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# Pulmonary Function between Heated Tobacco Users and Quitters

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Heated tobacco products (HTPs) have been promoted as safer alternatives to traditional combustible cigarettes (CCs). This study aimed to evaluate the health effects of HTP use by comparing pulmonary function test (PFT) results between current HTP users and individuals who have quit CCs. PFT measurements were collected from 226 current HTP users and 216 quitters who underwent health screening between 2021 and 2022 and completed standardized health questionnaires. Independent-samples t-test was used to analyze the forced vital capacity (FVC), FVC%, forced expiratory volume (FEV), FEV%, peak expiratory flow (PEF), PEF%, and FVC values. Among these parameters, only FEV and FVC showed statistically significant differences, with lower values observed in current HTP users than past users. These findings suggest that HTP users are at an increased risk of developing obstructive lung patterns.

**Keywords:** E-cigarette, Respiratory function test, Smoking

## Introduction

Heated tobacco products (HTPs) are electronic devices that heat, rather than burn, tobacco to produce nicotine-containing aerosols for inhalation [1]. Known as “vaping” in many English-speaking countries, various device types exist including heat-designed sticks, plugs, or capsules. Others vaporize liquid that passes through tobacco material, while some accommodate loose tobacco or marijuana [1]. HTPs were introduced in South Korea in 2017, and sales have steadily increased. By 2020, HTPs accounted for 10.6% of the domestic tobacco market, positioning South Korea as the second largest HTP market globally after Japan [2]. In 2023, HTP sales increased by 12.6% compared to the previous year, from 540 million to 610 million units [3].

HTPs have been marketed as safer alternatives to traditional combustible cigarettes (CCs), emphasizing the absence of fire, ash, or smoke, and purportedly reducing the emission of toxicants [4]. Some studies have demonstrated lower levels of harmful constituents in HTP aerosols than in CC smoke including nicotine, tobacco-specific nitrosamines, tar, aromatic amines, and carbonyl compounds such as formaldehyde and acetaldehyde [5-7]. Consequently, while many individuals initiate HTP use out of curiosity or peer influence, continued use is often motivated by the belief that HTPs are less harmful and odorous than CCs [8]. However, accumulating evidence suggests that HTPs emit hazardous compounds, some at higher concentrations than CCs. The U.S. Food and Drug Administration identified 56 harmful constituents omitted from a major HTP manufacturer’s modified risk tobacco product application including carbonyls (e.g., 2-cyclopentene-1,4-dione), furans (e.g., 2(5H)-furanone), and epoxides (e.g., anhydro linalool oxide) [9]. Among these, 2(5H)-furanone

has demonstrated potential for DNA damage in vitro [10] and 3-chloro-1,2-propanediol has been associated with carcinogenesis in animal models [11]. In addition, glycerol levels, 141% higher in HTP emissions compared to CC smoke, can cause irritations of the respiratory tract and eyes, and may contribute to dry cough symptoms [12].

Due to the relatively recent introduction of HTPs, evidence regarding their health effects remains limited, with few independent studies examining short-term outcomes [5]. A longitudinal study from Japan evaluated forced expiratory volume in one second (FEV1) decline among exclusive CC users, exclusive HTP users, dual users (both CC and HTP), quitters, and never-smokers over 4 to 7 years [13]. The study found that exclusive CC and HTP users exhibited similar rates of FEV decline. However, dual users experienced a significantly accelerated annual decline, indicating a cumulative adverse effect [13].

Given the increasing prevalence of HTP use and the paucity of robust health outcome data, the present study aimed to compare pulmonary function parameters between current HTP users and quitters by analyzing the health examination data of 442 male participants. This study aimed to further elucidate the potential pulmonary risks associated with the use of HTP.

## Methods

### Data collection

This study included 442 male participants (226 HTP users and 216 quitters). The participants were selected from among those who underwent health screenings and completed health questionnaires about smoking and lifestyle habits between 2021 and 2022 at Keimyung University Dongsan Hospital. HTP users were individuals who currently only use HTP, regardless of their CC use history. Quitters were those who stopped smoking within the last 10 years, randomly selected from the same age ( $\pm 2$  years) as HTP users. Individuals with serious illnesses that may affect the study results and those with missing values on the self-reported health behavior questionnaire were excluded from the analysis.

All participants underwent spirometry during health screening. The forced vital capacity (FVC), FVC (%), FEV1, FEV1 in %, peak expiratory flow (PEF), PEF in %, and FEV1/FVC were compared between the two groups to evaluate the differences in pulmonary function. FVC was measured in liters (L), FEV1 in liters, and PEF in liters per second (L/s). To measure these values, the participants inhaled rapidly and

completely from a resting state [14]. A breathing tube was inserted into each participant's mouth, ensuring that the lips were tightly sealed around the mouthpiece. After insertion, the participant was instructed to exhale forcefully and rapidly without hesitation or pause. Exhalation was stopped when the participant could no longer continue or until the volume-time curve showed no change in volume for more than 1 second, and the participant exhaled for 6 or more seconds [14]. The total amount of forcefully exhaled air was recorded as FVC, the amount of forcefully exhaled air for the first second was recorded as FEV1, and the maximum exhalation rate was recorded as PEF. FEV1/FVC was calculated by dividing the FEV1 value by the FVC value. Along with pulmonary measures, the patients' age, height, weight, body mass index (BMI), waist circumference, maximum blood pressure, minimum blood pressure, and average pulse were recorded during other health-screening procedures. For HTP users, the number of HTP smoking years and number of HTP users per day were recorded. For quitters, the number of since they stopped smoking was recorded.

### Data analysis

This study was approved by the Research Ethics Review Committee of the Keimyung University Dongsan Hospital (2022-06-047). Statistical analyses were performed using the IBM SPSS Statistics ver. 29.0 (IBM Corp.). An independent-samples t-test was conducted to compare FVC, FVC%, FEV1, FEV1%, PEF, PEF%, and FEV1/FVC between HTP users and quitters. A two-sided *p*-value of less than 0.05 indicated statistical significance.

## Results

The study included 442 male participants (226 HTP users and 216 quitters). The average age of the HTP users was 48.8 years old. They smoked HTP for a total of 3.2 years and smoked 12.7 HTPs per day on average. The mean age of the quitters was 49.0 years old. On average, have stopped smoking for approximately 9.2 years. Among the 226 HTP users, 198 previously smoked CCs before switching to HTP and used CCs for an average of 23 years. Overall, the HTP participants' height and minimum blood pressure level were slightly higher than those of the quitters, but none of the variables were significantly different between the two groups (Table 1).

An independent-samples t-test was used to examine the differences in pulmonary function between the two groups (HTP users and quitters). None of the pulmonary function

**Table 1.** Baseline health information and smoking habits

Variables	HTP users (n = 228)	Quitters (n = 216)
Age (years, Mean $\pm$ SD)	48.8 $\pm$ 9.1	49.0 $\pm$ 9.2
Height (cm, Mean $\pm$ SD)	172.3 $\pm$ 5.8	171.8 $\pm$ 6.0
Weight (kg, Mean $\pm$ SD)	76.2 $\pm$ 11.9	76.2 $\pm$ 12.0
BMI (Mean $\pm$ SD)	25.6 $\pm$ 3.3	25.8 $\pm$ 3.5
Waist length (cm, Mean $\pm$ SD)	92.2 $\pm$ 10.3	92.2 $\pm$ 9.8
Maximum blood pressure (mm Hg, Mean $\pm$ SD)	126.0 $\pm$ 12.7	127.3 $\pm$ 13.3
Minimum blood pressure (mm, Hg Mean $\pm$ SD)	79.6 $\pm$ 10.7	79.0 $\pm$ 10.9
Pulse (beats per minute, Mean $\pm$ SD)	74.3 $\pm$ 9.1	74.9 $\pm$ 10.6
Duration of HTP smoking (years, Mean $\pm$ SD)	3.2 $\pm$ 2.3	-
Number of HTP smoking per day (product per day, Mean $\pm$ SD)	12.7 $\pm$ 6.5	-
Duration of quitting (years, Mean $\pm$ SD)	-	5 $\pm$ 2.9

$p > 0.05$ , t-test. HTP, heated tobacco product.

**Table 2.** Comparison of pulmonary function between HTP group and quitter group

Variables	HTP users (n = 226)	Quitters (n = 216)	p-value
FVC (L, Mean $\pm$ SD)	4.4 $\pm$ 0.7	4.3 $\pm$ 0.7	0.136
FVC% (%), Mean $\pm$ SD)	94.5 $\pm$ 10.9	92.9 $\pm$ 12.6	0.147
FEV1 (L, Mean $\pm$ SD)	3.5 $\pm$ 0.6	3.5 $\pm$ 0.6	0.596
FEV1 % (%), Mean $\pm$ SD)	100.5 $\pm$ 11.9	100.6 $\pm$ 12.5	0.943
PEF (L/s, Mean $\pm$ SD)	8.9 $\pm$ 1.7	8.9 $\pm$ 1.6	0.959
PEF % (%), Mean $\pm$ SD)	103.9 $\pm$ 19.6	104.4 $\pm$ 17.5	0.759
FEV1/FVC (%), Mean $\pm$ SD)*	80.1 $\pm$ 5.6	81.4 $\pm$ 5.6	0.015

\* $p < 0.05$  using t-test. HTP, heated tobacco product; FVC, forced vital capacity; FEV, forced expiratory volume; PEF, peak expiratory flow.

measures except for one were significantly different between the groups. FVC, FVC%, and FEV1 were slightly higher in the HTPs group, while FEV1 %, PEF, and PEF% were slightly higher in the quitters. However, these differences were not significant (Table 2). In contrast, the FEV1/FVC measure was significantly lower in HTP by a value of 1.30 (95% confidence interval [-2.35, -0.25],  $t(440) = -2.445$ ,  $p = 0.015$ ; Table 2).

## Discussion

This study compared the pulmonary function test (PFT) outcomes between 226 current HTP users and 216 quitters, totaling 442 participants. Key spirometric parameters, including FVC, FVC%, FEV1, FEV1%, PEF, PEF%, and FEV1/FVC, were analyzed using independent-samples t-tests. Baseline characteristics, such as age, height, weight, BMI, waist circumference, systolic and diastolic blood pressure, and pulse rate, were also collected during routine health screenings. Although minor differences in these parameters were observed between the two groups, the variations were minimal, suggesting that the overall baseline health status was comparable.

Similarly, most PFT parameters did not differ significantly between the two groups. The only parameter showing a statistically significant difference was FEV1/FVC, which was lower among HTP users compared to quitters.

The FEV1/FVC ratio, representing the proportion of a person's vital capacity expelled in the first second of forced expiration, is a critical marker for detecting obstructive pulmonary diseases, such as chronic obstructive pulmonary disease and asthma. A reduction in this ratio reflects airflow limitation, characterized by difficulty in exhaling air quickly, even when total lung capacity (FVC) is relatively preserved. Conventionally, an FEV1/FVC ratio  $< 70\%$  indicates the presence of an obstructive ventilatory defect. In contrast, a normal FEV1/FVC with a reduced FVC suggests a restrictive pattern while concurrent reductions in both values imply a mixed ventilatory defect [15].

The absence of significant differences in FVC, FEV1, and PEF parameters complicates interpretation, potentially suggesting that HTP use has minimal impact on global pulmonary function [16]. However, the significantly lower FEV1/FVC among HTP users may suggest an increased risk of de-

veloping obstructive airway patterns. Although few studies have directly compared pulmonary function measures between HTP smokers and quitters, one previous study investigated the prevalence of airway obstruction among different smoking groups [17]. In that study, a higher prevalence of airway obstruction was reported among current HTP users (22.5%) than among quitters (19.9%), reflecting a 1.42-fold increase in airway obstruction. This difference was further accentuated (1.96-fold) among individuals who had quit CCs for more than five years [17].

While our study did not specifically categorize participants based on the 70% FEV1/FVC threshold, the overall trend of lower FEV1/FVC values among HTP users is consistent with these findings. Our results were partially aligned with data from Philip Morris International's 2014 US-based study (ZRHM-REXA-08-US) [18], which compared PFT outcomes over 90 days among CC, HTP, and abstainers. While FEV1 values showed no significant changes between groups, abstainers exhibited slight increases in FEV1/FVC compared to both CC and HTP users. Although the study did not conclude that HTP use was more harmful than CC use, the pulmonary function findings were generally consistent with our observations.

This study has several limitations. A significant proportion of the HTP users (198 of 226 participants) had an extended history of CC smoking (averaged 23.0 years) before switching to HTP use (averaged 3.2 years). Given the potential cumulative effects of long-term CC exposure, the observed pulmonary function changes cannot be exclusively attributed to HTP use. Furthermore, the cross-sectional nature of the study based on single-time-point PFT measurements limited its ability to infer causality or temporal trends. In the future, longitudinal studies designed to evaluate the changes in PFT measurements over time among HTP users and quitters, may provide stronger evidence of the pulmonary effects of HTP use.

HTP was first introduced in South Korea as safer alternatives to CC and rapidly gained popularity, particularly among younger smokers. However, independent data remain limited, owing to the relatively recent emergence of these products. In this study, the pulmonary effects of HTP use were evaluated by comparing spirometric parameters (FVC, FVC%, FEV1, FEV1%, PEF, PEF%, and FEV1/FVC) between 226 current HTP users and 216 former tobacco users. Most pulmonary function measures were similar between the two groups, except for FEV1/FVC. HTP users demonstrated significantly lower FEV1/FVC ratios compared to quitters, suggesting a potential increased risk of developing obstructive ventilatory patterns associated with continued HTP use.

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## Ethics approval

This study was approved by the Research Ethics Review Committee of the Keimyung University Dongsan Hospital (2022-06-047).

## Conflict of interest

The authors have nothing to disclose.

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