The Immediate Physiological Effects of E-Cigarette Use and Exposure to Secondhand E-Cigarette Vapor

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BACKGROUND: Vaping continues to grow as an alternative to smoking and as a recreational activity for people of all ages, including minors. The billion-dollar industry offers users a plethora of flavors, nicotine concentrations, e-juice combinations, and devices. While some studies suggest vaping is beneficial for certain ailments and as a smoking cessation tool, many studies report concerning health outcomes associated with vape use. Recent FDA regulations have banned certain vaping products following an increase of vaping-related lung injuries reported in 2019. Health care providers need to better understand the physiological effects of vaping-specific products and the impact of secondhand vapor. The specific aims of the present study were to understand the immediate effects on heart rate, breathing frequency, blood pressure, blood sugar, S_{pO_2}, pulmonary function, and oral temperature following e-cigarette use and secondhand vapor exposure. METHODS: A total of 149 volunteers participated in this study; 76 subjects vaped mint-flavored e-cigarettes with 5% nicotine for 20 min while seated next to 73 nonvaping subjects who agreed to be exposed to the vapor. Health variables including heart rate, blood pressure, breathing frequency, blood glucose, FVC, S_{pO_2}, and oral temperature were obtained prior to vaping or exposure to vapor and again after 20 min. RESULTS: Subjects who vaped had significantly higher heart rate, breathing frequency, and oral temperature, and significantly lower blood oxygenation levels (ie, S_{pO_2}) after vaping for 20 min. Nonvaping subjects exposed to vapor had significantly higher oral temperature after 20 min of exposure. Blood sugar and FVC were not significantly affected by vaping or exposure to vapor. CONCLUSIONS: Vaping with mint-flavored e-cigarettes with 5% nicotine for 20 min resulted in significant immediate physiological changes. Exposure to e-cigarette vapor significantly increased oral temperature within the same amount of time. *Key words: vaping; secondhand vapor; e-cigarettes; short-term health effects; e-juice.*
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Introduction

As the use of e-cigarettes and vaping continues to rise in replacement of cigarettes it is imperative that health care professionals understand the physiological implications of vape use.[1,2] A few studies suggest that vaping improves some medical conditions, such as tonsillitis and mental health.[3,4] However, many other vape studies suggest the potentially negative health effects of vaping. For example, toxins such as acrolein, acetaldehyde, and formalin, noted in the pulmonary system of vapers, are thought to be associated with the high temperatures used to vaporize the e-juice.[5,6] Respiratory tract irritation, bronchitis, and persistent coughing are identified

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pulmonary disorders associated with vape use.[7-9] Many other disorders, such as increased susceptibility to cardiovascular problems,[10,11] bacterial overgrowth,[12,13] increased risk for overdosing,[14] multiple-organ disorders,[15] nicotine addiction,[16] changes in weight,[17] bleeding disorders,[18] infections,[19] neurological disorders,[20] and chronic inflammatory lung conditions,[21] have all been associated with vape use. Increased heart rate and blood pressure are some of the immediate physiological responses found after vape use.[22-25]

Alarming numbers of young people are experimenting with vaping, many as early as middle school.[26] Children that young typically start vaping out of curiosity or to fit in with their peers. Children and young adults are not typically concerned with the long-term health effects of their behaviors. Additionally, young people often hide such behaviors from the adults in their lives, including parents and health care professionals. Even though a health care professional may be astute enough to ask a patient about vape use, many patients will not disclose use or will underreport use. It behooves health care professionals and researchers to better understand the immediate health effects of specific types of vape use. The information could help health care professionals make more timely and accurate diagnoses in their patients, or at least prompt health care professionals to ask additional questions if they suspect their patient may be vaping. Patient education about the potential negative health effects of vaping would likely be much more effective using short-term implications rather than long-term effects, especially in the younger population. Additionally, understanding the short-term implications of vaping can inform health care professionals of potential health problems that are likely to arise with continued vaping.

While the negative health effects reported in the literature are concerning, most of the studies did not specify the type of vape or composition of vape fluid used. There are thousands of combinations of vape types, e-juices, flavorings, nicotine concentrations, and length of vape time used by people who vape. The plethora of various vape combinations proved problematic in late 2019 when a national outbreak of vaping-related lung injuries occurred.[27] Identifying an etiology for the increase in vape-related lung injuries proved challenging. Most data suggest that the lung injuries were occurring when chemicals were added to the e-juice, such as tetrahydrocannabinol (THC) and vitamin E.[27] Increased numbers of vape-associated lung injuries were also linked with the use nonregulated e-juice, often purchased from uncontrolled sources instead of from regulated vape shops.[27] As a result, federal and state agencies placed stricter regulations on the billion-dollar vape industry, limiting the sale and distribution of vape products.[28-31]

The purpose of this study was to understand the immediate physiological effects of electronic cigarette (e-cigarette) use with a mint flavor and 5% nicotine, as well as the immediate physiological effects of secondhand e-cigarette vapor. The specific aims of the study were to understand the immediate effects on heart rate, breathing frequency, blood pressure, blood sugar, S_{pO_2}, pulmonary function, and oral temperature following e-cigarette use and secondhand e-cigarette vapor exposure.

QUICK LOOK

Current knowledge

Vaping is a relatively new, and rapidly growing, billion-dollar industry. People of all ages, including minors, engage in vaping. Some studies suggest vaping can be useful to quit smoking, but many other studies report concerning health-related effects associated with vaping. The long- and short-term health effects of specific vape products need to be better understood.

What this paper contributes to our knowledge

Our results indicate that people who vaped mint-flavored e-cigarette products with 5% nicotine for 20 min had significant increases in their heart rate, breathing frequency, and oral temperatures. Additionally, they also had decreases in their S_{pO_2} after 20 min of vape use. Vaping with this specific product and e-juice did not significantly affect blood sugar or FVC in the short term. People exposed second hand to the mint-flavored e-cigarette vapor with 5% nicotine did not experience any of the same short-term health effects except for increased oral temperature.

Methods

This study utilized a mixed factorial experimental design involving a between-groups factor (76 self-identified vape users vs 73 self-identified nonvapers who expressed a willingness to be exposed to secondhand vapor; total pooled sample size: $N = 149$) and several repeated measures factors (pre- and post-vaping physiological measurements). Physiological measurements included heart rate, breathing frequency, blood pressure, FVC, S_{pO_2}, blood sugar, and oral temperature.

Subjects from both vape and nonvape groups were asked to come to the vape lab at the University of Detroit Mercy; the study took place in a 12 ft by 12 ft enclosed room. Windows remained closed throughout each session. All subjects were instructed to not eat or drink for 60 min prior to beginning the study. Upon arrival at the lab, all subjects first provided informed consent and then completed a health assessment form to determine family history and identify predictors of health (Table 1). Thereafter, physiological measurements were taken of all subjects. Subjects

Table 1. Demographic and Health Variables

	Total ($N = 149$)	Nonvape Group ($n = 73$)	Vape Group ($n = 76$)
Age, y*	22.1 ± 7.3 (18–63)	23.8 ± 9.8 (18–63)	20.4 ± 2.8 (18–36)
Gender*			
Male	69 (46.3)	19 (26.0)	50 (65.8)
Female	80 (53.7)	54 (74.0)	26 (34.2)
Other	0 (0)	0 (0)	0 (0)
Present health			
Excellent	63 (42.3)	35 (47.9)	28 (36.8)
Good	82 (55.0)	35 (47.9)	47 (61.8)
Fair	3 (2.0)	2 (2.7)	1 (1.3)
Poor	1 (0.7)	1 (1.4)	0 (0)
Recreational drug use*			
Yes	37 (24.8)	7 (9.6)	30 (39.5)
No	112 (75.2)	66 (90.4)	46 (60.5)
Mental health treatment			
Yes	31 (20.8)	13 (17.8)	18 (23.7)
No	114 (76.5)	59 (80.8)	55 (72.4)
Unsure	4 (2.7)	1 (1.4)	3 (3.9)
Lung disease*			
Yes	26 (17.4)	7 (9.6)	19 (25.0)
No	123 (82.6)	66 (90.4)	57 (75.0)
Unsure	0 (0)	0 (0)	0 (0)
Oral disease			
Yes	6 (4.0)	2 (2.7)	4 (5.3)
No	141 (94.6)	71 (97.3)	70 (92.1)
Unsure	2 (1.3)	0 (0)	2 (2.6)
Cardiac disease			
Yes	6 (4.0)	3 (4.1)	3 (3.9)
No	143 (96.0)	70 (95.9)	73 (96.1)
Unsure	0 (0)	0 (0)	0 (0)
Cigarette use*			
Yes	8 (5.4)	1 (1.4)	7 (9.2)
No	133 (89.3)	69 (94.5)	64 (84.2)
Unsure or former	8 (5.4)	3 (4.1)	5 (6.6)
Alcohol use*			
Yes	89 (59.7)	38 (52.1)	51 (67.1)
No	59 (39.6)	35 (47.9)	24 (31.6)
Unsure or former	1 (0.7)	0 (0)	1 (1.3)

Data are presented as *n* (%) except age, which is presented as mean ± SD (range). Percentages represent the percent of the sample or group that falls in a given response category.
* The 2 experimental groups were found to significantly differ from each other in preliminary analyses.

from the vape and nonvape groups were mingled during the experimental sessions. Subjects in the vape group were then provided with a JUUL vaping device (Juul Labs, San Francisco, California) with mint-flavored e-juice and 5% nicotine and instructed to vape at a steady pace per their normal usage pattern. After 20 min of vaping, physiological measurements were again taken of all subjects.

All physiological measurements were collected by a registered nurse or trained research assistant. Heart rate was determined with an automatic finger monitor. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were obtained with an automatic blood pressure machine while the subject was seated with both feet on the floor; mean arterial pressure was calculated using the following formula: SBP + 2(DBP)/3. Breathing frequency was determined by counting respirations for 15 s and multiplying by 4 to determine the frequency (breaths/min). FVC was determined by exhaling into a PC-based spirometry device (Easy on-PC Spirometry System with Spirometry sensor and software, ndd Medical Technologies, Andover, Massachusetts). Each subject received their own spirette and performed a series of 3 tests to determine FVC. The best result was included in the study. Spirometry was performed according to manufacturer directions. Some of the standards established by the

American Thoracic Society and European Respiratory Society on proper spirometry procedures were also implemented, including proper hygiene and infection-control practices, proper use and calibration of equipment according to manufacture directions, optimal display of all results, trained equipment users, inclusion of subject data (blinded), demonstration of proper use for subjects by the researchers, and request to avoid smoking or vape use for at least 60 min prior to participation in the study.[32] Blood sugar was determined via finger prick with glucometer analysis. S_{pO_2} was determined with a noninvasive finger clamp, and oral temperature was measured with an oral digital thermometer.

The study was approved by the institutional review board at the University of Detroit Mercy. Volunteers were obtained through announcements made on social media outlets (eg, SnapChat, Instagram, Facebook), a university participant recruitment website, word of mouth, and by invitation from the researchers. All subjects were ≥ 18 y old and were required to provide written informed consent prior to volunteering in the study. Data collection occurred from April 2019 to January 2020. Each session had approximately the same number of volunteer vapers and nonvapers. Subjects signed up for available research sessions based on their availability. They were not matched on baseline characteristics except for all being over the age of 18. Subjects were provided with $10.00 in compensation for their involvement in the study. Prior to analysis, all data were de-identified to protect subject confidentiality, and all data were analyzed and are reported in aggregate form.

Statistical Analysis

A multi-step process was employed once data were collected. These steps included (a) evaluation of data quality and data cleaning (eg, identification of missing or out-of-range data points and imputation if needed, assessment of normality of distributions and homogeneity of variance); (b) power analysis to determine if the sample size was sufficient to ensure adequate statistical power; (c) preliminary analyses to determine if experimental groups were equivalent on main physiological variables as well as demographic and health variables; (d) correlation analysis to ascertain whether demographic and health variables were significantly associated (at $P < .05$) to physiological variables (used to identify potential covariates); and (e) main statistical analyses using mixed factorial analysis of variance (ANOVA), ancillary statistical analyses to assess the influence of covariates using mixed factorial analysis of covariance (ANCOVA), and nonparametric analyses (eg, Mann-Whitney and Wilcoxon tests) to ensure that any significant results with the parametric statistics remained significant with these different forms of analysis. For all statistical analyses, a P value ≤ .05 was used for statistical significance. Other than the power analysis, all analyses were done using SPSS software (Version 26; IBM, Armonk, New York). Detailed information about the outcomes of each of these steps and the findings of all analyses completed can be found in the supplementary material (available at http://www.rcjournal.com).

Results

Table 1 presents descriptive statistics and frequencies for all demographic and self-reported health variables for the total pooled sample and for each experimental group separately. Preliminary analyses revealed that the vape and nonvape groups differed significantly in terms of age, gender, recreational drug use, lung disease, cigarette smoking, and alcohol use. Analyses of pre-vape physiological variables revealed a statistically significant difference in FVC ($P < .001$), with the vape group producing the higher mean score. In addition, both pre-vape and post-vape physiological variables were found to statistically correlate with one or more demographic and health variables. These results indicate that the 2 experimental groups cannot be viewed as wholly equivalent pre-vape, and that demographic and health variables may influence experimental effects and, as such, need to be treated as covariates.

Given that the study used a 2 (between groups) by 2 (pre-post) experimental design, mixed factorial (also known as split plot) ANOVA analyses were computed for each of the physiological variables (Table 2). To evaluate the impact of demographic and health variables on the main results, 2 sets of mixed factorial ANCOVA analyses were also computed. In the first set, age and gender were used as covariates. In the second set, all 10 demographic and health variables were used as covariates (Table 2).

The ANOVA for heart rate produced nonsignificant main effects but a significant interaction effect ($P = .01$, partial eta^2 [η_p^2] = 0.04 [small effect]). This interaction remained significant after controlling for age, gender, and the 8 health variables in the ANCOVA analyses. Inspection of means indicates that exposure to vapor resulted in a reduction in mean heart rate for the nonvape group, whereas vaping contributed to an increase in mean heart rate for the vape group.

The between-groups main effect for blood pressure was found to be significant ($P = .042$, $\eta_p^2 = 0.03$ [small effect]), as was the interaction ($P = .02$, $\eta_p^2 = 0.04$ [small effect]). Examination of means across the study conditions indicates that the nonvape group showed a reduction in mean values at post-vape while the mean values at pre- and post-vape remained similar for the vape group. When controlling for covariates, the between-groups effect became nonsignificant while the interaction remained significant. Controlling for all demographic and health variables, however, resulted in the interaction becoming nonsignificant,

Table 2. Pre-Post Vaping Conditions and Results of Mixed Factorial ANOVA and ANCOVA Examining Physiological Variables as a Function of Vape Group (Between Groups)

	Nonvape Group		Vape Group		Significant Results		
	Pre-Vape	Post-Vape	Pre-Vape	Post-Vape	ANOVA	ANCOVA (age and gender covariates)	ANCOVA (age, gender, and 8 health variables covariates)
Heart rate, beats/min	88.81 ± 18.24	86.83 ± 18.01	84.20 ± 16.28	88.12 ± 15.27	Interact: $P = .01$ $\eta_p^2 = 0.04$	Interact: $P = .01$ $\eta_p^2 = 0.04$	Interact: $P = .03$ $\eta_p^2 = 0.04$
Blood pressure, mm Hg	94.03 ± 10.05	90.83 ± 10.29	95.14 ± 10.74	95.84 ± 10.07	Btw Gp: $P = .042$ $\eta_p^2 = 0.03$ Interact: $P = .02$ $\eta_p^2 = 0.04$	Interact: $P = .02$ $\eta_p^2 = 0.04$	Pre-Post: $P = .02$ $\eta_p^2 = 0.04$
Breathing frequency, breaths/min	11.18 ± 1.15	11.15 ± 1.10	11.29 ± 1.02	11.79 ± 1.06	Btw Gp: $P = .006$ $\eta_p^2 = 0.05$ Pre-Post: $P = .040$ $\eta_p^2 = 0.03$ Interact: $P = .02$ $\eta_p^2 = 0.04$	Btw Gp: $P = .009$ $\eta_p^2 = 0.05$ Pre-Post: $P = .040$ $\eta_p^2 = 0.03$ Interact: $P = .02$ $\eta_p^2 = 0.04$	Btw Grp: $P = .03$ $\eta_p^2 = 0.04$ Pre-Post: $P = .03$ $\eta_p^2 = 0.04$ Interact: $P = .01$ $\eta_p^2 = 0.04$
Blood sugar, mmol/L	97.53 ± 19.19	98.63 ± 18.05	94.45 ± 12.34	96.01 ± 14.73	NA	NA	NA
FVC, L/min	3.97 ± .88	3.97 ± .89	4.79 ± 1.07	4.73 ± 1.10	Btw Gp: $P < .001$ $\eta_p^2 = 0.14$	NA	NA
S_{pO_2}, %	97.97 ± 1.72	97.37 ± 2.94	98.20 ± 1.06	97.71 ± 1.66	Pre-Post: $P = .009$ $\eta_p^2 = 0.05$	Pre-Post: $P = .009$ $\eta_p^2 = 0.05$	Pre-Post: $P = .007$ $\eta_p^2 = 0.05$
Oral temperature, °C	36.59 ± .42	36.82 ± .27	36.51 ± .42	36.78 ± .42	Pre-Post: $P < .001$ $\eta_p^2 = 0.21$	Pre-Post: $P < .001$ $\eta_p^2 = 0.21$	Pre-Post: $P < .001$ $\eta_p^2 = 0.23$

Pre-Post values are presented as mean ± SD. For the nonvape group, $n = 73$ for all analyses except blood sugar, where $n = 72$ due to the exclusion of a case with an extreme value. For the vape group, $n = 76$. Only statistically significant results are reported for each analysis.

Btw Gp = between groups main effect

Pre-Post = pre-post (repeated measures) main effect

Interact = interaction effect

η_p^2 = partial eta-squared (effect size estimate)

NA = not applicable

though the repeated measures main effect emerged as significant ($P = .02$, $\eta_p^2 = 0.04$ [small effect]).

The ANOVA for breathing frequency revealed significant results for both main effects and the interaction effect, with all effects remaining significant after the control of covariates in the ANCOVAs. For the between-groups main effect ($P = .006$, $\eta_p^2 = 0.05$ [small effect]), the vape group was found to produce the higher mean value. For the repeated measures main effect ($P = .040$, $\eta_p^2 = 0.03$ [small effect]), post-vape mean values were higher. For the interaction effect, ($P = .02$, $\eta_p^2 = 0.04$ [small effect]), the vape group demonstrated a greater mean increase at post-vape.

With regard to blood sugar, ANOVA and ANCOVA results were nonsignificant. For FVC, the ANOVA produced a significant between-groups main effect ($P < .001$, $\eta_p^2 = 0.14$ [medium effect]), with the vape group generating the higher mean score. This finding became nonsignificant when controlling for covariates.

The ANOVA for S_{pO_2} produced a significant repeated measures main effect ($P = .009$, $\eta_p^2 = 0.05$ [small effect]), with both groups showing a reduction in mean values Post-vape. This result remained significant after controlling for covariates in the ANCOVAs. It is worth noting that S_{pO_2} was observed to be severely non-normal in our evaluation of data quality. In response, nonparametric analyses were also completed. Mann-Whitney tests were used to evaluate between group differences in pre- and post-vape values, and Wilcoxon tests were used to evaluate pre-post differences for the nonvape and vape groups separately. Both Mann-Whitney tests emerged nonsignificant, whereas the Wilcoxon test was significant for the vape group only ($P = .01$).

The ANOVA for oral temperature generated a significant repeated measures main effect ($P < .001$, $\eta_p^2 = 0.21$ [medium effect]), with both groups having produced higher mean values at post-vape. This result remained significant after controlling for covariates in the ANCOVAs.

Discussion

The findings are important because people who vape often do so in the presence of those not vaping, and second-hand vapor effects are also an important health topic. It should be noted that the volunteer vapers in this study had higher rates of smoking use, recreational drug use, mental illness requiring treatment, alcohol use, and lung diseases compared to the nonvape subjects. Only 36.8% of vaping subjects considered themselves to be in excellent health compared to 47.9% of nonvapers, suggesting that people who vape may think they are engaging in one or more behaviors leading to unhealthy outcomes. Those underlying differences in health risk behaviors and findings between the 2 groups may have influenced the results of this study.

An interesting finding was the immediate changes in heart rate that occurred in the subjects. The vaping subjects had a significant increase in heart rate, a known outcome of using nicotine.[33] Vape devices deliver higher concentrations of nicotine compared to cigarettes,[34] so the increased heart rate effects of vape use may be even more significant than that observed with cigarette use. The increase in heart rate among vapers has clinical implications associated with sustained tachycardia. This statistically significant finding requires additional clinical research as the effect size estimate (ie, $\eta_p^2 = 0.04$) suggests a small effect size and may not have major clinical importance for the health care provider but further research in this area is warranted.

Nonvaping subjects did not experience an increase in heart rate; in fact, their heart rates decreased after being seated for 20 min during the duration of the study, suggesting that exposure to vapor does not have the same effect on heart rate as actually using the e-cigarette product. Some studies suggest that elevated resting heart rates are the major contributing factor to cardiovascular disease, more so than blood pressure status.[33] Health care professionals may want to consider educating patients on this risk factor and suggest non-nicotine vape products for their patients who vape or are using vaping as a means to quit smoking.

Vaping effects on blood pressure also proved to be a significant finding in this study, but again with likely small clinical importance ($\eta^2 = 0.04$). Similar to heart rate, nonvapers experienced a significant decrease in blood pressure after being exposed to mint-flavored e-cigarettes with 5% nicotine, likely associated with being seated and resting for 20 min throughout the duration of the study. The vaping subjects' blood pressure did not decrease but remained unchanged from pre-vape status, suggesting that vaping prevents the expected reduction in blood pressure during times of rest. These findings are consistent with other studies reporting variable correlation between nicotine use and elevated blood pressure.[33,35,36] Clinically, this finding should be considered in patients with other hypertensive risk factors such as increased age, obesity, and hypercholesterolemia. Because people who vape do not experience a reduced blood pressure during periods of rest like their nonvaping counterparts, they are at risk for complications of hypertension (eg, heart attack and stroke). An otherwise small clinical importance could become a more serious health concern in some patients who vape or are exposed to vapor.

Another significant finding from this study was the increased breathing frequency identified in the vape group. vape users had significantly higher breathing frequencies at both the pre- and post-vape intervals. The etiology for this finding is unclear and requires further research. One possible explanation is that extended vape use contributes to sustained increases in heart rate and decreases in S_{pO_2} levels, triggering a compensatory increase in breathing frequency.

Vaping with mint-flavored e-cigarettes with 5% nicotine did not have a statistically significant effect on blood sugar. This finding should be further tested with different vape flavors, as many flavors are marketed as fruity or sugary. The results suggest that vaping or acute exposure to vapor is likely not a significant problem for patients with diabetes or hypoglycemia relating to serum glucose levels.

Similarly, vaping or exposure to secondhand vapor in this study did not produce any robust significant differences between groups regarding FVC. While FVC does not appear to change in the short-term for vape users or those exposed to vapor, additional research examining long-term FVC in both groups may yield different results and is worth exploring. Furthermore, an examination of FEV_1 may have produced more sensitive findings compared to testing the occurrence of airway obstruction following vape use or vapor exposure (ie, FVC).

One of the more concerning findings from this study was the significantly decreased S_{pO_2} levels noted in vapers at the post-vape assessment. The results indicate that vaping with mint-flavored e-cigarettes with 5% nicotine significantly decreased the oxygen level in the blood. Although the findings suggest a small effect size ($\eta^2 = 0$ .05), this could have significant clinical implications, especially for patients with other pulmonary disorders contributing to hypoxemia such as asthma or COPD. In addition to the increase in heart rate associated with vaping, this oxygen reduction further increases the user's risk of hypoxemia. Elevated heart rate in conjunction with hypoxemia increases myocardial work load. Patients presenting with symptoms of dyspnea, reduced cardiac ejection fractions, fatigue, light headedness, or dizziness should be further assessed for e-cigarette use. Patients with known cardiopulmonary disorders are at increased risk of worsening symptoms if they continue to vape with mint-flavored nicotine products. The effect may be similar for those exposed to vapor, but our statistical analysis returned as nonsignificant for the nonvape group, which suggests that nonvapers do not have the same health risks as their vaping counterparts.

Finally, it was noted that both the vaping and nonvaping groups had higher oral temperatures at post-vape. This finding may be a little more obvious for the vape group as e-cigarette devices operate on a lithium-battery system heating the e-juice to temperatures of 215°C to aerosolize the liquid.[31] It should be noted that the inhaled vapor is significantly cooler than 215°C, but the heating elements in vapes can become very hot. It was surprising to note that people exposed to secondhand vapor also experienced higher oral temperatures post-vape, which suggests that the inhaled vapor has heat. The results are clinically important at the medium effect size ($\eta^2 = 0.21$) and should be a consideration for health care providers caring for patients who vape or are exposed to vapor. These findings have an impact on oral health because sustained elevated oral temperatures can kill normal oral flora.[37] More research is needed on the health impact of persistently high oral temperatures associated with vaping and exposure to secondhand vapor. Additionally, further research needs to be conducted to determine why exposure to secondhand vapor contributes to increased oral temperature. The cause of this finding was not readily apparent.

Conclusions

The immediate physiological effects of vaping with mint-flavored e-cigarettes with 5% nicotine and exposure to the vapor have significant effects on several health variables. The notion that vaping or being exposed to vapor is safer than cigarette smoking may not necessarily be accurate. Our results indicate that vaping with mint-flavored e-cigarettes with 5% nicotine increases heart rate, breathing frequency, and oral temperature and decreases S_{pO_2} after 20 min of vape use. These short-term effects can have significant long-term health effects, especially if sustained. These findings have important implications for health care professionals who should be assessing for vape use in their patients and providing education on the negative health effects of use both in the short and long term.

Current evidence on vaping mostly focuses on long-term effects. This study examining the immediate impact of vaping provides evidence that there are acute effects related to blood pressure, heart rate, S_{pO_2}, and oral temperature following short periods of use or exposure. These immediate physiologic effects create an opportunity for clinicians to provide education to their patients who may help them make informed decisions about their choice to use vape products. It also provides a foundation for further research into the immediate and long-term health effects of vaping.

Additionally, people exposed to secondhand vapor do not experience the same level of health effects as people who vape, except for increased oral temperature after 20 min of exposure to vapor. This finding has implications for youth and others who are near people who vape. Education should be provided to minimize secondhand vapor exposure.

Finally, results from the health assessment survey of subjects indicate that people who vape are also statistically significantly more likely to engage in other risky behaviors such as alcohol and drug use (Table 1). Health care professionals should be aware of these potential risky behaviors when caring for patients who vape and consider appropriate interventions to reduce health risk.

REFERENCES

1. Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health. Introduction, conclusions, and historical background relative to e-cigarettes. In: E-cigarette use among youth and young adults: a

report of the Surgeon General. Atlanta: U.S. Department of Health and Human Services; 2016:1-19.
2. Nurasyikin MS, Leelavathi M, Tohid H. E-cigarette use, its impact on tobacco smoking. Med Health 2019;141:78-90.
3. Keane H, Weier M, Fraser D, Gartner C. Anytime, anywhere: vaping as social practice. Crit Pub Health 2017;27(4):465-476.
4. Miler J, Hajek P. Resolution of recurrent tonsillitis in a non-smoker who became a vaper: a case study and new phyothesis. Med Hypotheses 2017;109:17-18.
5. Geiss O, Bianchi I, Barrero-Moreno J. Correlation of volatile carbonyl yield emitted by e-cigarettes with the temperature of the heating coil and the perceived sensorial quality of the generated vapours. Int J Hyg Environ Health 2016;219(3):268-277.
6. Gillman IG, Kistler KA, Stewart EW, Paolantonio AR. Effect of variable power levels on the yield of total aerosol mass and formation of aldehydes in e-cigarette aerosols. Reg Tox and Pharm 2016;75:58-65.
7. Grana R, Benowitz N, Glantz SA. E-cigarettes: a scientific review. Circulation 2014;129(19):1972-1986.
8. Scheffler S, Dieken H, Krischenowski O, Forster C, Branscheid D, Aufderheide M. Evaluation of e-cigarette liquid vapor and mainstream cigarette smoke after direct exposure of primary human bronchial epithelial cells. Int J Environ Res Public Health 2015;12(4):3915-3925.
9. Vardavas CI, Anagnostopoulos N, Kougias M, Evangelopoulou V, Connolly GN, Behrakis PK. Short-term pulmonary effects of using an electronic cigarette: impact on respiratory flow resistance, impedance, and exhaled nitric oxide. Chest 2012;141(6):1400-1406.
10. Alzahrani T, Pena I, Temesgen N, Glantz SA. Association between electronic cigarette use and myocardial infarction. Am J Prevent Med 2018;55(4):455-461.
11. Glantz SA, Bareham DW. E-cigarettes: use, effects on smoking, risks, and policy implications. Annu Rev Public Health 2018;39:215-235.
12. Brieger K, Schiavone S, Miller F, Krause K. Reactive oxygen species: from health to disease. Swiss Med Week 2012;142:w13659.
13. Hwang JH, Lyes M, Sladewski K, Enany S, McEachern E, Mathew DP, et al. Electronic cigarette inhalation alters innate immunity and airway cytokines while increasing the virulence of colonizing bacteria. J Mol Med (Berl) 2016;94(6):667-679.
14. Centers for Disease Control and Prevention. New CDC study finds dramatic increase in e-cigarette-related calls to poison centers. Available at: https://www.cdc.gov/media/releases/2014/p0403-e-cigarette-poison.html. *Accessed February 18, 2021.*
15. Eltorai AE, Choi AR, Eltorai AS. Impact of electronic cigarettes on various organ systems. Respir Care 2019;64(3):328-336.
16. Hua M, Alfi M, Talbot P. Health-related effects reported by electronic cigarette users in online forums. J Med Internet Res 2013;15(4):e59.
17. Lanza IH, Pittman P, Batshoun J. Obesity and cigarette smoking: extending the link to e-cigarette/vaping use. Am J Health Behav 2017;41(3):338-347.
18. Qasim H, Karim A, Silva-Espinoza J, Khasawneh FT, Rivera JO, Ellis CC. Short-term e-cigarette exposure increases the risk of thrombogenesis and enhances platelet function in mice. J Am Heart Assoc 2018;7(15):e009264.
19. Sussan TE, Gajghate S, Thimmulappa R, Ma J, Kim JH, Sudini K, et al. Exposure to electronic cigarettes impairs pulmonary anti-bacterial and anti-viral defenses in a mouse model. PLOS One 2015;10(2):e0116861.
20. FDA investigates 127 seizure reports potentially linked to vaping. Forbes: Aug 8, 2019. Available at: https://www.forbes.com/sites/lisettevoytko/2019/08/08/fda-investigates-127-seizure-reports-potentially-linked-to-vaping/?sh=1ec4e7fa454b. *Accessed January 20, 2021.*
21. Ween M, Hodge G, Reynolds P, Hodge S. The new kid on the block: e-cigarettes can cause damage to airway cells and cause airway macrophage dysfunction. Am J Resp Crit Care Med 2016;193:A1194.
22. Vansickel AR, Eissenberg T. Electronic cigarettes: effective nicotine delivery after acute administration. Nicotine Tob Res 2013;15(1):267-270.
23. Nides MA, Leischow SJ, Bhatter M, Simmons M. Nicotine blood levels and short-term smoking reduction with an electronic nicotine delivery system. Am J Health Behav 2014;38(2):265-274.
24. Yan XS, D'Ruiz C. Effects of using electronic cigarettes on nicotine delivery and cardiovascular function in comparison with regular cigarettes. Regul Toxicol Pharmacol 2015;71(1):24-34.
25. Vlachopoulos C, Ioakeimidis N, Abdelrasoul M, Terentes-Printzios D, Georgakopoulos C, Pietri P, et al. Electronic cigarette smoking increases aortic stiffness and blood pressure in young smokers. J Am Coll Cardiol 2016;67(23):2802-2803.
26. Qasim H, Karim ZA, Rivera JO, Khasawneh FT, Alshbool FZ. Impact of electronic cigarettes on the cardiovascular system. J Am Heart Assoc 2017;6(9):e006353.
27. Centers for Disease Control and Prevention. Outbreak of lung injury associated with the use of e-cigarette, or vaping, products. Updated February 25, 2020. Available at: https://www.cdc.gov/tobacco/basic_information/e-cigarettes/severe-lung-disease.html. *Accessed September 10, 2020.*
28. McClelland M, Sesoko C, MacDonald DA. A mixed methods pilot study on the short-term physiological effects of vaping and attitudes regarding its use and health effects in samples of young adults. J Addict Nurs 2020;31(2):110-118.
29. Rimer S. Chasing the facts about e-cigarette health risks. Boston University Research in News SE Spotlight. May 12, 2016. Available at: https://www.bu.edu/eng/2016/05/12/chasing-the-facts-about-e-cigarette-health-risks. *Accessed September 3, 2020.*
30. Sharpless NE. FDA regulation of electronic nicotine delivery systems and investigation of vaping illnesses. Food and Drug Administration. Available at: https://www.fda.gov/news-events/congressional-testimony/fda-regulation-electronic-nicotine-delivery-systems-and-investigation-vaping-illnesses-09252019#. *Accessed September 29, 2020.*
31. McGinley L. Flavored e-cigarette pod ban starts Thursday: what it means for vapers, kids and parents. The Washington Post: Health: February 5, 2020. Available at: https://www.washingtonpost.com/health/2020/02/05/flavored-e-cigarette-pod-ban-starts-thursday-what-it-means-vapers. *Accessed September 29, 2020.*
32. Graham BL, Steenbruggen I, Miller MR, Barjaktarevic IZ, Cooper BC, Hall GL, et al. Update: an official American Thoracic Society and European Respiratory Society technical statement. Am J Respir Crit Care Med 2019;200(8):e70-e88.
33. Linneberg A, Jacobsen RK, Skaaby T, Taylor AE, Fluharty ME, Jeppesen JL, et al. Effect of smoking on blood pressure and resting heart rate. Circ Cardiovasc Genet 2015;8(6):832-841.
34. Talih S, Salman R, El-Hage R, Karam E, Karaoghlanian N, El-Hellani A, et al. Characteristics and toxicant emissions of JUUL electronic cigarettes. Tob Control 2019;28(6):678-680.
35. Benowitz N. Safety of nicotine in smokers with hypertension. Am J Hypertens 2001;14(7 Pt 1):731-732.
36. European Lung Foundation. E-cigarettes linked to increased arterial stiffness, blood pressure and heart rate in humans. ScienceDaily. September 10, 2017. Available at: www.sciencedaily.com/releases/2017/09/170910232512.htm. *Accessed September 23, 2020.*
37. Smith C. Effects of smoking on the mouth. June 2020. Available at: https://www.areasontosmileboise.com/effects-of-smoking-on-the-mouth. *Accessed September 23, 2020.*