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Associations between the Frequency and Quantity of Heated Tobacco Product Use and Smoking Characteristics among Korean Smoking Adolescents

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Purpose: Although heated tobacco product (HTP) use among adolescents is an emerging public health problem, little is known about the frequency and quantity of HTP use. Thus, we investigated the associations between the frequency and quantity of HTP use and smoking characteristics (i.e., combustible cigarette [CC] and electronic cigarette [EC] use, and attempts to quit smoking) among CC-smoking adolescents. **Methods:** We analyzed nationally representative data from 2,470 Korean adolescents who were current CC smokers. To investigate our aim, we conducted multinomial logistic and logistic regression analyses. **Results:** We found that daily and heavier CC users had greater likelihoods of more frequent and heavier HTP use. In addition, dual users of CCs and ECs were more likely to use HTPs more frequently and heavily than CC users who did not use ECs. Moreover, daily EC users had the highest risk of frequent and heavy HTP use. The frequency and quantity of HTP use were not associated with attempts to quit smoking. Compared to CC-only use, dual use of CCs and HTPs was not associated with quitting attempts, and triple use of CCs, ECs, and HTPs was associated with a lower likelihood of quitting attempts. **Conclusion:** HTP use was less likely to displace CC use and promote attempts to quit smoking. Thus, strict regulations are required to prevent the promotion of HTPs as a substitute for CCs or as a means of quitting smoking. Additionally, health professionals should consider preventive interventions for HTP, as well as CC and EC use among adolescents.

Key words: Adolescent; Electronic Nicotine Delivery Systems; Smoking; Tobacco Products; Tobacco Use Cessation

INTRODUCTION

Heated tobacco products (HTPs) are novel tobacco products that use an electronic device to heat dry tobacco at a low temperature of 350°C, delivering a nicotine-containing aerosol that users can inhale [1]. The HTP market has grown rapidly since Philip Morris International (PMI) launched the I-Quit-Ordinary-Smoking (IQOS) HTP system in 2014. Specifically, other tobacco companies have launched new products in the HTP market (e.g., Glo by British American Tobacco [BAT] and Lil by Korea Tobacco & Ginseng) [2], and recently, IQOS has been sold in over 60 countries [1,3].

As the HTP market has expanded globally, adolescents' HTP use has become a major public health concern owing to its adverse health effects and prevalence. Specifically, previous studies have found that adolescents' HTP use can have negative effects on physical (e.g., cancers, allergic rhinitis, and asthma) and mental health (e.g., depression, suicidal ideation, and suicide attempts) [4-7]. Moreover, HTPs have been shown to be more hepatotoxic than combustible cigarettes (CCs) and to release significantly more carcinogens than electronic cigarettes (ECs) [7,8]. Despite these negative consequences, 3.5% of adolescents in Korea have used HTP at least once in their lives, and 1.1% were current HTP users

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[9]. Notably, the prevalence of HTP use has increased faster than that of EC use among Korean adolescents [10]. In Canada, the US, and the UK, 5.6%~9.1% of adolescents were aware of IQOS [11]; the proportion of current HTP users among US adolescents was 1.3% and 1.4% for middle and high school students, respectively [12]. The widespread use of HTPs among adolescents can be attributed to (a) the perception that HTPs are less harmful and more socially acceptable than CCs, (b) their appealing flavors, such as mint, menthol, and berries, and (c) their design, which is similar to popular mobile electronic devices [13].

International tobacco companies claim that a complete switch from CC to HTP significantly reduces users' exposure to harmful chemicals [3,14]. However, one notable aspect of adolescents' HTP use is that a substantial number of HTP users are multiple tobacco product users. Specifically, among current HTP-using Korean adolescents, only 4.1% were single HTP users; 63.4% were triple users of CCs, ECs, and HTPs; and 32.4% were dual users of HTPs with CCs or ECs [15]. In a nationally representative study of US adolescents, 43% and 75% of current HTP users used CC and EC, respectively [16]. Moreover, current HTP users among adolescents have a greater likelihood of (a) CC, EC, or other tobacco product use and (b) frequent CC and EC use [10,15-17]. These findings indicate that HTP use in adolescents does not necessarily imply a decrease in the frequency or quantity of CC or EC use.

To comprehensively understand the characteristics of adolescents' HTP use and develop new interventions for their HTP use, it is necessary to consider the frequency and quantity of HTP use [16,18]. Although both frequency and quantity of tobacco products are associated with persistent tobacco product use and nicotine dependence [19,20], studies on the detailed characteristics of HTP use have been limited to adults [21,22]. However, previous studies have indicated that compared to adults, adolescents are (a) more sensitive to HTP use and advertisements [11,13,23] and (b) more likely to continue using HTP after a single experiment [23]. Despite the differences in HTP use between adults and adolescents, most previous studies on adolescents were limited to examining the associations between lifetime and monthly use of HTPs and smoking characteristics [10,15-17,24]. Although the intention to quit smoking is an important phase towards quitting smoking [25], few studies have identified an association between the detailed characteristics of HTP use and intention to quit smoking. Additionally, findings on the relationship between HTP use and attempts to quit smoking are inconsistent. Specifically, one study found no significant association between HTP use and attempts to quit smoking [10], whereas another study found that dual use of HTPs and ECs was associated with attempts to quit smoking [26]. Moreover, two review studies revealed a controversy over whether HTP use for smoking cessation is effective [27,28]. Nevertheless, a substantial number of HTP users consider HTP use helpful in quitting smoking [29]. Thus, this study aimed to investigate the associations between the frequency and quantity of HTP use and current smoking characteristics (i.e., current CC and EC use and attempts to quit smoking) among current CC-smoking adolescents.

METHODS

1. Design and study participants

This study was a secondary analysis of data from the 16th Korea Youth Risk Behavior Survey (KYRBS) conducted in 2020 to examine the associations between the frequency and quantity of HTP use and current smoking characteristics. The 16th KYRBS is an annual online survey on health behaviors (e.g., tobacco and alcohol use, physical activity, and eating habits) among Korean adolescents [9]. The KYRBS obtained a representative sample of middle and high school students using stratified multi-stage cluster sampling to investigate adolescents' health behaviors [9]. The sample comprised 54,948 students from 398 middle and 395 high schools. Our sample consisted of 2,470 current smokers who had smoked CC on at least one day during the past 30 days. We obtained an exemption from the Institutional Review Board of Daegu Catholic University (IRB No. CUIRB-2022-E007).

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2. Measures

1) Frequency and quantity of HTP use

Current HTP use was assessed using two questions: "In the past 30 days, on how many days did you use HTP at least once?" and "In the past 30 days, how many HTP sticks did you use per day on average?" Based on the answers, participants' monthly frequency of HTP use was divided into four groups: 0, 1~2, 3~9, and 10 or more days. We categorized the quantity of HTP used per day into four groups: 0, 1~9, 10~19, and 20 or more HTP sticks. We determined the frequency categories based on previous studies related to adolescent smoking: (a) the monthly frequency of alternative tobacco product use among adolescents can be classified into infrequent (i.e., 1~2 days) and frequent use (i.e., more than 3~5 days) [30], and (b) frequent use of alternative tobacco products for more than 10 days in a month is strongly associated with more frequent and heavier CC use [31,32].

2) Current smoking characteristics

We used four current smoking characteristics: current CC use, current EC use, multiple tobacco product use, and attempts to quit smoking. Current CC use was assessed using the following two questions: "In the past 30 days, on how many days did you smoke at least one cigarette?" and "In the past 30 days, how many cigarettes did you smoke per day on average?" These questions were measured using seven and six responses, respectively. The participants were categorized into four groups based on their responses: non-daily use, light daily use (< 10 cigarettes per day [CPD]), moderate daily use (10~19 CPD), and heavy daily use (≥ 20 CPD). To assess current EC use, participants were asked how many days they had used nicotine-containing ECs in the past 30 days. Current EC use was classified into three categories: non-use, non-daily use, and daily use. Multiple tobacco product use was categorized as CC-only, CC + EC, CC + HTP, or CC + EC + HTP. Finally, attempts to quit smoking were assessed by asking participants whether they had attempted to quit any tobacco product in the past 12 months.

3) General characteristics

Based on the literature [15-17,33], we adjusted for the nine general characteristics as control variables to obtain accurate associations between the frequency and quantity of HTP use and smoking characteristics. Specifically, we adjusted for the four sociodemographic factors: sex ("male" and "female"), grade level ("middle school" and "high school"), area of residence ("suburban or rural" and "urban"), and perceived economic status ("middle or high" and "low"). Additionally, we adjusted for five confounding factors: academic performance, stress, depressive feelings, binge drinking, and secondhand smoking at home. Subjective academic performance was assessed by inquiring about the participants' perceived levels of academic performance. Responses were measured using a 5-point Likert scale and divided into two categories: "middle or high" and "low." Perceived stress level was assessed by asking participants to rate the level of stress they usually felt using a 5-point Likert scale. The responses were divided into two categories: "low or average" and "high." We measured depressive feelings by asking participants whether they had felt sad or hopeless enough to stop doing their daily activities for two weeks in the past 12 months; possible responses were "yes" or "no." Binge drinking was defined as drinking an average of five or more drinks at a time, based on responses to the question about monthly average alcohol consumption [34]. The possible responses were "yes" or "no." Secondhand smoking at home was assessed by asking participants to respond to a question about the number of days of exposure to secondhand smoke in their home in the past seven days; possible response range was 0~7 days and was categorized as "non-exposed" and "exposed."

3. Statistical analysis

We conducted a survey data analysis, including domain analysis, using STATA version 12 to incorporate a complex sampling design (i.e., survey strata, clusters, and sample weights) [35]. First, we investigated the sample and smoking characteristics using descriptive statistics such as unweighted frequency and weighted percentage. Second, two multinomial logistic regressions were conducted to examine

the associations of the frequency and quantity of HTP use with current CC and EC use. Finally, we conducted three consecutive logistic regressions to investigate the associations between the characteristics of tobacco product use and attempts to quit smoking. Specifically, we investigated the associations between attempts to quit smoking and the frequency (Model I) and quantity of HTP use (Model II) as well as multiple tobacco product use (Model III). All regression models were adjusted for sex, grade, residential area, perceived economic status, subjective academic performance, stress, depressive feelings, binge drinking, and secondhand smoking at home. In Models I and II, we additionally adjusted for current CC and EC use. A p-value less than 0.05 was considered statistically significant.

RESULTS

1. General characteristics of the participants

In our sample, 71.1% were male, 80.6% were high school students, 55.3% lived in suburban or rural areas, and 20.1% perceived their household economic status to be low. Among the participants, 58.8% reported that their subjective academic performance was low. Approximately 47% reported a high level of stress and 43.9% reported feeling depressed. Additionally, 47.0% had experienced binge drinking, and 29.9% had been exposed to secondhand smoke at home (Table 1).

Table 1. General Characteristics among CC-smoking Adolescents (N = 2,470)

Factors	Frequency	%†
Sex		
Male	1,725	71.1
Female	745	28.9
Grade level		
Middle school	538	19.4
High school	1,932	80.6
Area of residence		
Suburban or rural	1,357	55.3
Urban	1,113	44.7
Perceived economic status		
Middle or high	1,955	79.9
Low	515	20.1
Subjective academic performance		
Middle or high	1,011	41.2
Low	1,459	58.8
Stress		
Low or average	1,327	53.5
High	1,143	46.5
Depressive feelings		
No	1,371	56.1
Yes	1,099	43.9
Binge drinking		
No	1,291	53.0
Yes	1,179	47.0
Secondhand smoking at home		
Non-exposed	1,699	70.1
Exposed	771	29.9

†Unweighted frequency and weighted percentage.

2. Frequency and quantity of HTP use according to smoking characteristics

In our study, 78.4% of participants were non-HTP users. Regarding the frequency of HTP use, 8.4% used HTPs for 10 or more days, followed by those who used HTPs for 1~2 days (7.3%) and 3~9 days (5.9%). Regarding quantity of HTP use, 17.6% of the participants reported using 1~9 HTP sticks and 2.0% each reported using 10~19 and 20 or more HTP sticks. The frequency and quantity of HTP use tended to increase in participants with more frequent and heavier CC use. For example, the percentages of frequent (i.e., using HTP for 10 or more days) and heavy HTP use (i.e., using 20 or more HTP sticks) were highest among heavy daily CC users (24.3% and 15.9%, respectively) and lowest among non-daily CC users (3.6% and 0.5%, respectively). Similarly, the percentages of frequent and heavy HTP use were highest among CC users with daily EC use (41.7% and 20.6%, respectively), followed by non-daily users and non-users. The percentages of frequent HTP use in triple users of CCs, ECs, and HTPs, and dual users of CCs and HTPs were similar, but those of heavy HTP use were much higher in triple users than in dual users (11.8% and 3.2%, respectively). Those who attempted to quit smoking had a higher rate of heavy HTP use than those who did not (3.8% and 1.2%, respectively; Table 2).

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Table 2. Frequency and Quantity of HTP Use According to Smoking Characteristics among CC-Smoking Adolescents[†] (*N* = 2,470)

Smoking characteristics	Full sample		Frequency of HTP (day)[††]								Quantity of HTP (stick)[§]							
			0		1~2		3~9		≥ 10		0		1~9		10~19		≥ 20	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Total	2,470	100.0	1,929	78.4	189	7.3	151	5.9	201	8.4	1,929	78.4	444	17.6	47	2.0	50	2.0
Current CC use																		
Non-daily use	1,168	46.9	1,001	85.9	76	6.2	53	4.3	38	3.6	1,001	86.0	154	12.9	8	0.6	5	0.5
Light daily use (< 10 CPD)	762	31.2	593	78.3	65	8.3	38	4.5	66	8.9	593	78.2	152	19.3	12	1.9	5	0.6
Moderate daily use (10~19 CPD)	334	13.6	224	67.0	32	8.9	34	9.9	44	14.2	224	66.9	85	26.0	19	5.0	6	2.1
Heavy daily use (≥ 20 CPD)	206	8.3	111	55.3	16	7.1	26	13.3	53	24.3	111	55.4	53	23.9	8	4.8	34	15.9
Current EC use																		
Non-use	1,631	66.1	1,467	90.6	59	3.2	45	2.7	60	3.5	1,467	90.6	146	8.5	11	0.6	7	0.3
Non-daily use	672	26.7	386	57.0	121	17.7	95	13.6	70	11.7	386	57.0	252	37.6	26	4.2	8	1.2
Daily use	167	7.2	76	46.3	9	5.9	11	6.1	71	41.7	76	46.3	46	27.0	10	6.1	35	20.6
Multiple tobacco product use																		
CC-only	1,467	60.0	1,467	100.0	-		-		-		1,467	100.0	-		-		-	
CC + EC	462	18.5	462	100.0	-		-		-		462	100.0	-		-		-	
CC + HTP	164	6.2	-		59	34.5	45	28.7	60	36.8	-		146	90.5	11	6.3	7	3.2
CC + EC + HTP	377	15.3	-		130	33.5	106	26.6	141	39.9	-		298	78.0	36	10.2	43	11.8
Attempts to quit																		
Yes	740	30.6	573	76.9	44	6.1	48	6.8	75	10.2	573	77.0	130	17.7	10	1.5	27	3.8
No	1,730	69.4	1,356	79.1	145	7.8	103	5.5	126	7.6	1,356	79.1	314	17.5	37	2.2	23	1.2

CC = Combustible cigarette; CPD = Cigarettes per day; EC = Electronic cigarette; HTP = Heated tobacco product.
[†]Unweighted frequency and weighted percentage.
[††]Monthly frequency of HTP use.
[§]Daily average quantity of HTP use.

3. Smoking characteristics associated with frequency and quantity of HTP use

In multivariate models for frequency of HTP use, daily and heavier CC users had greater risks of 3~9 days (relative risk ratios [RRRs] = 2.80~4.06) and 10 or more days of HTP use per month (RRRs = 2.20-5.89) than non-daily CC users. Compared with CC users who did not use ECs, dual users of CCs and ECs had greater risks of 1~2 days (RRRs = 3.03~8.73), 3~9 days (RRRs = 3.15~7.96), and 10 or more days of HTP use per month (RRRs = 5.54~16.90). In multivariate models for quantity of HTP use, daily and heavier CC users had greater risks of using less than 1~9 (RRRs = 1.54~2.38) and 10~19 HTP sticks (RRRs = 3.03~9.23) compared to non-daily CC users. Heavy daily CC users had a higher risk of using 20 or more HTP sticks (RRR = 17.38) than did non-daily CC users. Compared to CC users who did not use ECs, dual users of CCs and ECs had greater risks of using less than 1~9 (RRRs = 5.13~7.10), 10~19 (RRRs = 11.18~14.90), and 20 or more HTP sticks (RRRs = 6.87~89.51; Table 3).

4. Associations between frequency and quantity of HTP use and attempts to quit smoking

In Models I and II, frequency and quantity of HTP use were not associated with attempts to quit smoking. Additionally, compared to CC-only users, triple users were less likely to attempt to quit smoking in Model III (odds ratio = 0.78; Table 4).

DISCUSSION

This study found that 21.6% of current CC users reported their monthly HTP use. Similarly, in previous studies conducted in the US, the prevalence of current HTP use among current CC-smoking adolescents was 16.0% [16]. One of the notable findings of our study was that the percentages of

Table 3. Smoking Characteristics Associated with Frequency and Quantity of HTP Use among CC-Smoking Adolescents (*N* = 2,470)

Factors	Frequency of HTP (day)†,§,¶											
	1~2				3~9				≥ 10			
	RRR	95% CI		*p*-value	RRR	95% CI		*p*-value	RRR	95% CI		*p*-value
		Lower	Upper			Lower	Upper			Lower	Upper	
Current CC use (ref. = non-daily use)												
Light daily use (< 10 CPD)	1.39	0.94	2.04	.101	1.16	0.69	1.96	.580	2.20	1.40	3.44	.001
Moderate daily use (10~19 CPD)	1.67	0.99	2.83	.057	2.80	1.57	5.00	< .001	4.28	2.58	7.11	< .001
Heavy daily use (≥ 20 CPD)	1.57	0.78	3.15	.206	4.06	2.22	7.43	< .001	5.89	3.29	10.54	< .001
Current EC use (ref. = non-use)												
Non-daily use	8.73	6.16	12.38	< .001	7.96	5.03	12.60	< .001	5.54	3.60	8.52	< .001
Daily use	3.03	1.28	7.19	.012	3.15	1.38	7.23	.007	16.90	10.75	26.58	< .001
Factors	Quantity of HTP (stick)††,‖,¶											
	1~9				10~19				≥ 20			
	RRR	95% CI		*p*-value	RRR	95% CI		*p*-value	RRR	95% CI		*p*-value
		Lower	Upper			Lower	Upper			Lower	Upper	
Current CC use (ref. = non-daily use)												
Light daily use (< 10 CPD)	1.54	1.15	2.04	.003	3.03	1.08	8.55	.036	0.59	0.15	2.26	.437
Moderate daily use (10~19 CPD)	2.38	1.61	3.53	< .001	9.23	3.54	24.06	< .001	2.94	0.77	11.23	.114
Heavy daily use (≥ 20 CPD)	2.38	1.44	3.95	.001	8.72	2.70	28.19	< .001	17.38	5.31	56.95	< .001
Current EC use (ref. = non-use)												
Non-daily use	7.10	5.42	9.29	< .001	11.18	4.70	26.62	<. 001	6.87	2.04	23.06	.002
Daily use	5.13	3.22	8.19	< .001	14.90	5.31	41.78	< .001	89.51	30.32	264.22	< .001

CC = Combustible cigarette; CI = Confidence interval; CPD = Cigarettes per day; EC = Electronic cigarette; HTP = Heated tobacco product; ref. = Reference group; RRR = Relative risk ratio.

†Monthly frequency of HTP use.

††Daily average quantity of HTP use.

§The reference group = 0 day per month.

‖The reference group = 0 HTP stick per day.

¶Adjusted for sex, grade level, area of residence, perceived economic status, subjective academic performance, stress, depressive feelings, binge drinking, and secondhand smoking at home.

frequent and heavy HTP use were the highest among heavy daily CC users and CC users with daily EC use. In addition, the percentage of heavy HTP users among triple users was more than three times higher than that of dual users of CCs and HTPs. To the best of our knowledge, this study is the first to conduct a detailed assessment of adolescent HTP use in terms of frequency and quantity. Thus, it is difficult to directly compare the results of this study with those of other adolescent studies. However, our results are partially similar to the EC use patterns of current CC–using adolescents in Korea and the US: the proportion of frequent EC users was higher among frequent CC users and among EC users who also used other substances, such as CC or alcohol [32,36,37]. As the potential health effects of HTP use at the individual and population levels are still unknown and HTPs contain nicotine and toxic chemicals that can cause nicotine addiction

Table 4. Associations between Frequency and Quantity of HTP Use and Attempts to Quit Smoking (*N* = 2,470)

Factors	Attempts to quit†											
	Model I				Model II				Model III			
	OR	95% CI		*p*-value	OR	95% CI		*p*-value	OR	95% CI		*p*-value
		Lower	Upper			Lower	Upper			Lower	Upper	
Frequency of HTP (day)†† (ref. = 0)												
1~2	1.29	0.88	1.88	.189								
3~9	0.89	0.59	1.35	.591								
≥ 10	1.01	0.72	1.41	.964								
Quantity of HTP (stick)§ (ref. = 0)												
1~9					1.05	0.82	1.34	.700				
10~19					1.81	0.82	3.96	.140				
≥ 20					0.67	0.34	1.30	.236				
Multiple tobacco product use (ref. = CC-only)												
CC + EC									1.07	0.83	1.39	.601
CC + HTP									1.35	0.88	2.06	.165
CC + EC + HTP									0.78	0.61	0.99	.043

CC = Combustible cigarette; CI = Confidence interval; CPD = Cigarettes per day; EC = Electronic cigarette; HTP = Heated tobacco product; ref. = Reference group; OR = Odds ratio.

†The reference group = no attempts to quit.

††Monthly frequency of HTP use.

§Daily average quantity of HTP use.

[1,11], the high proportion of frequent and heavy HTP users among CC users is a matter of concern.

This study found that current CC and EC use was associated with the frequency and quantity of HTP use. First, the risks of more frequent and heavier HTP use were greater among daily and heavier CC users. Specifically, daily CC users had higher risks of more frequent and heavier HTP use than non-daily CC users. Daily CC users with more CPD were at greater risks of more frequent and heavier HTP use; and heavy daily CC users had the highest risks of frequent and heavy HTP use. Similarly, a nationally representative study of Japanese adults found that most dual users of CCs and HTPs used both daily and daily dual users used more HTP sticks per day than non-daily dual users [21]. These strong associations between CC and HTP use can be partly attributed to the high nicotine dependence among dual users of CCs and HTPs. Specifically, concurrent use of CCs and HTPs could increase nicotine intake [29], which may be linked to an increased likelihood of nicotine dependence. In addition, CC users who are highly nicotine-dependent may increase their nicotine dependence even further if they concurrently use HTPs [38]. Moreover, HTPs allow current CC users to smoke even in a smoke-free environment [39]. Specifically, an HTP can be attractive to smoking adolescents since it does not look like a tobacco product and has no smell or ash, allowing them to hide their smoking [2,40], and dual users can switch between HTP use and CC use depending on their circumstances [18]. Therefore, when planning an intensive smoking cessation program for CC users, particularly daily users, it is necessary to consider an integrated intervention for the use of various tobacco products rather than focusing on a specific product [17]. Furthermore, there is a need to strengthen the regulations prohibiting the use of indoor tobacco products in schools.

Second, dual users of CCs and ECs were more likely to use HTPs more frequently and heavily than current CC-only users. In addition, dual users of CCs and ECs, who reported their daily EC use, had the highest risks of frequent and heavy HTP use. A possible reason for these strong associations is that multiple tobacco users may have higher levels of nicotine addiction and may underestimate the risk of using multiple tobacco products than single tobacco product users

[17]. Indeed, a nationally representative study of US adolescents found that two or more tobacco product users were more likely to experience nicotine dependence symptoms than single tobacco users and frequent EC users were more likely to report nicotine dependence than less frequent EC users [41]. Furthermore, higher levels of nicotine dependence among multiple tobacco product users have been associated with frequent and heavy tobacco use [42]. These findings support the claim that HTP complements tobacco products [18]. Considering that most adolescent smoking patterns proceed to a wider variety of tobacco product use [43], frequent and excessive HTP use in dual users of CCs and ECs is unlikely to be a transient phenomenon. Rather, it may contribute to their perception of smoking behavior as normal, desirable, and socially acceptable (i.e., renormalization) [44].

Finally, we found that frequency and quantity of HTP use were not associated with attempts to quit smoking among current CC smoking adolescents. Consistent with these findings, a study of Japanese adults found an insignificant association between the frequency of HTP use in CC users and attempts to quit smoking [21]. Similarly, ever use of HTPs among Korean CC-smoking adolescents was not associated with attempts to quit smoking [10,17]. This phenomenon contradicts advertisements by tobacco companies claiming that HTP use can help people quit smoking [40]. Specifically, CC-smoking adolescents do not use HTPs as a tool to help them quit smoking or replace CCs, but are more likely to use HTPs concurrently with CCs as another means to consume nicotine [45]. Indeed, a study of Dutch adolescents and adults indicated that the primary reasons for using HTPs were curiosity and a better taste [46]. Nevertheless, considering that HTPs are advertised as less dangerous tobacco products or smoking cessation aids, strong policies banning advertising and marketing of HTPs as well as CCs should be pursued immediately [2].

In addition, our study found that triple users of CCs, ECs, and HTPs were less likely to attempt smoking cessation than CC-only users. Given that multiple tobacco use in adolescence can cause and intensify nicotine addiction [47], these results indicate that higher nicotine dependence among triple users acts as an obstacle to smoking cessation among adolescents.

Based on our findings, strategies should be established at the government, community, and school levels. First, at the government level, HTPs should be regulated at the same level as CCs in all tobacco control areas (e.g., tax increases on tobacco products, advertisement regulation, and indoor use regulation) according to the WHO guidelines [1]. For example, to prevent and regulate adolescent smoking and increase successful smoking cessation, legislation is needed for stronger monitoring and regulation of retailer sales of tobacco products, including HTPs [17]. In addition, there is a need for stricter regulations prohibiting the sale of HTPs as substitutes for CCs or as a means of quitting smoking. Moreover, considering the continued release of new tobacco products, the Korean government, like the U.S. Food and Drug Administration, needs to establish a legal process that requires robust pre-launch evaluation of the product [2,48].

Second, smoking cessation strategies tailored to adolescents' use of new-generation tobacco products are needed at the community and school levels. In particular, evidence-based education programs on the adverse consequences of HTP use and associations between frequency and quantity of HTP use and smoking characteristics should be urgently developed and implemented. For example, for adolescents who use HTPs to quit smoking, it is necessary to emphasize that the frequency and quantity of HTP do not have a significant relationship with smoking cessation, but can increase the likelihood of multiple tobacco product use and nicotine addiction. Furthermore, considering adolescents' indiscriminate exposure to HTP advertisements and HTP-related content online and on social media, efforts should be made to improve their media literacy skills to critically analyze and evaluate media messages on HTP use [49].

This study has two strengths. First, we investigated the association between adolescent HTP use and smoking characteristics, considering the frequency and quantity of HTP use in a nationally representative sample. Given that the intensity of tobacco product use is a critical factor of nicotine dependence [19], our findings may contribute to the development of policies or interventions to prevent and reduce underage smoking and nicotine dependence. Second, by incor-

porating the frequency and quantity of HTP use, this study found that HTP use in adolescents was more likely to reinforce tobacco product use and that multiple tobacco product use made it difficult for them to quit smoking. Despite these strengths, our study has three limitations. First, causal relationships between smoking-related characteristics and HTP use could not be established due to the use of cross-sectional data. Second, the data collected through self-reported questionnaires were analyzed, which may have caused measurement errors. For example, some adolescents may underreport their smoking behaviors due to social desirability and potential stigma. Third, it was not possible to evaluate the differences in the characteristics of HTP use based on CC users' reasons for using HTPs because the KYRBS, from which our sample was extracted, did not measure this aspect.

CONCLUSION

Our study of CC-smoking adolescents found that the risks of more frequent and heavier HTP use were significantly associated with daily and heavier CC use and daily EC use and the frequency and quantity of HTP use were not associated with attempts to quit smoking. These detailed findings on HTP use among current CC-smoking adolescents clearly indicate that HTP use in adolescence does not effectively substitute CC use, and provides strong evidence for the need for stronger regulation of HTP use among adolescents. Additionally, regarding strategies for smoking prevention and cessation, community and school health professionals should include interventions for the use of HTPs, as well as CC and EC.

Future research should consider the following. First, to strengthen the relationships between the frequency and quantity of HTP use and smoking characteristics, repeated studies with a representative adolescent population in other countries are required. Second, further investigation of the reasons for adolescents' HTP use and their perceptions and social norms regarding HTP are required. Finally, longitudinal studies are required to strengthen a causal relationship between detailed information on the use of HTP (e.g., frequency and quantity, reasons for use, and risk perceptions regarding HTP use) and other tobacco product use, which will contribute to establishing evidence-based strategies for regulating HTP use.

CONFLICTS OF INTEREST

The authors declared that no conflict of interest.

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DATA SHARING STATEMENT

Please contact the corresponding author for data availability.

AUTHOR CONTRIBUTIONS

Conceptualization or/and Methodology: Lee H & Lee BG.
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Funding acquisition: Lee H.
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Project administration or/and Supervision: Lee H & Lee BG.
Resources or/and Software: Lee H.
Validation: Lee BG.
Visualization: Lee BG.
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