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Original Article

Comparison between self-reported smoking habits and daily *ad-libitum* smoking topography in a group of Korean smokers

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Abstract

Tobacco smoking is associated with a high global mortality rate since it is known to cause cancers and lung and heart diseases. To control and reduce annual mortality attributed to smoking, it is essential to design applicable smoke cessation programs based on realistic tobacco exposure risk assessment. In this regard, understanding the smoking habits of the smoker is crucial. Using self-report smoking habit surveys is a common approach in measuring basic variables of smoking habits. However, smoking topography measurement devices have recently become available for investigating smoking habit variables accurately. In this study, we conducted a self-report survey to investigate a group of Korean smokers' smoking habit variables such as the number of smoked cigarettes per day, puff counts, and total smoking time. The survey also included items from the Fagerström Test for Nicotine Dependence (FTND). The results were compared with the corresponding variables from machine-determined data to investigate their correlation and reliability. Results indicate that Korean smokers have a reliable understanding of the average number of cigarettes they smoke daily ($\varrho = 0.517$, Cronbach's $\alpha = 0.754$) and the time to first cigarette (TTFC) after waking up ($\varrho = -0.587$, Cronbach's $\alpha = 0.623$), as fundamental items of the FTND score. Nevertheless, these smokers significantly under-reported the puff number and total smoking time, which can cause significant underestimation in the tobacco exposure risk assessment. Consequently, we suggest the application of self-report surveys that are based on the amount of daily smoked cigarettes (e.g. FTND) for clinical or risk assessment purposes. Using smoking topography measurement devices is recommended overusing self-report surveys in measuring smoking habit variables such as puff count and smoking time more accurately.

Keywords: *Ad-libitum* smoking topography, CPD, puff counts, self-report survey, smoking habits, total smoking time

Introduction

According to the World Health Organization (WHO), consuming tobacco is one of the most important global public health threats, causing more than seven million deaths annually [1]. In this regard, target 3.a of the Sustainable Development Goals (SDG3.a) aims to reinforce the implementation of the World Health Organization Framework Convention on Tobacco Control (FCTC) in all countries [2-6]. This is consistent with other items of the SDG3 including SDG3.4 [2,6,7]. According to Gunter et al. [8] in 2018, approximately 38.2% of Korean adult males and 5.9% of Korean adult women were smokers. This indicates that the total smoking rate among adult Koreans in 2018 was around 22%. To improve the Koreans' public health situation on the road to achieving SDG3, promoting smoking cessation based on realistic tobacco exposure risk assessment is essential. To achieve this, understanding accurate smoking behavior is necessary for social approaches to the development of effective smoking cessation programs.

There are several options to measure an individual's smoking behavior, including self-report surveys and using smoking topography instruments [9]. Despite the higher costs, topography measurement instruments are being used to determine smoking behaviors in several studies [10-13]. Investigation of smoking habits through a self-report survey is an easy way to investigate smoking habits, which have considerable potential as an indicator of smoking intensity for evaluation of population-based smoking habits [14]. In particular, studies of Yang et al. [15] and Shahab et al. [14] indicated that results of self-report puff behavior variables are associated with the level of cotinine in urine and saliva, which are biomarkers of exposure to tobacco smoke.

Nevertheless, it is essential to investigate the reliability of the smoking habits survey by comparing it to the

machine-determined smoking topography. In 2008, Shahab et al. [14] showed that for a group of 118 smokers from Australia, Canada, the United Kingdom, and the United States, the correlation between puff counts per cigarette and inter-puff intervals measured through self-report surveys with the ones measured using the CReSSmicro instrument are weak but statistically significant. On the other hand, results of a similar but more recent study conducted by Pulcu [16] in 2016 on 110 smokers in the United Kingdom indicate that smokers may underestimate the puff counts per cigarette. This underestimation was evaluated to be very significant because it could reduce susceptibility to the incidence of respiratory diseases.

Despite the importance of this matter, there is a limited number of studies on the evaluation of smoking behaviors of Korean smokers [7,10,11,15]. Most of these studies investigate the machine-determined smoking topography of Korean smokers with the biomarker of exposure to tobacco smoke. Therefore, fewer studies are designed to investigate the scalability and reliability of measuring smoking behaviors through self-report surveys compared to machine-determined *ad-libitum* daily smoking topography. Accordingly, this study aims to investigate the smoking habits of a group of Korean adults through a self-report survey, measure the daily *ad-libitum* smoking topography of the participants, and compare the results of these two investigations and measure their correlations.

Materials and Methods

Recruiting subject and the self-report smoking habit survey

Recruitment of subjects was conducted as described by Yang et al. [7]. Macromill Embrain Co. (Seoul, Rep. of Korea) recruited 100 smokers through a nationwide online invitation. Applicants who smoke any type of tobacco products except ordinary filtered cigarettes, pregnant women, and those who reported diagnosis of any mental or physical disorders, including smoking-related respiratory diseases were excluded. Immediately after the recruitment and before conducting the smoking topography experiment, the smoking habit survey we designed was conducted online by Macromill Embrain Co. The main questions, aimed at identifying the smoking habits of smokers, are summarized in Table 1.

Table 1. Smoking habits survey variables and questions.

Variable	Question type	Question	Choices for answers
$CPD_{Weekdays}$	Text	How many cigarettes do you usually smoke per day during weekdays (Monday-Friday)?	
$CPD_{Weekends}$	Text	How many cigarettes do you usually smoke per day during weekends (Saturday-Sunday)?	
PC_{Survey}	Multiple Choice	How many times do you usually puff when smoking one cigarette?	(1) 5-10 times; (2) 11-14 times; (3) 15-17 times; (4) 18-20 times; (5) > 20 times
TST_{Survey}	Multiple Choice	How long does it take for you to smoke one cigarette?	(1) < 30s; (2) 30s – < 1 min; (3) 1 min – < 1.5 min; (4) 1.5 min – < 2 min; (5) ≥ 2 min
Smoke Inhalation Depth	Rank Order Scaling	On a scale of 1 to 10, how deep do you inhale the smoke? [1]	1: No inhalation (keeping in mouth) ~ 10: Deep inhalation down to the lung

[1] The answer has to be a positive integer number from 1 to 10. **$CPD_{Weekdays}$**: Smoked Cigarettes per Day During Weekdays (Measured using self-report survey); **$CPD_{Weekends}$**: Smoked Cigarettes per Day During Weekends (Measured using self-report survey); **PC_{Survey}**: Smoked Cigarettes per Day (Measured using self-report survey); **TST_{Survey}**: Total Smoking Time (Measured using self-report survey).

The raw results of the survey were compared with the associated ones measured using the portable CReSS Pocket device. The estimation of smoked cigarettes per day in the survey was done using equation 1. In this equation, $CPD_{Survery}$ is the estimated amount of smoked cigarettes per day, $CPD_{Weekdays}$ and $CPD_{Weekends}$ refer to the number of smoked cigarettes during weekdays and weekends, respectively, as self-reported by the smoker in the survey.

$$CPD_{Survey} = \frac{(CPD_{Weekdays} \times 5) + (CPD_{Weekends} \times 2)}{7} \quad (1)$$

To investigate the smoking volume through the self-report smoking habit survey, a rank order scaling question is used to extract details on the smoke inhalation depth. The scale was ranged from 1 (no inhalation) to 10 (deep inhalation down to the lung), and the bigger number may indicate higher inhalation of smoking volume. The survey also included the Fagerström Test for Nicotine Dependence (FTND) [17]. The FTND includes items such as time to first cigarette ($TTFC_{FTND}$) and number of daily smoked cigarettes (CPD_{FTND}). The FTND score was used to evaluate the nicotine dependency of the participants and compare its association with smoking behavior variables measured by the self-report smoking habit survey and the smoking topography measurement device. The evaluation of nicotine dependency as very low, low, medium, high, and very high was done by considering the FTND score range of 0-2, 3-4, 5, 6-7, and 8-10, respectively [7,17].

Smoking topography experiments

The smoking topography experiments were conducted as described by Yang et al. [7] under careful consideration of the COVID-19 infection prevention protocols. Recruited participants were invited to visit the Institute for Environmental Research at Yonsei University College of Medicine, located in Seoul, Republic of Korea. The objectives and procedure of the study, data analysis, and privacy protection policies were comprehensively explained to all subjects. They subsequently signed a letter of consent and were compensated. A unique identification code was assigned to each participant. The Institutional Review Board (IRB) of the Severance Hospital of the Yonsei University Health System approved the study design. For each participant, smoking topography variables, including the number of recorded smoked cigarettes (CPD_{Device}), puff counts (PC_{Device}), puff time (PT), inter-puff interval (IPI), and total daily smoking volume (TSV_{Device}) were measured using a set of portable CReSS Pocket devices made by Borgwaldt KC GmbH (Hamburg, Germany). For each participant, the experiment is conducted for two days. On the first day, the participant gets a topography measurement device and learns how to use it. Each participant is asked to use the device for *ad-libitum* smoke of all cigarettes for 24 hours and return it on the second day. The participants were also asked to carefully record the time they wake up on the second day and report it when they return the device. For any device returned on the second day, raw recorded data downloaded from it and broken puff records, with puff duration <0.05s, were excluded. For each participant, total smoking time was estimated using equation 2 [7,16]. The time to first cigarette ($TTFC_{Device}$) is calculated by considering the differences between the reported wake-up time and the device-recorded time of the first cigarette after the reported time.

$$\text{Total Smoking Time } (\text{TST}_{\text{Device}}) = (\text{PC}_{\text{Device}} \times \text{PT}) + \left((\text{PC}_{\text{Device}} - 1) \times \text{IPI}\right) \quad (2)$$

Statistical analysis

Information provided by the self-report smoking habit survey is based on the knowledge of the smoker about himself. In contrast, using topography measurement devices may affect how they smoke, especially during the first few smoking events [18]. Accordingly, to conduct a more realistic comparison between the parameters of the self-report smoking habit survey and machine-determined smoking topography as well as minimize the effect of outlier data on further analysis, we considered the study conducted by De Jesus et al. [18]. For each participant, we calculated the 95% confidence interval (CI) of the measured variables, except CPD_{Device} and $TTFC_{Device}$. We then excluded the data out of the 95% CI and proceeded with statistical analysis. As for PC_{Survey} and TST_{Survey}, the median of the ranges in multiple choices was considered as the indicator number for further statistical analysis. Results of CPD_{Device} and $TTFC_{Device}$ were used for categorizing these variables in the same way as corresponding FTND items. Categorizing PC_{Device} and TST_{Device} is done in the same way as PC_{Survey} and TST_{Survey}. The association between self-reported smoking habits and topography variables measured using the CReSS Pocket devices was investigated by calculating Spearman's correlation coefficient (ϱ). We also tested the reliability of the self-reported smoking habit parameters by calculating Cronbach's α and Cohen's Kappa. The median difference between the corresponding variables measured by the survey and topography device was tested thorough Wilcoxon signed-rank test. All statistical analysis was conducted using IBM® SPSS® Statistics version 25 (IBM Company, Armonk, NY, USA) with a significance level set at 0.05.

Results and Discussion

Results of machine-determined smoking topography and self-report smoking habit survey

Results of machine-determined smoking topography and self-reported smoking habits are presented in Table 2. The ratio of the number of male participants to female participants is around 6.1, which is close to the ratio of male smokers to female smokers on a nationwide scale [8]. Considering the location where we conducted our study and the population density of South Korea, most of the participants were residents of Seoul.

The average FTND score of the participants is calculated to be 3.13, which indicates a low nicotine dependency. More than 70% of the participants were evaluated to have low or very low nicotine dependency and only 4% of the participants had an FTND score of more than 8. The $TTFC_{FTND}$ for more than 50% of the participants was 30 minutes after waking up. The average CPD determined by the smoking topography device (CPD_{Device}) is close to the CPD_{Survey}, which is calculated based on the results of the questionnaire items for the average number of cigarettes smoked during weekdays and weekends separately. The difference between the average $CPD_{Weekdays}$ and $CPD_{Weekends}$ is only one cigarette. The averages of PC_{Device} and TST_{Device} were 20.4 and around 3 minutes, respectively. According to the results of the self-report smoking habit survey, the majority of the participants declared that they try to smoke their cigarette with less than 14 puffs and within 1-1.5 minutes. Eleven subjects failed to report their wake-up time and were therefore excluded from the $TTFC_{Device}$ analysis. Under this circumstance, the average of $TTFC_{Device}$ was approximately 79 minutes.

Table 2. Results of self-reported smoking habits and machine-determined smoking topography.

Measurement	Variable	Group or unit	n	Value (%n or mean±SD)	Rang (Min-max)
Self-report smoking habit survey	Gender	Male	86	86%	
		Female	14	14%	
	Age (years)	20-39	42	42%	
		40-59	40	40%	
		>60	18	18%	
	Residence area	Seoul	63	63%	
		Incheon	8	8%	
		Gyeonggi Province	29	29%	
Machine-determined smoking topography[1]	CPD_{Device}	cig/day	100	10.8±4.49	3–21
	PC_{Device}	puff/cig	100	20.4±8.39	1–44
	TST_{Device}	s/cig	100	179.4±69.6	30–385
	TSV_{Device}	ml/day	100	14791±8238	2259–42620
	$TTFC_{Device}$	min	89	79.3±84.0	1–420
Self-report smoking habit survey	FTND Score	-	100	3.13±2.37	0–9
	Nicotine dependence evaluation	Very low (FTND Score=0-2)	44	44%	
		Low (FTND Score=3-4)	27	27%	
		Medium (FTND Score=5)	11	11%	
		High (FTND Score=6-7)	14	14%	
		Very High (FTND Score=8-10)	4	4%	
	$TTFC_{FTND}$	≤5 min	22	22%	
		6-30 min	21	21%	
		31-60 min	27	27%	
		>60 min	30	30%	
	CPD_{FTND}	≤10	50	50%	
		11-20	42	42%	
		20-30	6	6%	
		>30	2	2%	
	$CPD_{Weekdays}$	cig/day	100	10.3±6.76	0–40
	$CPD_{Weekends}$	cig/day	100	11.4±7.07	1–40
	CPD_{Survey}	cig/day	100	10.6±6.56	1.43–38.6
	PC_{Survey}	5-10 times	36	36%	
		11-14 times	40	40%	
		15-17 times	20	20%	
		18-20 times	3	3%	
		>20 times	1	1%	
	TST_{Survey}	<30s	0	0%	
		30s–<1 min	19	19%	
		1 min–<1.5 min	31	31%	
		1.5 min–<2 min	30	30%	
		≥2 min	20	20%	
	Smoke inhalation depth	-	100	6.89±1.48	3–10

[1] For each participant, the 95% confidence interval of the data stored by the topography measurement device, except CPD_{Device} and $TTFC_{Device}$, is considered. **CPD_{Device}**: Smoked Cigarettes per Day (Measured using CReSS Pocket device); **CPD_{FTND}**: Smoked Cigarettes per Day During Weekends (Measured using FTND); **CPD_{Survey}**: Smoked Cigarettes per Day (Measured using self-report survey); **$CPD_{Weekdays}$**: Smoked Cigarettes per Day During Weekdays (Measured using self-report survey); **$CPD_{Weekends}$**: Smoked Cigarettes per Day During Weekends (Measured using self-report survey); **FTND**: Fagerström Test for Nicotine Dependence; **PC_{Device}**: Puff Counts (Measured using CReSS Pocket device); **PC_{Survey}**: Puff Counts (Measured using self-report survey); **TST_{Device}**: Total Smoking Time (Measured using CReSS Pocket device); **TST_{Survey}**: Total Smoking Time (Measured using CReSS Pocket device); **TSV_{Device}**: Total Daily Smoking Volume (Measured using CReSS Pocket device); **$TTFC_{Device}$**: Time to First Cigarette (Measured using CReSS Pocket device); **$TTFC_{FTND}$**: Time to First Cigarette (Measured using FTND).

Association between variables measured using the survey and the smoking topography device

Table 3 shows the results of the association analysis between the variables measured through the self-report smoking habit survey and those measured using the CReSS Pocket device. Results indicate a distinct positive and statistically significant association between CPD_{Survey} and CPD_{Device} (ϱ=0.571, p<0.001). CPD_{Survey} also has a weak, negative, and statistically insignificant correlation with total smoking time. These results are consistent with the study of Yang et al. [7].

Results also yield that the $TTFC_{FTND}$ and $TTFC_{Device}$ have a strong negative and statistically significant correlation (ϱ = -0.587, p<0.001). The negative sign of the correlation coefficient is mainly because of the scoring method of FTND [17]. A higher measured $TTFC_{Device}$ indicates a lower $TTFC_{FTND}$ score, which means lower nicotine dependency. Results also indicate that CPD_{Device}, $TTFC_{Device}$, and TSV_{Device} have distinct positive and statistically significant correlations with FTND scores. Furthermore, TSV_{Device} has a weak positive association with smoke inhalation depth, which is significant at the 10% significance level.

Table 3. Results of Spearman's correlation coefficient (ϱ) for variables measured by survey and smoking topography device.

Measurement		Machine-Determined Smoking Topography				
		CPD_{Device}	**PC_{Device}**	**TST_{Device}**	**$TTFC_{Device}$**	**TSV_{Device}**
Self-report smoking habit survey	**CPD_{Survey}**	0.571***	-0.178+	-0.090	-0.276**	0.312**
	PC_{Survey}	0.029	0.048	0.079	-0.071	0.007
	TST_{Survey}	0.065	-0.047	0.061	-0.050	-0.048
	$TTFC_{FTND}$	0.465***	-0.119	-0.074	-0.587***	0.295**
	Smoke inhalation depth	0.062	0.061	0.022	0.015	0.186+
	FTND score	0.509***	-0.130	-0.081	-0.477***	0.322**

+ p < 0.1; * p < 0.05; ** p < 0.01; *** p < 0.001.
CPD_{Survey}: Smoked Cigarettes per Day (Measured using self-report survey); **FTND**: Fagerström Test for Nicotine Dependence; **PC_{Survey}**: Puff Counts (Measured using self-report survey); **TST_{Survey}**: Total Smoking Time (Measured using self-report survey); **$TTFC_{FTND}$**: Time to First Cigarette (Measured using FTND)

Correlations between PC_{Survey} and TST_{Survey} with the corresponding machine-determined variables, puff count and total smoking time, are positive but are neither strong nor statistically significant. The correlation between PC_{Survey} and machine-determined puff count in our study is lower than the one reported by Shahab et al. [14] which was between 0.2-0.4.

Reliability of variables measured by the survey compared to results obtained using the smoking topography device

The Cronbach's α was calculated for variables measured by the self-report smoking habit survey against the corresponding ones measured by the CReSS Pocket device. Cronbach's α for CPD_{Survey} and CPD_{Device} was calculated to be 0.623, indicating a relatively high reliability of the average number of daily smoked cigarettes investigated by the self-report smoking habit survey. Similarly, the Cronbach's α for $TTFC_{FTND}$ and $TTFC_{Device}$ was 0.754. Accordingly, it may be possible to rely on surveys such as FTND that are designed based on the self-reported daily smoked cigarettes for clinical and tobacco smoke risk assessment exposures [7, 15, 17]. Cronbach's α values calculated for PC_{Survey} and TST_{Survey} against machine-determined puff count and total smoking time were 0.053 and -0.020, respectively. The positive value of Cronbach's α for puff count is consistent with the results presented by Shahab et al. [14].

The results of inter-rater reliability evaluation between smoking habit variables obtained using the survey with the corresponding ones measured by topography device and calculated using Cohen's Kappa value were consistent with the results of Cronbach's α. In particular, the Kappa value for agreement between $TTFC_{FTND}$ and $TTFC_{Device}$ was calculated to be 0.298, which was statistically significant (p=0.001). For $TTFC_{FTND}$ and $TTFC_{Device}$, the Kappa value was 0.226 (p<0.001). This is in contrast with the Kappa values calculated for PC_{Survey} and TST_{Survey} against PC_{Device} and TST_{Device} were -0.041 (p=0.252) and 0.009 (p=0.791), respectively, indicating very weak and statistically insignificant inter-rater reliability.

Comparison of results based on multiple answers in the self-report smoking habit survey

Figure 1 presents the comparison of the results for the number of cigarettes smoked per day, puff counts, and total smoking time measured using the CReSS Pocket device and the self-report smoking habit survey. Results indicate that majority of the smokers have relatively accurate knowledge of the average number of cigarettes they smoke per day.

Nevertheless, two smokers who declared that they smoke more than 30 cigarettes per day in the self-report survey have over-reported. The Wilcoxon signed-rank test results indicated that there was no statistically significant difference between the median of CPD_{Survey} and CPD_{Device} measurements (z= -1.002, p=0.316, r=0.100). In contrast, there was a statistically significant difference between the puff counts (z = -7.639, p < 0.001, r = 0.764) and total smoking time (z= -7.928, p<0.001, r=0.793), with a relatively large effect size.

Regarding puff count, the Wilcoxon signed-rank test result shows that 85% of the smokers underestimate the puff number per cigarette. This finding is consistent with the results of Pulcu [16] with English smokers under-reporting puff numbers in a self-report survey. Similarly, 86% of smokers under-reported the total smoking time in the self-report survey. This indicates that the majority of smokers are exposed to cigarette smoke for a longer period than they think they are. In this regard, it is essential to rely on the results that are obtained using smoking topography measurement devices to have a more realistic understanding of cigarette smokers' exposure to tobacco smoke.

Since about 10% of the subjects failed to provide their wake-up time, we could not calculate the $TTFC_{Device}$ for them. Accordingly, because the *Wilcoxon* signed-rank test results are heavily related to the number of available data, we decided to exclude running the test between the $TTFC_{FTND}$ and $TTFC_{Device}$.

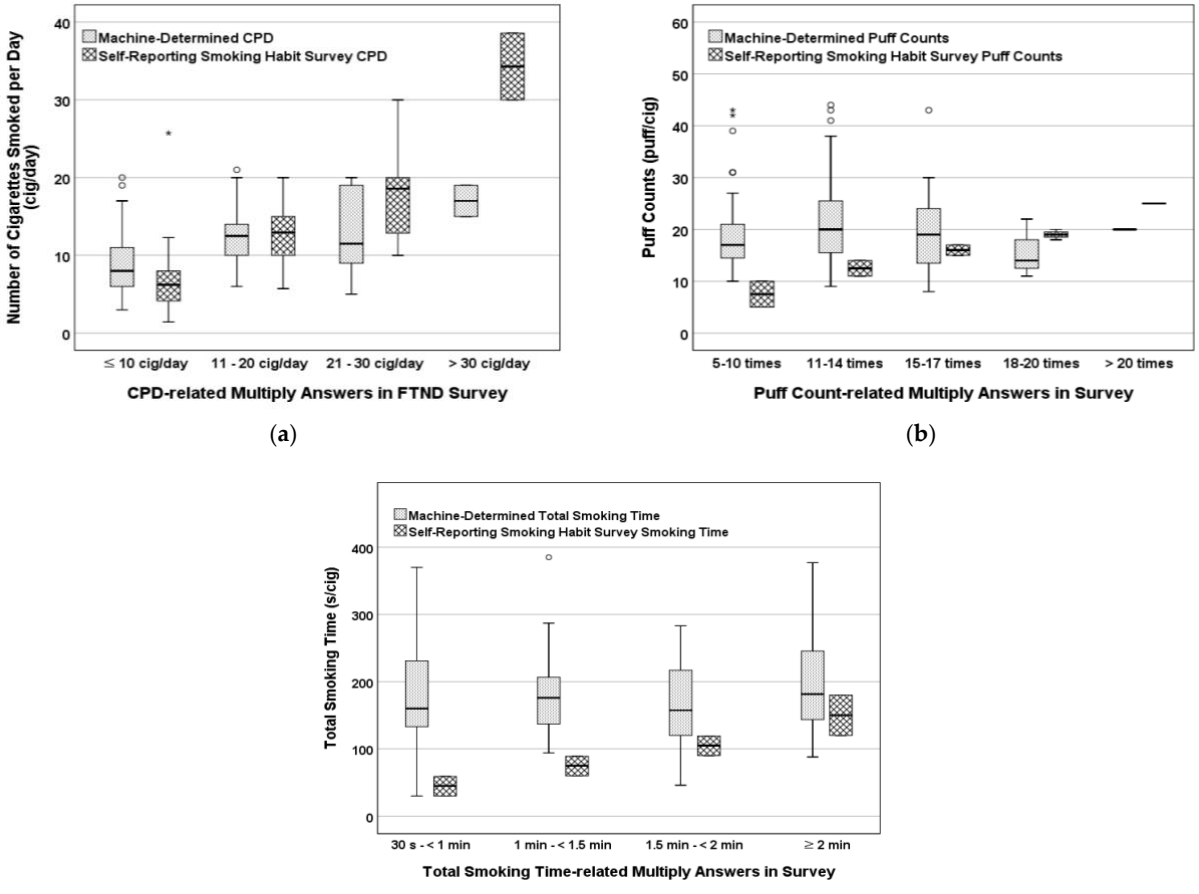

Figure 1. Comparison of results measured using the CReSS Pocket device and the self-report smoking habit survey for (a) number of cigarettes smoked per day; (b) puff counts; (c) total smoking time.

Study limitations

This study should be considered with several limitations that are primarily due to limited funds and resources. The number of participants is relatively small compared to the nationwide population of South Korea and the majority of the participants were not heavy smokers. Due to the social limitations during the COVID19 pandemic, it was challenging to execute the investigation to involve more subjects. Moreover, the number of female smokers who volunteered to participate in this study was relatively lower than male smokers owing to cultural challenges. Also, considering the location of the venue where we conducted our study, we could not gather many subjects from provinces of South Korea that are of considerable distance from Seoul. Finally, since 11 subjects decided not to report their wake-up time, there were challenges in analyzing the $TTFC_{Device}$ for the whole study community.

Nevertheless, we believe that these limitations may not have a significant effect on the results, which are consistent with those obtained by several prior studies such as Shahab et al. [14] in 2008 and Pulcu [16] in 2016, which were conducted with a similar number of subjects as the present study [14,16]. It is also worth noting that the ratio of the number of male smokers to female smokers in this study is close to the ratio of male smokers to female smokers on the nationwide scale.

Conclusions

In this study, we have examined different smoking habit variables using a self-report survey and smoking topography measurement device for a group of Korean smokers. We then compared the results and investigated their association and reliability with the results obtained from the smoking topography measurement device. Our results demonstrate that Korean smokers have a relatively realistic understanding of the average number of cigarettes they smoke daily and the time to their first cigarette of the day. Nonetheless, they under-report their puff numbers and total smoking time, which are key elements in measuring exposure to tobacco smoke. Underestimating these key variables can significantly lead to underestimation of risks of exposure to tobacco smoke. Accordingly, it is recommended not to rely on self-report surveys for smoking topography measurements. Instead, using surveys that are based on measuring the number of cigarettes smoked daily such as FTND, is more reliable for clinical applications, risk assessment procedures, and in designing applicable smoking cessation programs. Accordingly, we recommend that the national organizations running nationwide health investigation programs such as the Korea National Health and Nutrition Examination Survey (KNHANES) to include both FTND and topography measurements for active smokers in their survey programs.

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Conflict of interest

The authors declare no conflicts of interest.

CRediT author statement

JY: Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Resources, Writing - Review & Editing; SH: Methodology, Formal Analysis, Investigation, Visualization, Writing - Original draft Preparation; CL: Methodology, Formal Analysis, Investigation, Data Curation; WH: Formal Analysis, Investigation, Visualization; YS: Formal Analysis, Investigation; YL: Conceptualization, Supervision, Writing- Reviewing and Editing.

Abbreviations

Abbreviation	Meaning
CPD_{Device}	Smoked Cigarettes per Day (Measured using CReSS Pocket device)
CPD_{FTND}	Smoked Cigarettes per Day During Weekends (Measured using FTND)
$CPD_{Survery}$	Smoked Cigarettes per Day (Measured using self-report survey)
$CPD_{Weekdays}$	Smoked Cigarettes per Day During Weekdays (Measured using self-report survey)
$CPD_{Weekends}$	Smoked Cigarettes per Day During Weekends (Measured using self-report survey)
FCTC	Framework Convention on Tobacco Control
FTND	Fagerström Test for Nicotine Dependence
IPI	Inter-Puff Interval
KNHANES	Korea National Health and Nutrition Examination Survey
PC_{Device}	Puff Counts (Measured using CReSS Pocket device)
PC_{Survey}	Puff Counts (Measured using self-report survey)
PT	Puff Time
SDG	Sustainable Development Goal
TST_{Device}	Total Smoking Time (Measured using CReSS Pocket device)
TST_{Survey}	Total Smoking Time (Measured using self-report survey)
TSV_{Device}	Total Daily Smoking Volume (Measured using CReSS Pocket device)
TTFC, $TTFC_{FTND}$	Time to First Cigarette (Measured using FTND)
$TTFC_{Device}$	Time to First Cigarette (Measured using CReSS Pocket device)
WHO	World Health Organization

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References
[1] World Health Organization (WHO). Tobacco. Assessed on February 17, 2022. https://www.who.int/news-room/fact-sheets/detail/tobacco

[2] United Nations (UN). Goal 3 | Department of economic and social affairs. Assessed on February 17, 2022. https://sdgs.un.org/goals/goal3

[3] Woo BL, Lim MK, Park EY, Park J, Ryu H, Jung D, et al. Characteristics of non-smokers' exposure sing indirect smoking indicators and time activity patterns. Sustainability 2020;12(21):9099-9099. https://doi.org/10.3390/su12219099

[4] Hashemi S. Sustainable integrated clean environment for human & nature. MDPI; 2021. https://doi.org/10.3390/books978-3-0365-1881-7

[5] Hashemi S. Perspectives on sustainable integrated clean environment for human and nature. Sustainability 2021;13(8):4150. https://doi.org/10.3390/su13084150

[6] Yang J, Hashemi S, Han W, Song Y, Lim Y. Exposure and risk assessment of second- and third-hand tobacco smoke using urinary cotinine levels in South Korea. Int J Environ Res Public Health 2022;19(6):3746. https://doi.org/10.3390/ijerph19063746

[7] Yang J, Hashemi S, Han W, Lee C, Song Y, Lim Y. Study on the daily Ad Libitum smoking habits of active Korean smokers and their effect on urinary smoking exposure and impact biomarkers. Biomarkers 2021;26(8):691-702. https://doi.org/10.1080/1354750X.2021.1981448

[8] Gunter R, Szeto E, Jeong SH, Suh SA, Waters AJ. Cigarette smoking in South Korea: a narrative review. Korean Journal of Family Medicine 2020;41(1):3-13. https://doi.org/10.4082/kjfm.18.0015

[9] Blank MD, Disharoon S, Eissenberg T. Comparison of methods for measurement of smoking behavior: mouthpiece-based computerized devices versus direct observation. Nicotine Tob Res 2009;11(7):896-903. https://doi.org/10.1093/ntr/ntp083

[10] Chung S, Kim SS, Kini N, Fang HJ, Kalman D, Ziedonis DM. Smoking topography in Korean American and white men: preliminary findings. Journal of Immigrant and Minority Health 2015;17(3):860-866. https://doi.org/10.1007/s10903-013-9921-6

[11] Kim S, Yu S. Smoking topography among Korean Smokers: Intensive smoking behavior with larger puff volume and shorter interpuff interval. International Journal of Environmental Research and Public Health 2018;15(5):1024. https://doi.org/10.3390/ijerph15051024

[12] Matsumoto M, Inaba Y, Yamaguchi I, Endo O, Hammond D, Uchiyama S, et al. Smoking topography and biomarkers of exposure among Japanese smokers: associations with cigarette emissions obtained using machine smoking protocols. Environmental Health and Preventive Medicine 2013;18(2):95-103. https://doi.org/10.1007/s12199-012-0293-7

[13] Williams JM, Gandhi KK, Lu SE, Kumar S, Steinberg ML, Cottler B, et al. Shorter interpuff interval is associated with higher nicotine intake in smokers with schizophrenia. Drug and Alcohol Dependence 2011;118(2-3):313-319. https://doi.org/10.1016/j.drugalcdep.2011.04.009

[14] Shahab L, Hammond D, O'Connor RJ, Michael Cummings K, Borland R, King B, et al. The reliability and validity of self-reported puffing behavior: evidence from a cross-national study. Nicotine Tob Res 2008;10(5):867-874. https://doi.org/10.1080/14622200802027156

[15] Yang J, Hashemi S, Han W, Lee C, Kang Y, Lim Y. Korean male active smokers: quantifying their smoking habits and the transformation factor among biomarkers in urine and blood. Biomarkers 2020;25(8):659-669. https://doi.org/10.1080/1354750X.2020.1797879

[16] Pulcu E. Self-report distortions of puffing topography in daily smokers. J Health Psychol 2016;21(8):1644-1654. https://doi.org/10.1177/1359105314560917

[17] Fagerstrom KO, Schneider NG. Measuring nicotine dependence: a review of the Fagerstrom Tolerance Questionnaire.

Journal of Behavioral Medicine 1989;12(2):159-182. https://doi.org/10.1007/BF00846549

[18] De Jesus S, Hsin A, Faulkner G, Prapavessis H. A systematic review and analysis of data reduction techniques for the CReSS smoking topography device. Journal of Smoking Cessation 2015;10(1):12-28. https://doi.org/10.1017/jsc.2013.31