behavior. There are patents describing other mechanic models using a striking force to study cigarette ash falling but not aimed at measuring the cigarette ash flicking behavior (5). A common drawback of these methods is that they do not have real smokers' in-use cigarette handling behavior data and cannot reflect the real-life complexity of consumer behavior. Therefore, we believe that obtaining results of smokers' real in-use behavior on how they deal with cigarette ash is important for understanding hot coal fallout. In-use behavior studies have been used in other smoking behavior evaluations (6–9).

Our work was aimed at recording and characterizing certain parameters of smokers' ash removal behavior, such as the type of force applied (flicking *vs*. tapping), the magnitude of the force, the way the cigarette is held in hand, etc. The data gathered was also used to study hot coal fallout propensities of different cigarettes. The results will be published at a later date.

2. MATERIAL AND METHODS

2.1. Material

Two types of commercial cigarettes were used in this study: one King Size (KS) with a circumference of 24.2 mm and a total length of 84.0 mm (filter length 24.0 mm), the other a Superslim (SS) with a circumference of 17.0 mm and a total length of 97.0 mm (filter length 30.0 mm). The descriptions of the two cigarettes, e.g., physical dimensions, ISO "tar", and static burn rates are listed in Table 1. All test cigarettes were conditioned for at least 48 h at 22 °C and relative humidity of 60%.

Table 1. The characteristics of physical dimensions and other parameters.

Type	Physical dimensions			weight (g)	ISO "tar" (mg)	Static burn rate (mm/s)
	Rod lenght (mm)	Filter lenght (mm)	Diameter (mm)			
King Size (KS)	60.0	24.0	24.2	0.896	10.6	0.11
Superslim (SS)	67.0	30.0	17.0	0.526	8.8	0.13

2.2. Sampling design for human in-use behavior survey

A total of 309 (18 females, 291 males) healthy adult smokers were recruited in Guiyang (104), Shijiazhuang (100) and Nanchang (105). The female:male smoking ratio (~1:20) is typical of the smoker population.

All volunteers read and signed a consent form and their age and identity were checked before commencing the study. More details of their age and location distribution are shown in Table 2.

2.3 Two common actions consumers use to remove cigarette ash

There were two main actions to remove ash buildup from a lit cigarette: flicking and tapping.

Three steps may be used to describe the flicking action (see Figure 1): Firstly, holding the cigarette filter end with the thumb and middle fingers, with the index figure hovering above the rod. The grip is firm enough but without crushing the filter. Secondly, moving the index finger slightly along the rod direction, holding the filter with the thumb and middle fingers. Thirdly, with a single flicking movement, removing the cigarette ash in upward direction with the index finger.

Table 2. List of volunteers' information by age and daily cigarette usage.

Survey location	Age distribution (%)				Cigarette consumption frequency per day (%)		
	20~30	30~40	40~50	>50	>20	10~20	<10
Nanchang	23.81	23.81	28.57	23.81	38.10	52.38	9.52
Guiyang	25.00	25.00	25.00	25.00	40.38	48.08	11.54
Shijiazhuang	25.00	25.00	25.00	25.00	40.00	50.00	10.00
Average	24.60	24.60	26.21	24.60	39.48	50.16	10.36

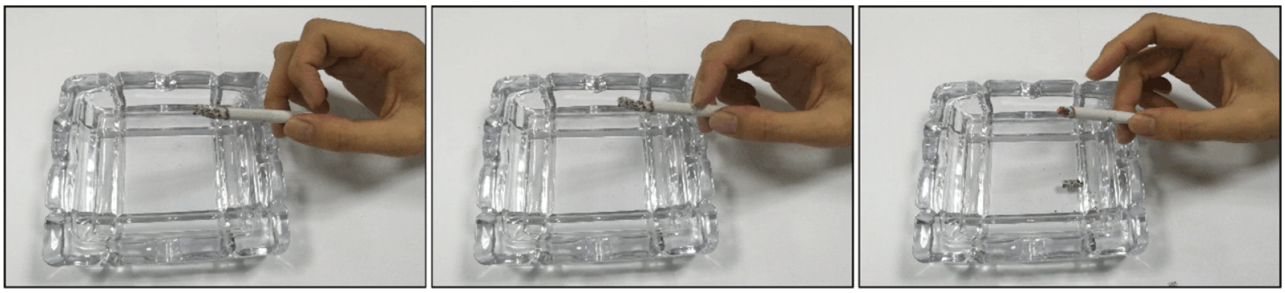


Figure 1. The flicking action to remove ash buildup from a lit cigarette.

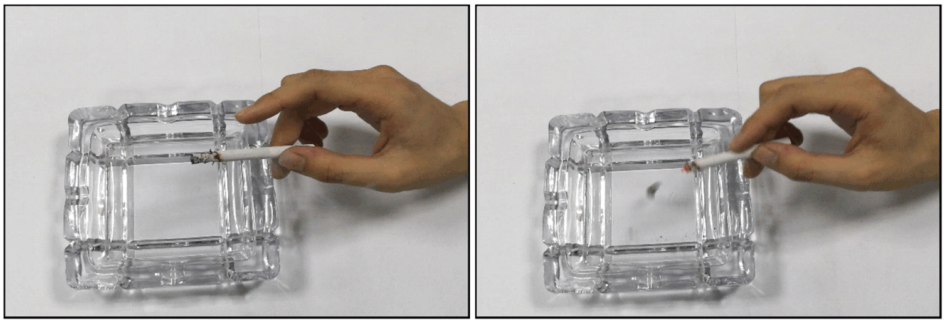


Figure 2. The tapping action to remove ash buildup from a lit cigarette.

Figure 2 describes the two-step action of the tapping method to remove ash. A lit cigarette is held between thumb and middle finger, and a gentle tap is applied on the top of the cigarette rod with the index finger. There may be other ways of removing the cigarette ash buildup, but it seemed that the flicking and tapping methods are the most common and uniquely identifiable among smokers worldwide.

2.4 *A real-time ash-removing force-recording apparatus for in-use monitoring*

In order to characterize the two most common methods to remove ash from a lit cigarette (Figures 1 and 2) by consumers, outlining e.g., the type of force applied, the magnitude of the force, the duration of the force, the position along the cigarette where the force was applied and its angle, a recorder was designed (Figure 3). The system was also able to record the cigarette-holding force (Figure 4 (A)), the holding position along the rod (Figure 4 (B)), the number and the frequency of each action (Figure 4 (C)), and the instantaneous direction of the cigarette rod (Figure 4 (D)).

Two cigarette-holding angles are defined as shown in Figure 5. There are many more angles possible in a 3D space. However, these two angles were found to be typical for smokers in all locations and were hence selected. For all the parameters measured, we set the statistical significance level at 0.05 for a paired Student's t-test.

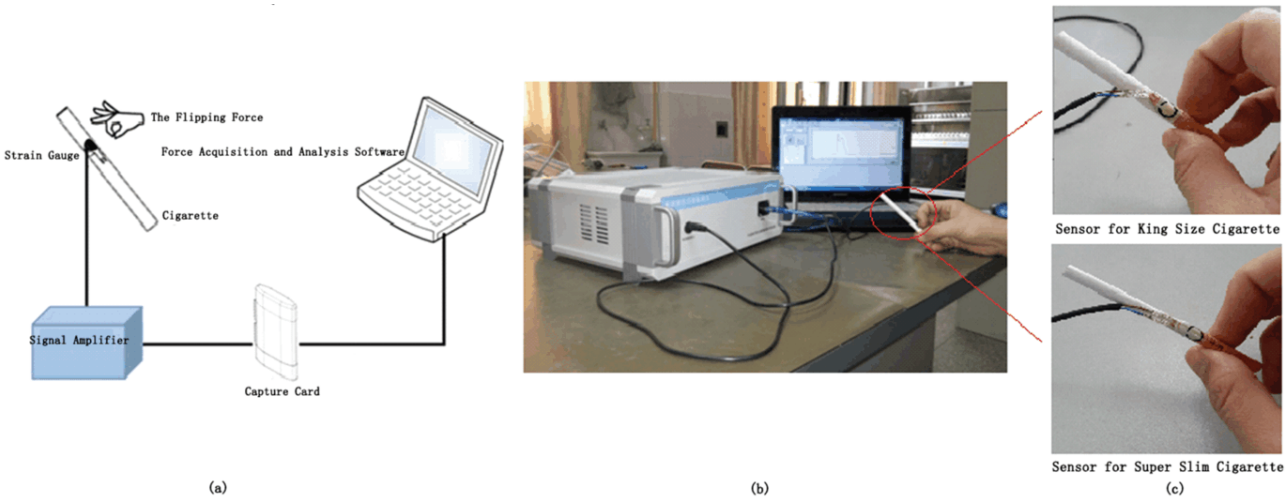
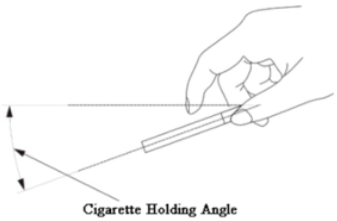


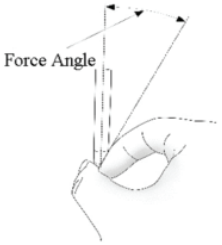
Figure 3. A real-time recorder for the force applied to a lit cigarette. (a) Schematic of the force-recording system; (b) photo of the force-recording system; (c) the force sensor fixed onto a cigarette rod.

Information on the method to remove ash from a King Size cigarette			
Holding force (N) [A]	Position of force application [B] (mm)	Magnitude of force (N) Duration time (s)	File name
The first flicking action			
Holding position (mm) Direction of the cigarette horizontal / vertical Force mechanisms 1. Flicking 2. Tapping 3. Others	Direction of the cigarette [D] 1. Upward (15–30°) 2. Upward (0–15°) 3. Downward (0–15°) 4. Downward (15–30°) 5. Others	Flicking time Burning line position (mm) Interval time (s) Puffs	Frequency of flicking [C] 1. Once 2. Twice 3. Three times 4. More

Figure 4. Data acquisition chart.



(a) The angle of force applied in relation to the horizontal direction



(b) The cigarette holding angle in relation to the cigarette rod direction

Figure 5. The two angles investigated in the study.

The force recorder (Figure 3) used has a force sensor in the range of 0–100 gram-force (gf) (Hefei Institutes of Physical Science, CAS and Zhengzhou Tobacco Research Institute, CNTC, China). It also has a high-speed video camera (Model PCO Dimax HD, Kelheim, Germany), with an image recording resolution of 1000 × 1000 pixels at 7039 frames per second (fps). The video camera was set up in a position directly facing the smoker to allow the full movement during smoking to be recorded.

2.5 In-use survey process

Each survey was conducted in a prearranged work space with fixed appointments for each subject. Test cigarettes were marked with vertical lines in relation to the rod length to facilitate the video camera's observation of the cigarette's burn line position and relevant information on other rod positions .

The recording and in-use survey sessions were conducted along the following steps:

Step 1: before the start of each survey, staff members explained the study plan to the volunteers in order to ensure that they understood the purpose of the test. Each volunteer's information was checked to confirm his/her identity again before he or she was enrolled as a respondent. Each volunteer was then registered with a unique number.

Step 2: volunteers were asked to dye (using a food dye) the fingertip of the index finger they normally used to smoke cigarettes. Each volunteer smoked two test cigarettes (one King Size and Superslim each) in turn while sitting and without any other physical constraints.

Step 3: the entire smoking session was recorded by the force recorder and the high-speed video camera. After smoking, staff members measured the cigarette-holding position, cigarette butt lengths, and the location where the force was applied according to the staining trace and the video information. The flicking angles were determined by video-recording the hand-flicking action. A total of 20 ash-flicking or -tapping actions was recorded for each volunteer. The data of one volunteers' flicking and tapping actions are shown in Table 3.

3. RESULTS

3.1 Type of force applied during smoking

The data of the types of force (flicking *vs*. tapping) applied to a cigarette during smoking gathered from one single volunteer as well as from three survey locations are presented in Table 3 and Table 4 respectively. As Table 4 shows, it is common for consumers to use both flicking and tapping methods to remove the cigarette ash during a single smoking session. During the study it was also recorded that, when there was only a light degree of ash-buildup, a longitudinal sliding action was used to push the rod against an object, such as the side of an ashtray to remove a layer of burning ash. This observation has not been followed up in the study. For the chosen volunteer, it seemed that his flicking action was more forceful but with shorter intervals than for the tapping action, and that the differences between the King Size and Superslim cigarettes were minor.

When the tests were conducted in the three locations with more volunteers, the results (Table 4) show that 57.3% of the respondents (a total of 177 persons) applied flicking whereas 42.4% (a total of 131 respondents) were tapping. A negligible 0.3% (1 respondent) showed a behavior that was neither flicking or tapping.

3.2 Analysis of force applied

3.2.1 Magnitude of force

The magnitude of force recorded during the smoking process is shown in Table 5. When the flicking action was used, the average force applied on the King Size cigarettes was 0.37 N, with a 68% confidence interval from 0.23 N to 0.51 N and around 90% of the data was distributed within 0.16 N to 0.67 N. The average force applied on Superslim cigarettes (SS) was 0.31 N, with a 68% confidence interval from 0.18 N to 0.45 N. Although the average force applied on Superslim cigarettes appeared to be lower than that applied on King Size cigarettes, this was not statistically significant. Both the median force and the mode of force are shown in Table 5. For the tapping action, the average force magnitude was 0.16 N, with a 68% confidence interval ranging from 0.07 N to 0.24 N. The average tapping force on Superslim cigarettes was 0.14 N, with a standard deviation range from 0.08 N to 0.20 N. Again, the average, the median and the mode of force were not statistically significant between the two types of cigarettes. Compared with the flicking action, the average magnitude of the flicking force in both KS and SS cigarettes was about 2.3 times stronger than the average magnitude of the tapping force. The measured intensity of force, including the average value, the median value and the mode value, was stronger in King Size Cigarettes than in Superslim cigarettes for both methods.

3.2.2 The time duration of force applied

The duration of the force application is defined using a threshold force level (0,02 N) for both starting and finishing of the recordings (Figure 6). The average duration and a 68% confidence interval of force application for the flicking method in KS cigarettes and SS cigarettes did not differ, both were 0.03 s and 0.01–0.05 s. Median values and mode values of the flicking method in KS cigarettes or SS cigarettes were identical.

For the tapping method there was a difference however. The average value in KS cigarettes was 0.12 s, which was not identical to the respective value in SS cigarettes. Median and mode values in KS and SS cigarettes were also different. The median value in KS cigarettes was 0.10 s and in SS cigarettes it was 0.09 s.

Table 3. The data of 20 ash-flicking and -tapping actions for one volunteer.

Cigarette type	Type of force application	Force (N)		Time (s)	
		Mean	Standard deviation	Mean	Standard deviation
King Size	Flicking	35.86	1.708	0.0336	0.0081
	Tapping	18.06	2.5187	0.0900	0.0188
Superslim	Flicking	29.12	2.8578	0.0229	0.0024
	Tapping	13.79	1.6846	0.1319	0.0498

Table 4. The distribution of the type of force applied.

Type of force applied	Nanchang		Guiyang		Shijiazhuang		Total	
	Population	Ratio (%)	Population	Ratio (%)	Population	Ratio (%)	Population	Ratio (%)
Flicking	54	51	56	54	67	67	177	57.3
Tapping	51	49	48	46	32	32	131	42.4
Mixture	—		—		1	1	1	0.3

Mode values in KS cigarettes and SS cigarettes were 0.015 s and 0.055 s, respectively. The 68% confidence interval in KS cigarettes for the tapping method was from 0.06 s to 0.18 s whereas in SS cigarettes it was from 0.03 s to 0.17 s. Compared to the tapping method, the three values, including average, median and mode, both in KS cigarettes and SS cigarettes, were significantly lower.

Table 5. Magnitude of force applied.

Type of force applied	Cigarette type	Average (N)	68% Confidence interval (N)	90% Confidence interval (N)
Flicking	KS	0.37	0.23–0.51	0.16–0.67
	SS	0.31	0.18–0.45	0.12–0.59
Tapping	KS	0.16	0.07–0.24	0.05–0.23
	SS	0.14	0.08–0.20	0.06–0.23

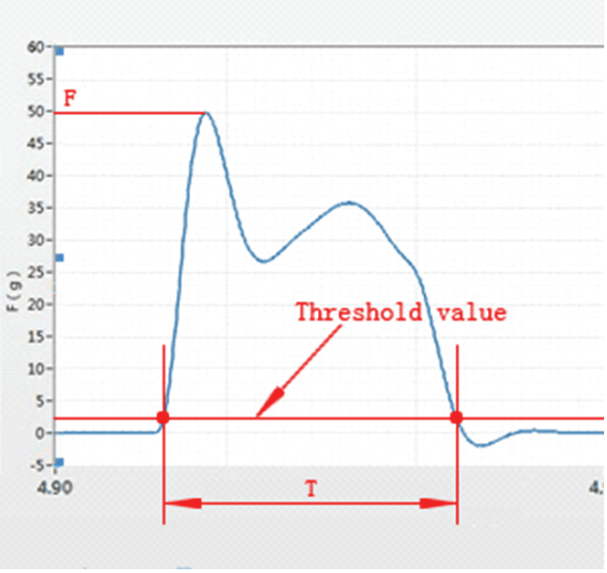


Figure 6. The threshold measurement of the duration of force application.

3.2.3 The position of force application

Table 7 summarizes the distance from the mouth end to the point of the force application. In the flicking action, the average distance on the KS cigarettes was 30 mm, which had a 68% confidence interval from 25 mm to 35 mm. About 90% of the observations fell within a distance of 21 mm to 38 mm. The average distance on the SS cigarettes was 32 mm, which had a 68% confidence interval from 26 mm to 38 mm and about 90% of the samples showed a distance range from 22 mm to 41 mm. It appears that the average length of the flicking force on SS cigarettes was higher than that on the KS cigarettes, and median values were in line with average values. In the tapping mode, the average distance on the KS cigarettes was 34 mm, with a 68% confidence interval from 28 mm to 40 mm and about 90% of the samples showed a distance range from 25 mm to 44 mm. The average distance for the SS cigarettes was 37 mm, with a 68% confidence interval from 30 mm to 43 mm and about 90% of the samples showed a distance range from 27 mm to 45 mm. In summary, the average distance from the mouth end to the point of force application for SS cigarettes was longer than for KS cigarettes. Compared with the flicking movement, the distance for the tapping seemed longer.

Table 6. Duration of force applied.

Type of force applied	Cigarette type	Average (s)	Median (s)	68% confidence interval (s)
Flicking	KS	0.03	0.03	0.01–0.05
	SS	0.03	0.03	0.01–0.05
Tapping	KS	0.12	0.10	0.06–0.18
	SS	0.10	0.09	0.03–0.17

Table 7. Position along the cigarette rod where force was applied.

Type of force applied	Cigarette type	Average (mm)	68% confidence interval	Main distribution scope (90%)
Flicking	KS	30	25–35	21–38
	SS	32	26–38	22–41
Tapping	KS	24	28–40	25–44
	SS	37	30–43	27–45

3.3 Results of cigarette holding parameters

3.3.1 Holding force

In addition to the characterization of the finger movements to remove ash, as described in the previous sections, this study also recorded other cigarette-holding parameters. Table 8 displays the holding force, which is the force the fingers apply to hold a cigarette during smoking.

In the flicking action, the average holding force on the KS cigarettes was 0.18 N (with a 68% confidence interval from 0.13 to 0.23 N). The average holding force for SS cigarettes was 0.16 N (with a 68% confidence interval from 0.10 to 0.22 N). For the tapping action, the average holding force for KS cigarettes was 0.17 N (with a 68% confidence interval from 0.11 to 0.23 N), and the average holding force for SS cigarettes was 0.16 N (with a 68% confidence interval from 0.09 to 0.23 N). In both cases, the average holding force for SS cigarettes was marginally lower than that for KS cigarettes and the median values were in line with this trend. There was no statistically significant difference between the flicking and the tapping modes concerning the holding force.

3.3.2 Holding position

Table 9 shows the measured distance from the mouth end to the holding position along the cigarette length. For flicking, the average distance for KS cigarettes was 18 mm with a 68% confidence interval from 13 mm to 23 mm. The average distance of the mouth end to the holding position for the SS cigarettes was 19 mm with a 68% confidence interval from 14 mm to 24 mm. The average distance for

Table 8. The holding force (N) recorded.

Type of force applied	Cigarette type	Average	68% confidence interval
Flicking	King Size	0.18	0.13–0.23
	Superslim	0.16	0.10–0.22
Tapping	King Size	0.17	0.11–0.23
	Superslim	0.16	0.09–0.23

SS cigarettes was thus similar to that of KS cigarettes.
For tapping, the average distance of the mouth to the holding position on the KS cigarettes was 19 mm with a 68% confidence interval from 14 mm to 24 mm. The average distance of the holding position for SS cigarettes was 12 mm with a 68% confidence interval from 16 mm to 28 mm. The average distance from the mouth end to the point of holding for KS cigarettes was shorter than the respective average distance for SS cigarettes. It was found that the distance from the mouth end to the holding position was longer with tapping than with flicking. The distance of the mouth end to the holding position for KS cigarettes was shorter than that for SS cigarettes in both methods.

Table 9. Cigarette rod holding position.

Type of force applied	Cigarette type	Average (mm)	68% confidence interval
Flicking	King Size	18	13–23
	Superslim	19	14–24
Tapping	King Size	19	14–24
	Superslim	22	16–28

3.3.3 Number of individual actions of ash-removing

A successful individual action of ash-removing is defined as all the motions a smoker makes every time he removes ash from his cigarette. A "complete round" of ash-removing movements is the total number of individual ash-removing motions during one complete cigarette is smoked. Table 10 shows the numbers of individual flicking or tapping actions in one "complete round". The average number of ash-flicking motions for the KS cigarettes was five (ranging from two to eight); the number was the same for SS cigarettes (flicking) and for KS cigarettes and SS cigarettes (tapping). Their respective median and mode numbers were close to the average.

Table 10. Number of individual ash-removing actions.

Cigarette type	Data type	Flicking actions	Tapping actions
King Size	Average	5	5
	Median	5	5
	Mode	5	4
	Range	2–8	2–8
Superslim	Average	5	5
	Median	5	5
	Mode	4	4
	Range	2–8	2–8

3.3.4 Frequency of ash-removing motions

Table 11 shows the recorded frequency of motions for clearing ash during one individual action of ash-removal. The frequency of ash-flicking was the highest in the KS cigarettes, about twice per individual action, for SS cigarettes, it was once. The frequency of ash tapping was the highest for the KS cigarettes, at three per individual action. This compared to twice per individual action for the SS cigarettes.

Table 11. Frequency of ash-removing motions.

Cigarette type	Frequency	Ratio (%)	Ratio (%)
King Size	1	30.0	12.8
	2	45.3	22.9
	3	12.7	20.4
	>3	12.0	43.9
Superslim	1	46.1	20.5
	2	37.0	32.1
	3	10.0	18.4
	>3	6.6	29.0

3.3.5 The timing of force applied

The timing of the ash-removing for KS cigarettes is shown in Table 12 and for SS cigarettes in Table 13, respectively. The burnt part of the cigarette was 10 mm and the puff number around 2.5 at the first ash removal. Respondents who smoked KS cigarettes were the first to remove ash from their cigarettes. The second ash-removing occurred at the burnt length of 16.4 mm and around 1.6 puffs. The interval between the first and the second action was approximately 32.8 s. The third clearance happened at the burnt length of 21.7 mm and around 1.5 puffs. The interval time was 32 s. After the second removal, the interval period, the burning distance as well as the interval puff numbers were very similar: 32 s, 5 mm and 1.5 puffs, respectively. Compared with the KS cigarettes, the burnt part and the interval times of SS cigarettes were longer and the interval puffs were nearly the same.

3.3.6 Cigarette holding angles

Table 14 shows the results of the measuring of the holding angles for the test cigarettes. For flicking and tapping most respondents held their cigarettes at an angle of 15° (horizontal).

3.3.7 The angle of force applied

Table 15 shows the angle of force applied when consumers tried to clear the ash buildup. The highest angle was 45°, the average value was 40° with a distribution from 23° to 58°.

4. DISCUSSION

Statistical analysis of all the results showed that there were no significant differences between the ash-clearance force parameters, cigarette holding force and the holding position along the cigarette rod. The statistical results and the

Table 12. Different time intervals of ash clearance for King Size cigarettes.

Serial number	Items	Average value (King Size cigarettes)			
		Nanchang	Guiyang	Shijiazhuang	Total
	Burnt lenght (mm)	10.1	10.0	10.0	10.0
1	Puffs	2.4	2.4	2.7	2.5
	Interval time (s)	31.1	—	38.4	—
	Burnt lenght (mm)	16.9	16.0	16.2	16.4
2	Puffs	1.6	1.6	1.7	1.6
	Interval time (s)	33.6	31.3	33.8	32.8
	Burnt lenght (mm)	22.3	21.5	21.6	21.7
3	Puffs	1.4	1.4	1.6	1.5
	Interval time (s)	32.3	29.33	35.23	32.0
	Burnt lenght (mm)	26.1	25.5	25.8	25.7
4	Puffs	1.3	1.4	1.6	1.4
	Interval time (s)	28.0	31.0	34.9	31.0
	Burnt lenght (mm)	28.6	28.0	27.6	28.1
5	Puffs	1.1	1.1	1.2	1.1
	Interval time (s)	25.3	29.0	27.9	27.3

Table 13. Different time intervals of ash clearance for Superslim cigarettes.

Serial number	Items	Average value (Superslim cigarettes)			
		Nanchang	Guiyang	Shijiazhuang	Total
	Burnt lenght (mm)	11.9	10.6	11.9	11.5
1	Puffs	2.4	2.5	2.6	2.5
	Interval time (s)	38.9	22.5	44.0	35.0
	Burnt lenght (mm)	20.8	17.9	19.9	19.6
2	Puffs	1.6	1.7	1.7	1.7
	Interval time (s)	39.5	36.1	38.7	38.0
	Burnt lenght (mm)	28.0	24.4	27.3	26.5
3	Puffs	1.4	1.6	1.5	1.5
	Interval time (s)	36.5	34.4	38.0	36.3
	Burnt lenght (mm)	33.2	29.7	31.7	31.5
4	Puffs	1.4	1.4	1.4	1.4
	Interval time (s)	32.1	30.6	33.6	32.0
	Burnt lenght (mm)	35.6	32.8	35.5	34.6
5	Puffs	1.1	1.3	1.3	1.2
	Interval time (s)	28.7	27.5	32.0	29.3

Table 14. The statistical data of the cigarette-holding angle.

Cigarette type	Angle	Ratio of flicking actions (%)	Ratio of tapping actions (%)
King Size	< ± 15°	84.79	86.58
	15°–± 30°	13.09	12.44
	Other angles	2.13	0.98
Superslim	< ± 15°	82.52	86.60
	15°–± 30°	15.15	12.31
	Other angles	2.32	1.09

Table 15. The statistical data of the force angle.

	Average	Mode	Range
Force angle (degree °)	40	45	23–58

distribution of force applied, the number of rounds of the ash-clearance, the frequency of the ash clearance, the way consumers held the cigarettes and the time of ash-clearance were similar in the two types of test cigarettes. The results show that smokers from three different locations behave similarly on their ash-clearing habits. The data gathered from the study may in fact represent the average adult smoker's ash-clearance behavior in China because the three locations investigated are distributed over the country.

If we set the statistical significance level at 0.05 for the paired Student's t-test, the result shows that there were some differences in the force parameters between flicking and tapping. The results of the holding force and holding position showed no significant difference. However the flicking force was stronger than the tapping force by about 2.4 times. The frequency of ash clearance in one individual ash-removing action and the way the cigarettes were held during both, flicking and tapping, were similar. There were also some statistically significant differences in the magnitude of force applied, the position of the force applied, and the holding position between the KS cigarettes and SS cigarettes. The results of the clearance duration and the magnitude of force applied showed no significant differences. There were some differences in the frequency of

ash clearance in one individual ash-removing action between the KS cigarettes and SS cigarettes. The highest ratio for the SS cigarettes was once per individual ash-removing action and the highest ratio for the KS cigarettes was twice per individual ash-removing action. The direction in which the cigarettes were held and the number of individual ash-removing actions were the same for the two types of cigarettes, respectively.

The result shows that different length of the tipping paper had much effect on the holding position but had no effect on point of force application. The results of the survey showed that the magnitude of force made no difference on the duration of force in both flicking and tapping method.

5. CONCLUSIONS

This study provides a quantitative characterization of consumers' behavior when clearing the ash build-up on their cigarettes. No significant difference was found between the flicking and tapping actions used to clear cigarette ash when a survey was conducted in three different locations. The statistical data from 309 respondents was generally coherent. The values of the force parameters (the magnitude of the force, the duration of the force, the position along the cigarette where the force was applied, and the angle of the force), the values of the static parameters (the holding force, the holding position along the rod, the number and the frequency of the flicking actions, the time point of each flicking and tapping action, the instantaneous direction of the cigarette) for the two methods and the differences of characteristics of flicking behaviors were determined. The novel method described in this study may be useful to complement the picture of consumers' smoking rituals and to develop a new method to characterize cigarette handling behavior.

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