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Patterns of heated tobacco product use and biochemically verified smoking status among customers of dedicated heated tobacco product stores

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Abstract

To understand the population impact of heated tobacco products (HTPs), examining the profile of their users is crucial. This study aimed to assess characteristics, patterns of HTP use, and biochemically verified smoking status of customers visiting specialized HTP stores in Greece. Two specialized stores selling IQOS HTPs were randomly selected in Athens. Researchers recruited consecutive adult customers purchasing products for personal use during store visits. Current smoking status was determined by measuring exhaled carbon monoxide (eCO), with ≥ 7 ppm classifying participants as current smokers. A questionnaire explored demographics, past and current smoking history, HTP use patterns, and dependence indicators. A total of 373 HTP users participated. The vast majority (98.1%) had a smoking history prior to HTP initiation. Former smokers represented 67.8% of the study sample, defined based on self-report and having eCO < 7 ppm, with 90.1% of them reporting they had quit with the use of HTPs. Current smokers represented 30.3% of the sample and reported a 50% median reduction in daily cigarette consumption post-HTP use initiation. Never-smokers represented 1.9% of the sample, all of whom had eCO ≤ 3 ppm. Daily HTP use was the predominant pattern of use in both groups, but was more prevalent among former smokers. Most participants perceived HTPs as less harmful than cigarettes. From logistic regression analysis, factors associated with being a former smoker were HTP use duration (OR: 1.06, 95% CI 1.02–1.09) and daily HTP use (OR: 6.93, 95% CI 1.93–24.92). Customers of specialized HTP stores in Greece were predominantly individuals with a history of smoking. A substantial proportion was biochemically verified former smokers and reported they had quit with the help of HTPs. Use by never-smokers was rare in this retail setting, and did not lead to subsequent smoking.

Keywords Heated tobacco products · Smoking · Smoking cessation · Nicotine · Tobacco harm reduction

Introduction

Tobacco smoking remains a leading cause of preventable morbidity and mortality globally, despite considerable progress in tobacco control [1, 2]. While complete cessation of all tobacco and nicotine products is the ideal outcome, a significant proportion of smokers find it difficult to quit or are unwilling to do so, sometimes citing reasons such as smoking for stress relief which can impact motivation to stop [3]. This reality has fueled interest in tobacco harm reduction (THR), a strategy aiming to reduce the health risks associated with combustible cigarette smoking by promoting switching to less harmful alternative nicotine delivery systems for those who cannot or will not quit [4, 5]. If effectively implemented, THR could complement existing tobacco control measures by providing smokers with viable, lower-risk alternatives [6].

Among the alternative products developed under the THR paradigm are heated tobacco products (HTPs). These devices heat processed tobacco to temperatures sufficient to generate a nicotine-containing aerosol but below the point of combustion [7]. The principle behind HTPs is that heating, rather than burning, tobacco significantly reduces the

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formation and emission of harmful and potentially harmful constituents (HPHCs) typically found in cigarette smoke [8, 9]. Users insert tobacco sticks (often resembling small cigarettes) into an electronic holder which heats the tobacco, allowing the user to inhale the resulting aerosol. Several HTP brands are now available globally, marketed as potentially reduced-risk alternatives to conventional smoking [10].

Emergence and increased market presence of HTPs have generated considerable scientific and public health debate. Evidence indicates that HTP aerosols contain significantly lower levels of many key toxicants, such as carbonyls, compared to cigarette smoke [8, 9, 11, 12] although they are not risk-free and contain nicotine, which can cause dependence, as well as other potentially harmful compounds [12, 13]. Population-level observations show varying patterns. Notably, market data from Japan suggest a strong temporal association between the introduction and the rapid market uptake of HTPs and an unprecedented acceleration in the decline of conventional cigarette sales, potentially indicating substantial displacement [14–16]. Similar analyses point toward a possible albeit perhaps less pronounced, displacement effect in other markets like Spain [17]. HTP prevalence rates in 2023 in Japan were estimated at 12.4% for exclusive use, with an additional 7.4% reporting dual use of HTP and tobacco cigarettes [18], while in Poland, the current use rate was reported at 10.9% [19]. The public health impact of HTPs is influenced by the complex use patterns, including frequent reports of dual use with conventional cigarettes alongside concerns about potential initiation by non-smokers [20]. While sustained dual use without eventual smoking cessation is suboptimal from a public health perspective [21], it might represent a transitional phase for some individuals progressing toward complete cessation as it may happen with other tobacco harm reduction products [22, 23]. Furthermore, substantial smoking reduction accompanying dual use could potentially lead to reduced toxicant exposure compared to exclusive smoking [24, 25]. Balancing these nuances, there are concerns regarding the potential for HTPs to attract youth and non-smokers. Current evidence suggests the majority of established HTP users are current or former smokers [20, 26], but monitoring uptake among vulnerable populations remains critical [2, 27].

Evidence regarding the effectiveness of HTPs specifically for achieving complete smoking cessation remains conflicting and uncertain. Some observational studies, including prospective cohorts often sponsored by manufacturers, report segments of participants switching completely from cigarettes to HTPs, showing reduced biomarker exposure [28]. However, data from population-based studies are inconsistent. For instance, cross-sectional surveys from Korea have yielded contradictory findings: one study suggested an association between HTP use and successful cigarette quitting [29], while another found HTP use was not associated with quitting combustible cigarettes [30]. Furthermore, a longitudinal study from Japan concluded that HTP use did not help smokers quit smoking or prevent relapse among former smokers [31]. Such discrepancies highlight the potential for bias and confounding that often remain unaddressed in broad surveys that rely on self-reported smoking status. High-quality evidence from randomized controlled trials (RCTs) is essential but remains limited. A recent Cochrane review identified very few relevant RCTs [32]. One subsequent RCT, the CEASEFIRE trial, compared the effectiveness of HTPs versus refillable e-cigarettes for cigarette substitution and found a 39% smoking cessation rate at 12 weeks among smokers randomized to HTPs, providing valuable comparative data but not directly against standard cessation aids [33].

Given the conflicting findings and the varying limitations of different study designs, the scarcity of robust RCT evidence, and the inherent potential for bias in many existing studies, the true impact of HTPs on smoking cessation at the population level is not yet clearly understood. For HTPs, like any alternative nicotine product, to confer a net public health benefit within a harm reduction framework, their ability to facilitate complete and sustained cessation of combustible smoking among established adult smokers is paramount [5, 34]. This potential benefit must be rigorously evaluated against potential harms. While large-scale population surveys and RCTs provide crucial pieces of the puzzle, there is also a specific need for real-world observational studies that can offer detailed insights into the characteristics and behaviors of dedicated users in specific environments where these products are accessed. Particularly, understanding the profile of consumers who engage with these products through dedicated retail channels, their past smoking history, and how their smoking status changes after initiating HTP use provides crucial context. Objective verification, such as through eCO measurement, is critical for overcoming self-reporting inaccuracies in such focused assessments of established users [35, 36].

In Greece, HTPs have gained considerable market presence, and specialized vendor stores were opened since the beginning of their availability in the country. In 2022, the prevalence rate of HTP use was estimated at 7.4% [37]. However, detailed information on the characteristics, use patterns and, crucially, an objective verification of the smoking status of users is lacking. These dedicated retail environments represent a key interface for a segment of HTP users and may influence usage patterns and switching success. Therefore, studying this population offers a unique opportunity to observe patterns among individuals who are actively engaging with and purchasing these products for personal use. Consequently, the purpose of this study was to determine the patterns of HTP use, user characteristics,

and smoking status, objectively verified by measuring eCO, among adult customers visiting specialized HTP stores in Athens, Greece. This approach, while specific in its setting, aims to provide robust, objectively verified data on a distinct segment of HTP consumers, contributing to a more nuanced understanding of HTP use in a real-world retail setting and complementing broader population data.

Methods

Study design and participants

The study design involved visiting specialized HTP stores in the city of Athens. At the time of the study design, there were 5 dedicated stores selling a specific HTP product (IQOS, Philip Morris International, Neuchatel, Switzerland). Two of these stores were randomly selected. A letter was sent to each store seeking written permission to visit the shop and recruit their customers as participants to the study. All shops accepted to be included in the study, but none of their staff was involved in any procedures related to the study.

Researchers (ED, TA, and GT) visited the stores according to their convenience during morning or afternoon hours. Each visit lasted for an average of 3–4 h. This study was conducted from March 2019 to December 2019. Study participants were customers visiting the stores. The only inclusion criteria were to be adults (≥ 18 years) and have visited the stores in order to purchase products for personal use. Therefore, all participants were by definition current HTP users. Every consecutive customer visiting the store during the researcher's presence was asked to participate to the survey. Each participant received detailed information about the study purpose and design. This study was approved by the ethics committee of the National School of Public Health in Greece and all participants signed a written informed consent before participation.

Procedures

Biochemical confirmation of the current smoking status of each participant was performed by measuring exhaled carbon monoxide (eCO) using a calibrated device (piCO Smokerlyzer, Bedfont Scientific, Kent, UK). Subsequently, a questionnaire was provided to the participants, which was available online through a major survey website (www.surveymonkey.com). The questionnaire was completed on-site, using a tablet provided by the researcher to the participants. It composed of 3 main sections and was based on a similar survey performed for e-cigarettes [38] with some modifications. The questionnaire was validated using the method of cognitive interviewing on 6 HTP users (3 current and 3 former smokers) who were not included into the study sample [39]. Initially, demographics were recorded, including age, gender, economic status, marital status and level of education. Subsequently, questions addressed the current and the past smoking status. Based on the response to the question about current smoking status and the measurement of eCO, current smokers were defined as those who reported smoking tobacco cigarettes at the time of survey participation or had eCO ≥ 7 ppm [40]. Former smokers were those who reported past smoking, had eCO < 7 ppm and reported that they were not currently smoking. Never-smokers were those who reported no past smoking and had eCO < 7 ppm, with the latter used to exclude smoking at the time of the survey. Additional questions examined smoking duration and consumption (for those reporting current and former smoking), with past consumption recalled retrospectively, a method generally found to be reliable for adult self-reports of smoking history[41], as well as smoking cessation duration (for former smokers). Finally, the first question of the Fagerstrom test for Cigarette Dependence ("*How soon after you wake up do you smoke your first cigarette?*") was asked in both current and former smokers [42, 43], with the latter being asked to respond based on recollection at the time they were smoking. Response options were: "within 5 min" (a score of 4), "6 to 30 min (a score of 3), 31 to 60 min (a score of 2) and "after 60 min" (a score of 1).

Questions about HTP use included assessment of duration and frequency of use, as well as consumption. Participants were classified according to frequency of HTP use as daily or occasional (less than daily) users. Those who were still smoking at the time of the survey were asked to report the number of cigarettes they were smoking at the time of HTP use initiation, in order to examine changes in consumption. Former-smoking HTP users were asked to report how they managed to quit smoking. Response options were: 1. by myself (without the use of any other support, products or medication; 2. with the use of pharmaceutical nicotine replacement therapies; 3. with the use of psychological support; 4. with the use of e-cigarettes; 5. with the use of HTPs; and, 6. other, with the ability to choose more than one option. This question addressed the possibility that HTP use resulted in a relapse to nicotine use among at least some former smokers, mainly for those who had already quit with other methods before becoming HTP users. Participants were also asked to report their perception of the risk profile of HTPs, with response options addressing both relative harm to tobacco cigarettes and absolute harm. Specifically, the response options were: "substantially more harmful than cigarettes", "more harmful than cigarettes", equally harmful to cigarettes", "less harmful than cigarettes", "substantially less harmful than cigarettes", "absolutely harmless" and "I don't know".

Statistical analysis

The sample was divided into current and former smokers according to the definitions mentioned above. The sample size varied by variable because of missing data; therefore, for some questions, the sum of responses was less than 100%. Continuous variables were reported as median (interquartile range, IQR) and categorical variables as number (percentage). Cross-tabulations and chi-square tests were used to compare groups for categorical variables (with post hoc Bonferroni correction), and Mann–Whitney U test was used for continuous variables. Within-group comparisons between the periods before and after HTP use initiation were performed using Wilcoxon signed-rank test. Logistic regression analysis was performed among current and former smokers to examine factors associated with being a former smoker. Independent variables included demographics (age, gender, marital status, and household economic status), smoking duration, time to smoking the first cigarette in the morning, duration and frequency of HTP use, and risk perceptions for HTPs. A p value of < 0.05 was considered statistically significant and all analyses were performed with commercially available software (SPSS v. 25, Chicago IL, USA).

Results

Demographic characteristics of study participants

A total of 373 adult subjects participated to the study. Of those, 253 (67.8%) were former smokers and 113 (30.3%) were current smokers. Seven participants reported they had never smoked, and their characteristics are presented separately below. The demographic characteristics of the whole sample and separately for current and former smokers are shown in Table 1. The median age of the study sample was 47 years old. There was an almost equal distribution of males and females in the sample and in current and former smoking groups. Most participants had at least university education, with no difference between groups. Similarly, no difference was observed in marital status. As for the household economic status, more former than current smokers reported having no financial problems and more current than former smokers were able to cope without saving a lot.

Smoking and HTP use patterns

Current and past smoking patterns, as well as HTP use patterns of current and former smokers are presented in Table 2. Of the 253 former smokers, 228 (90.1%) reported that they managed to quit smoking with the use of HTPs, while 21

Table 1 Demographic characteristics of study participants

	Whole sample (1)	Current smokers	Former smokers	*p*
	n (%) or median (IQR)			
Participants	373	113 (30.3%)	253 (67.8%)	
Gender				
Males	184 (49.3%)	57 (50.4%)	128 (50.6%)	0.532
Females	199 (50.7%)	56 (49.6%)	125 (49.4%)	
Age, years	47 (33–56)	47 (31–55)	47 (35–56)	0.384
Education				
High school (or less)	91 (24.4%)	27 (23.9%)	63 (25.1%)	0.646
Technical education	63 (16.9%)	18 (15.9%)	45 (17.9%)	
University education	170 (45.6%)	50 (44.2%)	115 (45.8%)	
Postgraduate education	47 (12.6%)	18 (15.9%)	28 (11.2%)	
Marital status				
Single	144 (38.6%)	44 (39.3%)	94 (37.5%)	0.093
Married	188 (50.4%)	56 (50.0%)	132 (52.6%)	
Divorced/widowed	38 (10.2%)	12 (10.7%)	25 (10.0%)	
Household economic status				
Unable to cope with household finances	6 (1.6%)	2 (1.8%)	4 (1.6%)	0.010
Able to cope but with difficulties	57 (15.3%)	18 (16.1%)	38 (15.1%)	
Able to cope but without saving a lot	184 (49.3%)	71 (63.4%)	109 (43.4%)	
No financial problems	123 (33.0%)	21 (18.8%)	100 9.8%)	

(1) The sample includes 7 participants (1.9%) who reported they had never smoked, and they were analyzed separately

Table 2 Smoking and HTP use patterns among current and former smokers who participated in the study. Never-smokers have been excluded from this analysis

	Current smokers	Former smokers (1)	p
	n (%) or median (IQR)		
Participants	113 (30.3%)	253 (67.8%)	
Smoking duration (months)	246 (140–363)	240 (144–360)	0.741
Smoking consumption before HTP initiation	20 (15–30)	20 (15–30)	0.876
Current smoking consumption (2)	10 (5–20)		< 0.001
Smoking cessation duration		12 (5–24)	
Time to smoking 1 st cigarette	2 (2–3)	3 (2–4)	0.109
Within 5 min	12 (10.6%)	70 (27.7%)	0.049
6–30 min	29 (25.7%)	66 (26.1%)	
31–60 min	25 (22.1%)	54 (21.3%)	
> 60 min	20 (17.7%)	58 (22.9%)	
Duration of HTP use (months)	8 (3–20)	12 (6–24)	0.003
HTP use frequency			
Daily	99 (87.6%)	245 (96.8%)	0.001
Occasional	12 (10.6%)	5 (2.0%)	
HTP consumption	20 (10–20)	20 (15–25)	0.329
Time to using 1 st HTP stick (score)	2 (1–3)	3 (2–4)	0.027
Within 5 min	12 (10.6%)	63 (24.9%)	0.021
6–30 min	42 (37.2%)	77 (30.4%)	
31–60 min	24 (21.2%)	48 (19.0%)	
> 60 min	31 (27.4%)	58 (22.9%)	
Harm perceptions for HTPs			
Substantially more harmful than smoking	0 (0%)	0 (0%)	0.054
More harmful than smoking	0 (0%)	0 (0%)	
Equally harmful to smoking	4 (3.5%)	15 (5.9%)	
Less harmful than smoking	59 (52.2%)	122 (48.2%)	
Substantially less harmful than smoking	30 (26.5%)	91 (36.0%)	
Absolutely harmless	1 (0.9%)	6 (2.4%)	
Don't know	15 (13.3%)	15 (5.9%)	

(1) Smoking patterns for former smokers refer to the time they were smoking

(2) Comparison with smoking consumption before HTP initiation

(8.3%) reported quitting by themselves, 2 (0.8%) with the use of nicotine replacement therapies, 1 (0.4%) with oral smoking cessation medications, 4 (1.6%) with e-cigarettes, and 1 (0.4%) with other methods.

Both groups had a smoking history of similar duration. Additionally, the reported cigarette consumption before HTP use initiation was similar between groups. Current smokers reported a statistically significant reduction in smoking consumption post-HTP use initiation, reducing the number of cigarettes smoked daily by half (Wilcoxon signed-rank test $P<0.001$). Marginal differences existed in time to smoking the first cigarette after waking, with post hoc analysis identifying that more former smokers reported smoking their first cigarette within 5 min (when they were still smoking) compared to current smokers. Former smokers were using HTPs for longer time and were more likely to use them daily although daily use was by far the most prevalent user pattern for current smokers too. HTP consumption was similar between groups, but more former smokers reported using HTPs within 5 min after waking compared to current smokers. Finally, no difference between groups was observed in harm perceptions about HTPs although the result was marginal ($P=0.054$). Even after excluding the response "I don't know", still no statistically significant differences were observed ($P=0.321$). None of the subjects reported that they perceived HTPs as more harmful or substantially more harmful than smoking.

Factors associated with being a former smoker

The results from the logistic regression analysis are shown in Table 3. Daily HTP use was associated with higher odds of being a former smoker compared with occasional use. Furthermore, for every additional month of HTP use, the odds of being a former smoker were increased by 6% (95%

Table 3 Logistic regression analysis to identify factors associated with being a former smoker

	OR	95% CI		p
		Lower	Upper	
Age	1.02	0.98	1.07	0.268
Gender				
Male (ref)				
Female	1.26	0.69	2.28	0.452
Marital status				
Married (ref)				
Single	1.04	0.50	2.19	0.909
Separated/divorced/widowed	0.76	0.29	1.97	0.573
Education				
High school or less (ref)				
Technical education	0.89	0.36	2.20	0.805
University education	0.62	0.29	1.31	0.211
Postgraduate education	0.45	0.16	1.24	0.122
Household economic status				
Unable to cope with household finances (ref)				
Able to cope but with difficulties	1.06	0.08	13.56	0.961
Able to cope but without saving a lot	1.02	0.08	12.24	0.988
No financial problems	2.42	0.19	30.12	0.493
Smoking duration	1.00	0.98	1.02	
Time to smoking first cigarette				
> 60 min				
31–60 min	0.64	0.28	1.46	0.288
6–30 min	0.58	0.25	1.31	0.189
Within 5 min	1.26	0.48	3.35	0.637
HTP use duration (months)	1.06	1.02	1.09	0.001
Frequency of HTP use (daily)				
Occasionally (ref)				
Daily	6.93	1.93	24.92	0.003
Risk perceptions for HTPs				
Don't know (ref)				
Equally harmful	5.44	0.99	29.57	0.051
Less harmful	1.84	0.68	5.00	0.229
Substantially less harmful	2.77	0.96	8.02	0.060
Absolutely harmless	2.64	0.20	35.26	0.463

CI 2–9%). No other factor was found to be significantly associated with being a former smoker.

HTP use among never-smokers

The characteristics of HTP users who reported they had never smoked are presented in Table 4. None of them were currently smoking according to the eCO measurements, with eCO ≤ 3 ppm in all subjects. The majority of never-smokers were females, and arithmetically younger than current and former smokers (no formal statistical analysis was performed because of the low sample size in this group). Almost all had at least university education, were single, and had relatively good household economic status. They reported using HTPs for a median of 8 months. Only 3 of them reported daily use, with a consumption of 2, 5, and 15 sticks. All daily users reported they used the first stick > 60 min after waking in the morning. Finally, concerning perceptions of harm, 3 of them reported that they did not know how to assess the harm potential of HTPs. Again, none of the subjects reported that they perceived HTPs as more harmful or substantially more harmful than smoking.

Table 4 Characteristics of HTP users who reported they had never smoked

Characteristics	Never-smokers *n* (%) or median (IQR)
N	7 (1.9%)
Gender	
Males	2 (28.6%)
Females	5 (71.4%)
Age, years	32 (27–44)
Education	
High school (or less)	1 (14.3%)
Technical education	0 (0.0%)
University education	5 (71.4%)
Postgraduate education	1 (14.3%)
Marital status	
Single	6 (85.7%)
Married	0 (0.0%)
Divorced/widowed	1 (14.3%)
Household economic status	
Unable to cope with household finances	0 (0.0%)
Able to cope but with difficulties	1 (14.3%)
Able to cope but without saving a lot	4 (57.1%)
No financial problems	2 (28.6%)
Duration of HTP use (months)	8 (5–10)
HTP use frequency	
Daily	3 (42.9%)
Occasional	4 (57.1%)
Time to using 1 st HTP stick (score) (1)	1 (1–1)
Within 5 min	0 (0.0%)
6–30 min	0 (0.0%)
31–60 min	0 (0.0%)
> 60 min	4 (100.0%)
Harm perceptions for HTPs	
Substantially more harmful than smoking	0 (0%)
More harmful than smoking	0 (0%)
Equally harmful to smoking	1 (14.3%)
Less harmful than smoking	1 (14.3%)
Substantially less harmful than smoking	2 (28.6%)
Absolutely harmless	0 (0.0%)
Don't know	3 (42.9%)

(1) For those who reported daily HTP use

Discussion

This study provides novel insights into the real-world use patterns and biochemically verified smoking status of adult customers purchasing HTPs from specialized vendor stores in Athens, Greece. To our knowledge, this is the first study to combine recruitment from these specific retail points with objective measurement of smoking status using eCO. The primary finding was that the vast majority (98.1%) of HTP customers had a history of smoking, with a substantial proportion (67.8% of the total sample, or 69.1% of ever-smokers) being biochemically verified former smokers at the time of the survey as confirmed by eCO levels below 7 ppm.

A high prevalence of former smokers among specialized HTP store customers observed herein aligns conceptually with findings from our previous study on e-cigarette users recruited from vape shops in the same region, where nearly 70% of participants were verified former smokers [38]. It also contrasts somewhat with broader population surveys and systematic reviews where dual use of HTPs and cigarettes is often reported as more prevalent, with considerable variability across populations [18, 20, 26, 37]. Data from Japan, for instance, while showing significant switching [14–16], still indicate a notable proportion of dual users [18]. A high proportion of former smokers identified in our sample might be influenced by the recruitment setting. Specialized HTP stores, similar to vape shops for e-cigarettes [38, 44], may attract smokers who are more motivated to attempt switching, may include more dedicated users of these products or provide a more supportive environment and detailed product information that users find helpful in their switching attempts compared to general retail outlets. Users frequenting such stores may represent a self-selected group already further along the switching pathway.

Consistent with the principles of tobacco harm reduction focusing on smokers [4, 5], almost all participants in our study (98.1%) had a history of smoking before initiating HTP use. This finding is echoed in systematic reviews showing that the majority of HTP users worldwide are current or former cigarette smokers [20, 26] and may be reassuring regarding concerns that these specialized stores primarily attract non-smokers. Another important issue is to understand whether harm reduction products may act as route to relapse to nicotine use. In our sample, approximately 10% reported having quit with other methods rather than through the use of HTPs. It is not clear, however, which proportion represents relapse to nicotine use that would have never happened had HTPs not being available, or an attempt to use HTPs to prevent smoking relapse. Our study was not designed to address those issues; thus, dedicated research is needed, preferably with longitudinal follow-up, in order to understand the reasons for former smokers initiating HTP use after quitting smoking.

The small fraction (1.9%) of participants who reported never smoking prior to HTP initiation remained biochemically verified non-smokers at the time of the survey. While any uptake by never-smokers warrants concern and continued population surveillance, the absolute number identified in this specific retail environment was low, aligning with findings from some other countries where never-smoker HTP use is minimal compared to use among smokers [27]. These never-smoking HTP users in our sample

were predominantly female, younger, and reported mostly occasional use, suggesting potentially different motivations and use patterns compared to the former smokers who initiated HTPs.

Among participants who were still smoking (dual users), we observed a significant, self-reported 50% reduction in daily cigarette consumption coincident with HTP use. While complete cessation is the optimal goal [21], substantial reductions in smoking intensity among dual users may lead to reduced exposure to toxicants compared to exclusive smoking [24, 25] and could represent a transitional step toward eventual cessation for some individuals as suggested by longitudinal studies on alternative product use [22, 23]. This finding highlights a potential intermediate benefit for smokers unable or unwilling to quit smoking entirely at a given point, although the long-term health implications of dual use require further investigation [45].

Several characteristics differentiated former smokers from current smokers in our sample. Former smokers had been using HTPs for a longer duration and were significantly more likely to be daily HTP users although daily use was the predominant pattern of use even among current smokers. This aligns with findings for e-cigarettes, where daily use was strongly associated with being a former smoker [38, 46]. Furthermore, former smokers in our study exhibited higher indicators of past cigarette dependence (more likely to report smoking within 5 min of waking when they were smokers) and current HTP dependence (more likely to use their first HTP stick within 5 min of waking) compared to current smokers. This observation might suggest that HTPs could be particularly appealing or satisfying for more dependent smokers, among whom a higher proportion were observed to have switched completely. Studies comparing HTPs to other nicotine products show that HTPs deliver nicotine effectively [47], though typically less than cigarettes, which may be explained by the lower nicotine delivery to the aerosol [48]. These products have also been shown to provide user satisfaction ratings higher than some refillable e-cigarettes, potentially contributing to their appeal and abuse liability among former smokers [47]. This finding contrasts slightly with some e-cigarette findings where being a former smoker was sometimes linked to lower nicotine concentrations used after quitting [38], reflecting differences in product characteristics and user adaptation. The multivariate analysis identified that only duration and frequency of HTP use were associated with being a former smoker. While the effect of daily vs. occasional use is understandable and has been observed in studies on e-cigarettes too [38, 49], the cross-sectional nature of the study, however, precludes from making causal interpretations between these factors and having quit smoking. Furthermore, a larger sample size is need to identify confounders associated with former smoking.

Harm perceptions regarding HTPs did not significantly differ between current and former smokers, with the majority in both groups perceiving HTPs as less or substantially less harmful than cigarettes. This perception aligns with findings from surveys of adult users in other countries [50, 51] and may be a factor in the decision of smokers to switch [5]. However, it also underscores the need for accurate public health communication emphasizing that while HTPs may present lower risks than continued smoking, they are not harmless [12, 13, 21], a point reflected in the uncertainty expressed by some users in qualitative studies [52]. The significant proportion reporting"I don't know"regarding HTP harms in our study suggests persistent uncertainty among users. A small proportion considered HTPs as absolutely harmless. Since it is important to accurately communicate the message that harm reduction products are not expected to eliminate the risks of smoking, the findings in this study appear reassuring that, even in this sample of dedicated users, risk perceptions remain reasonable, at least for the majority.

Limitations

This study has several limitations that should be considered when interpreting the findings. Firstly, the cross-sectional design precludes establishing causality; we cannot definitively conclude that HTP use caused the observed smoking cessation. It only shows an association at a single point in time among current HTP users. Factors influencing the decision to switch, such as prior motivation to quit smoking, were not assessed in detail. Second, recruitment was conducted exclusively in specialized HTP vendor stores in Athens selling a specific brand (IQOS). Therefore, the findings may not be generalizable to the broader population of HTP users in Greece, particularly those who purchase HTPs from other retail outlets like kiosks, supermarkets, or potentially online, whose characteristics and motivations might differ, or those using other HTP product brands. It is possible that, depending on the retail policy and the relevant advice provided by the staff, never-smokers may be advised against trying HTPs, which would deter use. That would result in underrepresentation of this population subgroup in our sample. However, it would not be practical or even feasible to perform such a study with personal interviews and biochemical verification of the smoking status in other settings. Thus, while this study provides a more reliable assessment of use patterns, due to personal contact with the researchers, and an objective assessment of the current smoking status, it may have included more dedicated users while occasional users may have been underrepresented. Furthermore, at the time of this study, there was no other brand selling HTP

products in specialized stores, and no dedicated stores were available in other cities besides Athens. Third, the study population consists of established HTP users who visited the stores for purchases. Individuals who tried HTPs and discontinued use (due to dissatisfaction, side effects, cost, or successful quitting through other means) were not captured, potentially biasing the sample toward more successful or persistent users. Fourth, while current smoking status was biochemically verified, information regarding past smoking history, consumption levels before HTP initiation, and past dependence relied on self-report and is subject to recall bias. While self-reported smoking history is a widely used measure in epidemiological studies [53], displays substantial concordance with daily process measures [54], and may be considered generally reliable even for past smoking history [41], the precision of recalling exact quantities smoked in the past can vary among individuals and may be influenced by the time elapsed. Underreporting of retrospective recall has been observed [55], and this remains a potential limitation in our study. Fifth, although we randomly selected stores from the available list of specialized stores at the time, this study was conducted only in Athens (the only place where such stores were available at the time of the survey), and these findings might not fully represent rural areas or other cities in Greece. Additionally, dependence was assessed using only the first question of the FTCD. This was done in order to reduce the time needed to complete the survey and increase study participations, considering that the participants were invited to participate without prior notice, at the time and the location of product purchase. Still, the time to first cigarette question has been shown to be highly predictive of dependence, correlates well with biomarkers of exposure, and is often considered the single most powerful item in the FTCD [56–59]. Finally, we did not collect detailed data on potential confounders such as concurrent use of other cessation aids at the time of the survey, household smoking rules, or detailed socioeconomic indicators beyond education and self-reported economic status.

Conclusions

This study provides real-world data on customers of specialized HTP stores in Athens, Greece. We found that the overwhelming majority were current or former smokers, the latter being biochemically verified. Dual users reported significantly reducing their cigarette consumption. Uptake by never-smokers was very low within this specific retail environment. These findings suggest that HTPs, when accessed through these dedicated channels, may serve as a smoking cessation or reduction tool for some smokers. However, given the study's cross-sectional nature, the specific recruitment setting, and the conflicting evidence from broader population studies and longitudinal research on HTPs'effectiveness for cessation, caution is warranted. Further research, particularly longitudinal studies tracking users over time, studies including diverse retail settings, and comparisons with standard cessation methods, is essential to fully elucidate the population-level impact of HTPs on smoking cessation and public health in Greece and beyond. An objective verification of smoking status should remain a cornerstone of such a research.

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Declarations

Conflict of interest The authors report no conflicts of interest related to this work.

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