Measurement and changes of exhaled nitric oxide fraction while vaping with a brief education intervention session

Received: 5 July 2022
Accepted: 17 Nov 2022

To the Editor:

The use of e-cigarettes and vaping devices has been increasing rapidly, with a focus on nicotine and even the use of tetrahydrocannabinol (THC) [1, 2]. Commonly used devices include JUUL and Puff Bar, which come with disposable pods [3, 4]. When asked, users reported reasons for using vapes/e-cigarettes as: to replace smoking; not the same as smoking; and/or being marketed as being a healthier option due to the absence of carbon monoxide production [3].

The American Thoracic Society has reported that the measurement of exhaled nitric oxide fraction (F_{ENO}) is simple and can be used as a biomarker in the assessment and management of airways disease [5]. The change in F_{ENO} due to inflammatory responses seen in the airway fluctuates from breath to breath, making repetitive sample collection crucial for accuracy, yet recent studies involving measurements of airway inflammation using F_{ENO} with e-cigarettes have shown mixed results [6–8]. To our knowledge, there are no studies reporting changes in F_{ENO} in an individual's "natural element" over time. Natural element is defined as the regular environment where an individual would normally vape taking into consideration such factors as frequency and depth of puffs during any given time vaping. In this study, we report changes in F_{ENO} levels pre- and post-vaping nicotine over a 30-min period in the vaper's natural element. In addition, we assessed behavioural changes from baseline *versus* 2 weeks after a 15-min brochure-based education session on the danger of vaping.

The study was approved by the institutional review board at Loma Linda University Health (Loma Linda, CA, USA). Subjects were recruited using snowball sampling, as well as social media in California, USA. They signed the informed consent form and were given a monetary gift upon study completion. Subjects were asked to abstain from vaping for $\geqslant$3 h prior to data collection. Inclusion criteria were adults aged 18–35 years who vaped Puff Bar or JUUL products. F_{ENO} measurement was collected using a NIOX device (Circassia). Figure 1 presents the study flow diagram.

Data were analysed using SPSS (version 28.0). Using F_{ENO} as a primary end-point, a sample size of 21 participants was estimated using a moderate effect size of 0.25, α=0.05 and power of 0.8. Data were summarised using mean±SD or median (range) for quantitative outcomes and count (%) for categorical variables. The normality of the quantitative variables was examined using box plots and the Shapiro–Wilk test. To examine whether there was a change in behaviour regarding smoking and vaping pre- *versus* post-education, the Chi-squared test was conducted. Since the distribution of F_{ENO} values was not approximately normal, the Friedman test was used to examine changes in F_{ENO} over time. If the result was significant, the Wilcoxon signed rank test was used to examine which values were different over time. To examine changes in likelihood of quitting vaping, pre- *versus* 2 weeks post-education, the Chi-squared Fisher's exact test was used. The level of significance was set at $p\leqslant0.05$.

In our findings, 21 subjects with a mean age 24.7±3.1 years participated in the study. The majority were male (n=14, 66.7%), reported vaping daily (n=16, 76.2%), vaped $\geqslant$10 times per week (n=15, 71.4%) and inhaled/vaped five or more puffs at a time (n=12, 57.1%). 20 (95%) subjects vaped Puff Bar products and one vaped JUUL products. The majority of the subjects were gainfully employed (n=20, 95%), of whom six (30%) worked from home. Seven (33%) subjects have pulmonary disease diagnoses (four have asthma

Shareable abstract (@ERSpublications)
A brief, 15-min education intervention session might be helpful to highlight the dangers of vaping and aid in cessation. In addition, post-washout period (15 min), F_{ENO} levels increased significantly. https://bit.ly/3Xu4X5Y

Cite this article as: Kandhola A, Daher N, Williams T, *et al*. Measurement and changes of exhaled nitric oxide fraction while vaping with a brief education intervention session. *ERJ Open Res* 2023; 9: 00327-2022 [DOI: 10.1183/23120541.00327-2022].

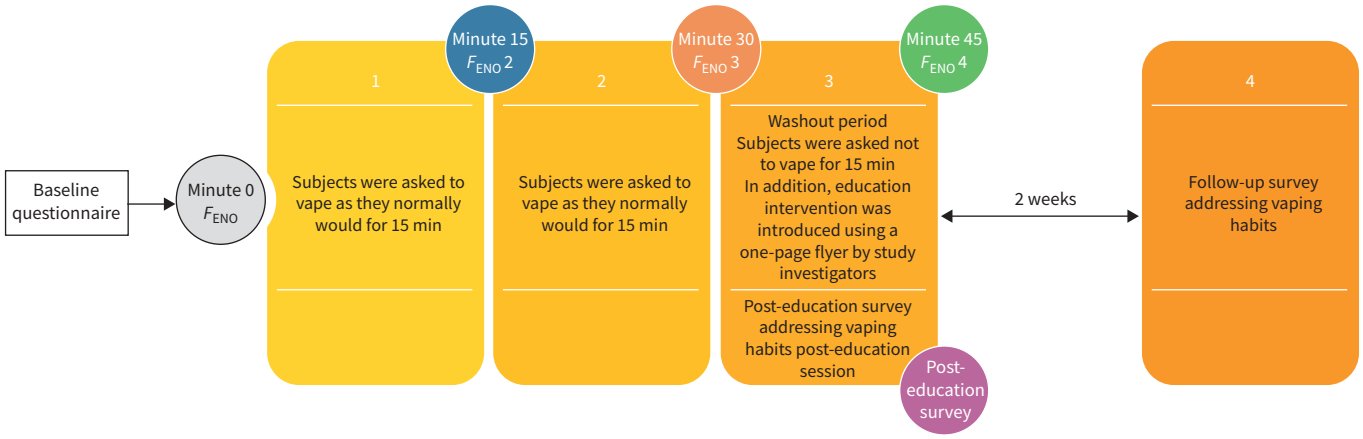

FIGURE 1 Study flow chart. F_{ENO}: exhaled nitric oxide fraction.

and three have bronchitis). 13 (61.9%) subjects indicated that they had attempted to quit vaping previously, with 18 (85.7%) indicating that they were interested and likely to quit vaping.

When asked about some general misconceptions about vaping, 13 (61.9%) reported that vaping is safer than smoking, 11 (55%) indicated that second-hand vape is real, 15 (75%) believed that vaping affects only the younger population, and the majority (n=18, 85.7%) did not believe that vaping protects them from coronavirus disease 2019.

Results of the Fisher's Chi-squared test showed that a higher proportion of participants were more likely to quit vaping 2 weeks post- *versus* pre-15-min education intervention session (80% *versus* 61.9%, Chi-squared 4.9, p=0.047). In addition, there was a significant change in median (range) F_{ENO} levels over time (baseline *versus* after 15 min *versus* after 30 min *versus* after 45 min) (17 (8–103) ppb *versus* 18 (7–87) ppb *versus* 17 (5–93) ppb *versus* 18 (7–103) ppb; Chi-squared 9.9, p=0.019). Findings from the Wilcoxon signed rank test showed that the change was significant between F_{ENO} 45 min and F_{ENO} 30 min (z=−2.2, p=0.027). However, when repeating the same analysis and excluding subjects with pulmonary diseases, there was no significant change in F_{ENO} over time (Chi-squared 5.3, p=0.098).

Our findings showed a decrease in F_{ENO}, from baseline, over the 30-min observational period during which subjects were free to vape as they usually would. This was followed by a significant increase in F_{ENO} from minute 30 to minute 45, during which the 15-min washout period took place. The findings of this study are similar to other studies that found an increase in F_{ENO} levels with different washout period times [8]. In contrast, when comparing subjects with asthma against healthy indiviuals, there are reports that indicate a decrease in F_{ENO} in heathy subjects and an increase in subjects with asthma [9, 10]. Others reported a decrease of F_{ENO} in smokers with pulmonary diseases. Conversely, a significant increase of F_{ENO} post-washout period is an interesting finding [11]. The delay of significant F_{ENO} increase occurred immediately following the 15-min washout period. This finding raises the possibility that if vaping inhibits the inflammatory response while vaping occurs, an increase could occur later, following the initial exposure. In addition, the changes seen in F_{ENO} in this study and others illustrate the challenges of quantifying the inflammatory response based on differing lung diseases and possible atopy in a population [7–10].

Lastly, another interesting finding is the desire to quit vaping 2 weeks after receiving a 15-min brochure-based education. It raises the question whether a brief 15-min education session is enough to cause a behaviour change in young people over time. In addition, it raises the question of whether a vaping cessation programme or more follow-up could have further improved results, or if shorter education is more beneficial due to time allocation and attention span. This education was designed to be short, concise, easy to follow and open to questions. Subjects suggested the possibility of asking more questions *via* text after the study ended; however, thus far, no further communication from subjects has been received, although behavioural changes did occur. This suggests that this short education may be effective.

One of the strengths and unique characteristics of this study is the measurement of individuals vaping in their natural element. There are several limitations in the study that need to be addressed in future studies.

First, since there was an increase in F_{ENO} post-washout period, after a decrease while vaping, other measurements of F_{ENO} at minute 60 might have provided more clarification of whether the rise continues. In addition, since the median change was equal to 1 in the F_{ENO} results, which might not be clinically important, there was a variability in significance of F_{ENO} noticed when looking at minimum and maximum levels from baseline to minutes 15 and 30. Therefore, additional studies are warrented to truly understand the clinical importance as well as change in variability. Moreover, longitudinal follow-up of subjects could better evaluate whether more subjects had quit vaping, providing us with data on the actual effect of the education intervention past the 2-week mark. Moreover, we did not collect the number of puffs taken by each vaper. Future studies should consider adding this as an outcome. Lastly, future studies should examine more healthy subjects using more data points to evaluate true clinical change.

Arshdeep Kandhola[1], Noha Daher[2], Taylor Williams[1], David Lopez[1], Laren D. Tan[1,3] and Abdullah Alismail[1,3]

[1]Department of Cardiopulmonary Sciences, School of Allied Health Professions, Loma Linda University Health, Loma Linda, CA, USA. [2]Allied Health Studies, School of Allied Health Professions, Loma Linda University Health, Loma Linda, CA, USA. [3]Department of Medicine, School of Medicine, Loma Linda University Health, Loma Linda, CA, USA.

Corresponding author: Abdullah Alismail (aalismail@llu.edu)

Provenance: Submitted article, peer reviewed.

Author contributions: A. Kandhola, N. Daher, D. Lopez, L. Tan and A. Alismail conceived the idea and design of the study. A. Kandhola and T. Williams performed data collection. N. Daher and A. Alismail performed data analysis. A. Kandhola and A. Alismail performed literature review. All authors contributed to the writing of this manuscript.

Conflict of interest: None declared.

References

1 Sapru S, Vardhan M, Li Q, *et al.* E-cigarettes use in the United States: reasons for use, perceptions, and effects on health. *BMC Public Health* 2020; 20: 1518.
2 Cecchini MJ, Mukhopadhyay S, Arrossi AV, *et al.* E-cigarette or vaping product use-associated lung injury: a review for pathologists. *Arch Pathol Lab Med* 2020; 144: 1490–1500.
3 Newcombe KV, Dobbs PD, Oehlers JS, *et al.* College students' reasons for using JUULs. *Am J Health Promot* 2021; 35: 835–840.
4 Allem J-P, Dormanesh A, Majmundar A, *et al.* Leading topics in Twitter discourse on JUUL and Puff Bar products: content analysis. *J Med Internet Res* 2021; 23: e26510.
5 Dweik RA, Boggs PB, Erzurum SC, *et al.* An official ATS clinical practice guideline: interpretation of exhaled nitric oxide levels (F_{ENO}) for clinical applications. *Am J Respir Crit Care Med* 2011; 184: 602–615.
6 McSharry CP, McKay IC, Chaudhuri R, *et al.* Short and long-term effects of cigarette smoking independently influence exhaled nitric oxide concentration in asthma. *J Allergy Clin Immunol* 2005; 116: 88–93.
7 Schober W, Szendrei K, Matzen W, *et al.* Use of electronic cigarettes (e-cigarettes) impairs indoor air quality and increases F_{eNO} levels of e-cigarette consumers. *Int J Hyg Environ Health* 2014; 217: 628–637.
8 Burress SL, Diamond TJC, Waugh JB. Short-term effect of e-cigarette use on spirometry and F_{ENO} on young adults. *Respiratory Care* 2019; 64: Suppl. 10, 3214506.
9 Kotoulas SC, Pataka A, Domvri K, *et al.* Acute effects of e-cigarette vaping on pulmonary function and airway inflammation in healthy individuals and in patients with asthma. *Respirology* 2020; 25: 1037–1045.
10 Pataka A, Kotoulas SC, Domvri K, *et al.* Acute effects of vaping one e-cigarette in airway inflammation of asthmatic patients. *Eur Respir J* 2019; 54: Suppl. 63, PA1685.
11 Vardavas CI, Anagnostopoulos N, Kougias M, *et al.* Short-term pulmonary effects of using an electronic cigarette: impact on respiratory flow resistance, impedance, and exhaled nitric oxide. *Chest* 2012; 141: 1400–1406.