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Abstract

TITLE: Health Risk Perceptions Regarding Electronic Nicotine Delivery Systems (ENDS) Among Individuals with Respiratory Illnesses

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Electronic nicotine delivery systems (ENDS), also known as electronic cigarettes, are portable battery-powered devices used to smoke or "vape" a flavored solution which usually contains nicotine. Many national organizations (CDC, AMA, AAFP, ALA, AHA) have recognized the alarmingly increased rates of ENDS use in the United States, especially among certain populations. Those most likely to engage in ENDS use are youth and young adults, and adults who already smoke combustible cigarettes. Many people perceive ENDS use as a healthier alternative to smoking regular cigarettes and thus, are more willing to initiate ENDS use. However, research has indicated that ENDS use is associated with negative health effects, especially to those already diagnosed with a respiratory illness or disease such as asthma, chronic obstructive pulmonary disease (COPD), interstitial lung disease, and lung cancer. The purpose of this study was to determine the rates of ENDS use among those with respiratory illnesses and to examine their health risk perceptions associated with ENDS. Other risk factors, including demographic, psychosocial, and health-related factors associated with ENDS risk perceptions were also examined.

This study included 270 adult participants with respiratory illnesses who were current/past smokers (n = 28, 10%), current/past vapers (n = 7, 3%), current/past dual users (n = 208, 77%), and ever dual users (n = 27, 10%). The sample included 146 men, 101 women, 19 transwomen, 3 transmen, and one individual who identified as gender fluid. Most respondents were between the ages of 25-34 years old.

Results demonstrated that risk perceptions associated with ENDS use were significantly greater for those smoking or vaping a single product compared to those who were current dual users, U = 3988, z = -6.18, $p < .001$. ENDS risk perceptions were also significantly associated with gender, ethnicity, geographic region, and race. Particularly, participants who identified as male/transman, Hispanic/Latino, from the South and Midwest U.S. regions, and of a minority race were more likely to report lower risk perceptions associated with ENDS use. Likewise, those who had one or more friends who vaped were more likely to have lower ENDS risk perceptions compared to those who had no friends who vaped.

More than half of this sample endorsed ENDS use as an effective coping method for stress management (n = 146, 54%). Similarly, 66% (n = 179) agreed that ENDS use is an effective tool for smoking cessation and 76% (n = 206) agreed that ENDS products could help with reducing the number of cigarettes smoked (*i.e.*, harm reduction strategy). Although more than half of the participants (n = 159, 59%) endorsed that their health care providers have **never** advised the use of ENDS products for smoking cessation, 33% (n = 90) endorsed being advised this **once or twice**, and 8% (n = 21) of participants endorsed being advised **frequently** from a healthcare provider to use ENDS products for smoking

cessation. In terms of respiratory-health risk factors, an individual's overall health status significantly predicted ENDS Risk Perceptions, $B = 0.70$, $t\ (265) = 3.42$, $p < .001$, indicating that on average, a one standard deviation-unit increase in Health Status score increased the value of ENDS Risk Perception scores by 0.70 standard deviation units. Those with a poorer health status were more likely to have higher risk perceptions related to ENDS use.

Based on the results from this study, medical practitioners can be more mindful in sharing the negative health outcomes of dual using among those who have a chronic respiratory condition and currently smoke and vape. Since this population often requires frequent medical care and hospital visits, it would be worthwhile to modify respiratory medical standards to include education about the negative health effects of vaping to be regularly discussed with patients. The association between health perceptions and smoking/vaping status demonstrated in this study, and the fact that health perceptions are modifiable, suggests that provider advice about smoking/vaping-related health risks may influence behavioral change.

TABLE OF CONTENTS

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Review of the Literature

Prevalence of Tobacco, ENDS, and Dual Use Among the General U.S. Population

Electronic Nicotine Delivery Systems (ENDS) are defined as portable, noncombustible smoking products in contrast to conventional tobacco, combustible cigarettes. These products use an "e-liquid" that may contain nicotine, as well as varying mixtures of flavorings, propylene glycol, vegetable glycerin, water, and other ingredients (FDA, 2020). The e-liquid is then heated to create an aerosol that the user inhales into their lungs. Bystanders can also breathe in this aerosol when the user exhales it into the atmosphere. ENDS may be manufactured to look like conventional cigarettes, cigars, or pipes. Some devices resemble pens or USB flash drives. Larger devices, such as tank systems or mods, generally do not resemble cigarettes. ENDS are known by various names colloquially: vapes, vaporizers, vape pens, hookah pens, electronic cigarettes (e-cigarettes or e-cigs), and e-pipes. Although each ENDS device varies in design, the products generally contain similar components: a mouthpiece, cartridge tank that holds the e-liquid, heating element that turns the e-liquid into vapor, microprocessor, switch to activate the heating element, and a battery (FDA, 2020).

ENDS were first introduced in the United States in 2007; the availability and use of ENDS devices have increased exponentially in more recent years (Gravely et al., 2014; McMillen, et al., 2015). The significant increase in ENDS use has been especially notable among youth in the U.S., whose ENDS use has surpassed combustible cigarettes as the most used tobacco product in the past two years (Wang et al., 2018). According to the CDC, in 2018 more than 3.6 million U.S. middle and high school students used e-cigarettes in the past 30 days, including approximately 5% of middle school students and

20% of high school students. According to analysis done by the American Lung Association (ALA, 2021) on the CDC's National Youth Tobacco Survey, from years 2011 to 2019, "current use" of e-cigarettes (vaping on most or some days over the past month) increased 1650% among middle school students, from 0.6% to 10.5%; it has also increased 1733% among high school students, from 1.5% to 27.5%. In 2019, close to 2.9 million youth started using e-cigarettes, demonstrating a significant increase from previous years (ALA, 2021).

While rates of ENDS use among adults are relatively low compared to youth, ENDS use has similarly increased among a select group of adults- young adults. A review of the rates in all ages (adults 18 years and older), based on data from The National Health Interview Survey conducted in 2018, showed that 14.9% had ever used an electronic cigarette and 3.2% were current e-cigarette users (Villarroel et al., 2020). The highest prevalence among adults who had ever used or was a current e-cigarette user was among those aged 18–24 years, or what is known as the 'young adult' demographic. Specifically, 25.8% of young adults reported ever using e-cigarettes, the highest amongst all other age groups. This shows a 3% increase from the rates collected in 2016 (CDC, 2017). In another analysis conducted by the American Lung Association (ALA, 2021) on trends of the National Health Interview Survey, the number of young adults (aged 18-24) who currently used e-cigarettes increased by 49% from years 2014 to 2018. To put that into perspective, all other adult age groups demonstrated a slight decrease in e-cigarette use over those same years (ALA, 2021).

The term "dual use" describes using different forms of tobacco products such as electronic cigarettes (e-cigarettes), smokeless tobacco, or other tobacco products in

addition to combustible cigarettes (CDC- Dual Use, 2020). For example, an individual who smokes regular combustible cigarettes **and** e-cigarettes would be considered a "dual user." Based on the data from The National Health Interview Survey conducted in 2018, the percentage of adults who had ever used an e-cigarette varied significantly based on individuals' cigarette smoking status (Villarroel et al. 2020). The percentage of adults who had ever used an e-cigarette and were current e-cigarette users was highest among former cigarette smokers who quit within the past year. The percentage of adults who were current e-cigarette users was lower for current cigarette smokers (9.7%) than for former cigarette smokers who quit within the past year (25.2%) and former cigarette users who quit between 1–4 years ago (17.3%). These findings suggest that people who smoke combustible cigarettes are more likely to begin using e-cigarettes, shortly after quitting combustible cigarettes.

In a recent study conducted by Kava et al. (2020), the authors measured and compared the use of conventional cigarettes, e-cigarettes, and dual use among adult employees in the workplace. Out of the 221,264 survey respondents, approximately 17% were current smokers of any product, 14% used conventional cigarettes, 5% used e-cigarettes, and 2% were dual users. E-cigarette only and dual use were generally highest among young adults (18–24 years), male, and less-educated respondents and lowest for respondents who identified as black, Asian/Native Hawaiian/Pacific Islander, or Hispanic than for white respondents. Interestingly, rates of cigarette-only and dual use were higher for respondents who did not have health care coverage (Kava et al. 2020).

Prevalence of Tobacco Smoking Among Those with Respiratory Illness

While vaping rates among individuals who have respiratory illnesses have not been determined for various reasons, rates for cigarette smoking among this medically compromised group are available. Prevalence rates for cigarette smoking among asthmatics in the U.S. averages around 21% and ranges by state, from lowest being 12% in Minnesota/Utah to the highest being 32% in Kentucky, according to the BRFSS (CDC, 2010). Furthermore, rates from the BRFSS (CDC, 2017) showed that among those with Chronic Obstructive Pulmonary Disease (COPD) in the U.S., 15.2% are current smokers, 7.6% are past smokers, and 2.8% are never smokers (CDC, 2017). In comparison to other medically comprised groups, studies have shown a range between 50%-83% of cancer patients that continue to smoke even after receiving a cancer diagnosis (Cataldo et al. 2010; Duff et al., 2008; Sardari Nia et al., 2005). A longitudinal study including over 10,000 individuals which measured smoking habits of people with cardiovascular disease (CVD) and coronary heart disease (CHD), found that for the daily smokers, 11.2% had CVD and 10.3% had CHD. For the ever smokers, 6.3% had CVD and 5.4% had CHD, for the former smokers, 13.4% had CVD while 10.8% had CHD (Amiri et al., 2019). Notably, this suggested that people with respiratory or other chronic medical conditions often continue to smoke despite continued medical problems.

Geographic location in the U.S. also plays a role in the prevalence rates of smoking among individuals with respiratory illnesses (CDC, 2017). Among current smokers, age-adjusted COPD prevalence ranged from 7.8% in Hawaii to 25.9% in West Virginia. Among former smokers, age-adjusted COPD prevalence ranged from 4.7% in Hawaii to 15.1% in West Virginia. Among never smokers, age-adjusted COPD

prevalence ranged from 1.6% in Minnesota to 6.0% in West Virginia. Rates of current asthma in the U.S. vary by region, the Northeast having the highest prevalence at 8.6% and the Midwest with the lowest prevalence at 7.7.% (NHIS, 2019). Similarly, rates of asthma attacks are more prevalent in the Northeast region of the U.S. at 3.5% and lowest in the Midwest region of the U.S. at 3.0% (NHIS, 2019). Alternatively, COPD presents highest prevalence rates in the South region of the U.S. at 5.3% and lowest prevalence rates in the Northeast and Western regions of the U.S. at 3.7% (NHIS, 2019). This information demonstrates higher prevalence rates in certain geographic areas.

Regions throughout the U.S. show varying prevalence rates of smoking as well. The U.S. Census Bureau divides the country into 4 major regions as follows: Northeast, Midwest, South, and the West. Among current smokers, COPD prevalence was highest in the South and Midwest regions; and higher prevalence of COPD was identified in Southern states, regardless of smoking status (CDC, 2017). According to the Surgeons General Report on The Health Consequences of Smoking- 50 Years of Progress (USDHHS, 2014), people living in certain regions more often suffer from poor health, including chronic respiratory ailments, due to higher rates of tobacco use and cigarette smoking in those areas. According to the results from the National Survey on Drug Use and Health (SAMHSA, 2017), rates of cigarette smoking among U.S. adults are highest among people living in the South (22.7%) and Midwest (22.2%) regions, and lowest among individuals living in the Northeast (20.1%) and West (16.3%) regions. People in the South and Midwest also tend to use several types of tobacco products including smokeless tobacco (*i.e.*, chewing tobacco, snuff, snus, dissolvable tobacco) and cigarettes, increasing their risks of developing serious illnesses/diseases (USDHHS,

2014).

Furthermore, the Truth Initiative (2019) released a report describing specific states in the South and Midwest regions of the U.S. that have consistently exceeded national adult smoking rates over the past decade. Because of the disproportionately higher rates found in Alabama, Arkansas, Indiana, Kentucky, Louisiana, Michigan, Mississippi, Missouri, Ohio, Oklahoma, South Carolina, Tennessee and West Virginia, these states have been coined as the "Tobacco Nation" by the Truth Initiative (2019). Compared to the rest of the U.S., the "Tobacco Nation" showed significant differences in important life areas beyond just the increased smoking rates, such as disparate income level, health ratings, and public policies. These 13 states have ranked among the top 25% of tobacco using states in the U.S. consistently over the past 10 years. Individuals living in the "Tobacco Nation" earn on average 25% less per year than individuals living in other states. Furthermore, access to healthcare is limited and perceived health ratings among residents are reported to be more than 20% worse than the average Americans' rating. This can be reasonably understood given that the rates of serious diseases, such as lung cancer, heart disease, and COPD, are higher in the "Tobacco Nation" compared to the rest of the U.S. Finally, public policy laws protecting citizens from second-hand smoke in the "Tobacco Nation" are lacking; only two states in the "Tobacco Nation" (Michigan and Ohio) have laws forbidding indoor smoking (i.e., workplaces, restaurants, and bars) compared to more than 50% of the rest of the country. Buying a pack of cigarettes is on average 19% cheaper in the "Tobacco Nation" as well (Truth Initiative, 2019).

Perceived Benefits of Using E-Cigarettes

There is substantial debate in the literature regarding the health risks of ENDS use, with most studies reporting insufficient evidence to establish a conclusive finding (CDC, 2020). Alternative viewpoints in the current literature have deemed the use of e-cigarettes as 'safe' in comparison to cigarette smoking when analyzing potential risks among current smokers; however, when analyzing potential risks among non-smokers, the safety perception of using e-cigarettes varies (Fairchild et al., 2019). Many studies have reported on the effectiveness of e-cigarettes in smoking cessation via a harm reduction model as well (Beaglehole et al., 2019; Hajek et al., 2019; McNeill et al., 2018; National Academies of Sciences, Engineering, and Medicine [NASEM], 2018; Royal College of Physicians of London, 2016). However, most of these studies focus on the relative benefits of e-cigarettes compared to the risks involved in continued cigarette smoking, while the absolute value inherent in e-cigarettes remains unverified (Fairchild et al., 2019).

In a Cochrane Review of using electronic cigarettes for smoking cessation, Hartmann-Boyce and colleagues (2016) evaluated results from various randomized controlled trials (RCTs) published from 2004 to 2016. The main outcome measure assessed across the studies was abstinence from smoking after at least six months follow-up. The combined results, involving 662 participants, showed that using e-cigarettes containing nicotine increased the chances to stop smoking by 45% compared to using e-cigarettes without nicotine. However, due to limitations in various study designs, it could not be determined if the e-cigarettes were better than a nicotine patch in helping people with smoking cessation. Stated limitations included having a small number of trials, wide

confidence intervals, and a low number of participants. Due to this, confidence in the results was rated as 'low' according to the GRADE system. This means that "further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate," ultimately indicating that any potential smoking cessation benefit seen in this review was inconclusive (Hartmann-Boyce et al., 2016, p.2).

In another RCT conducted by Bullen and colleagues (2013), similar results were reported. The study involved 657 individuals who were randomly assigned to 3 groups: nicotine e-cigarettes (289 participants), nicotine patches (295 participants), or placebo e-cigarettes (73 participants). The primary outcome measure was continuous abstinence at six months that was biochemically verified via exhaled carbon monoxide measurement less than 10 ppm. At the six-month mark, verified abstinence was 7.3% (21 of 289) for nicotine e-cigarettes, 5.8% (17 of 295) for nicotine patches, and 4.1% (3 of 73) for placebo e-cigarettes. The authors reported insufficient statistical power to conclude an advantage of nicotine e-cigarettes over nicotine patches or the placebo e-cigarettes since the abstinence levels were substantially lower than anticipated given the power calculation. Thus, final conclusions from the study suggested that e-cigarettes, with or without nicotine, were mildly effective at helping smokers quit, with similar abstinence levels seen with nicotine patches (Bullen et al., 2013).

Another well-known study conducted by Hajek and colleagues (2019), showed that e-cigarettes reduced smoking rates, however, participants continued to use e-cigarettes after terminating cigarette smoking. A total of 886 participants were randomized into 2 groups to assist with smoking cessation: using nicotine-replacement

products (patch, gum, lozenge, nasal spray, inhalator, mouth spray, mouth strip, and microtabs) or using e-cigarettes with nicotine. The treatment also included weekly behavioral support for at least one month. The primary outcome measure was biochemically validated sustained abstinence for one year which was verified via exhaled carbon monoxide level of less than 8 ppm. Data was recorded at baseline, after one month, and then at the one-year mark. Other outcome measures included self-reported adherence to the treatment protocol and respiratory symptoms. Results revealed that at the one-year abstinence mark, 18% were abstinent in the e-cigarette group compared to 9.9% abstinent in the nicotine-replacement group. Furthermore, among these participants who reached one-year abstinence, those in the e-cigarette group were more likely to continue the use of their assigned e-cigarette product (80%) than those in the nicotine-replacement group (9%); this is concerning as this may pose health risks if participants transition to using e-cigarettes for long term use. Both e-cigarettes and nicotine-replacement products were perceived to be less satisfying in comparison to regular cigarettes; however, participants reported greater satisfaction from e-cigarettes than nicotine-replacement products. In terms of respiratory symptoms, throat/mouth irritation was more frequently reported in the e-cigarette group (65.3%) than in the nicotine-replacement group (51.2%). Conversely, the occurrence of cough and phlegm production showed a decline in both groups at the one-year mark. Additionally, nausea was more frequently reported in the nicotine-replacement group (37.9%) than in the e-cigarette group (31.3%). Overall conclusions indicated that e-cigarettes were more effective than nicotine-replacement therapy, when accompanied by behavioral intervention, and when e-cigarettes were used for smoking cessation in heavily dependent cigarette smokers

(Hajek et al., 2019).

In a longitudinal study of 322 adult daily smokers and dual users, researchers examined the course of dual smoking and likelihood for discontinuation of either combustible cigarettes, e-cigarettes, or both (Piper et al., 2020). Results revealed that most dual users transitioned to exclusive smoking of one product. Sustained e-cigarette use was related to baseline e-cigarette dependence. Largely, the research suggested that dual use was not sustainable for most, but a sustained pattern was more likely evident if the user was more dependent on e-cigarettes to begin with. There was also evidence that dual users were more likely to quit than exclusive smokers of one product; however, this may be due to factors other than their dual use (Piper et al., 2020).

A meta-analytic review comprised of 65 studies indicated various perceived benefits and reasons for vaping among e-cigarette users, cigarette smokers, dual users, and non-users (Romijnders, Osch, Vries, & Talhout, 2018b). Among adult smokers and e-cigarette users, e-cigarettes were used primarily for purposes of smoking cessation and the perceived benefits revolved around convenience and attractiveness of the product. These benefits included positive experiences such as improved taste/smell, social acceptance, avoidance of smoking restrictions/bans, and using a cool/fashionable product. Additionally, dual users indicated vaping for the perceived benefit of reducing cigarette smoking cravings and improving their health. Adult e-cigarette users, dual users, and non-users also reported a perceived benefit for bystanders' health when e-cigarettes were used instead of traditional combustible cigarettes. Non-users indicated reasons for potentially initiating e-cigarette use would be the expected benefits (enjoyable taste and a variety of flavors), experienced benefits (reduce stress and enables control of weight

gain), avoidance of smoking restrictions by dual use, convenience of the product, curiosity, and influence from the social environment (recommended by friends). Smoking cessation was found to be a major reason why individuals use e-cigarettes; however most other reported motives revolved around the perceived health benefits e-cigarettes can provide in comparison to traditional cigarettes (Romijnders, Osch, Vries, & Talhout, 2018b).

While e-cigarettes were initially used as a method of attempting to quit combustible cigarettes, growing evidence suggests that people may be using e-cigarettes for other reasons. In a content analysis study of Twitter postings regarding ENDS and related terms, the data suggested that reasons for vaping have shifted from smoking cessation towards social image over the span of 2012 to 2016 (Ayers et al., 2017). Early years included quitting combustible cigarettes as the most cited reason for using ENDS (e.g., "I couldn't quit till I tried e-cigs"). Other reasons included social image, indoors use, favorable odors/flavorings, perceived safety relative to combustible cigarettes, and cost efficiency. Notably, Twitter postings related to quitting combustible cigarettes and using e-cigarettes indoors significantly declined throughout the years. Researchers postulated that this most likely has to do with the increase in consumer knowledge on the health risks of vaping and new policy restrictions made on indoor vaping (Ayers et al., 2017).

The U.S. Preventive Services Task Force recently issued a recommendation which stated, "the current evidence is insufficient to assess the balance of benefits and harms of e-cigarettes for tobacco cessation in adults" such that patients should continue using established tobacco cessation interventions (Krist et al., 2021, p. 265). Even when

comparing the potential health risks of continued tobacco smoking, evidence is inconclusive on whether e-cigarette smoking is beneficial or not. Additionally, in the most recent Surgeons General Report which focuses on Smoking Cessation, it was concluded that there is insufficient evidence to state that e-cigarettes help with smoking cessation; thus, traditional smoking cessation interventions approved by the FDA should continue to be used (USDHHS, 2020). The Surgeon General's Report on smoking cessation strongly endorses behavioral counseling and FDA-approved medication as evidence-based methods, proven safe and effective, for smoking cessation. Behavioral counseling significantly increases the chance of quitting successfully and can be delivered in a variety of different ways including individual or in group settings. FDA-approved smoking cessation medications include nicotine-replacement therapy such as nicotine gum, throat lozenge, transdermal patch, nasal spray, oral inhaler, and sublingual tablet. Other FDA-approved smoking cessation medications include non-nicotine therapy such as bupropion sustained released (e.g., Zyban, Wellbutrin) and varenicline tartrate (i.e., Chantix). Despite these explicit recommendations, there remains a widespread perception among the U.S. population that e-cigarettes are a safer and healthier alternative to combustible cigarettes, and an effective method of smoking cessation (Baeza-Loya et al., 2014; Brose et al., 2015; Delnevo et al., 2016; Huang et al., 2019). These perceived benefits have contributed to the observed increase in e-cigarette use overall. While e-cigarettes might not be as harmful as combustible cigarettes, e-cigarettes are not completely without risk.

Risks of Using E-Cigarettes

Various particles and chemical substances currently found in e-cigarette aerosols, e-liquid cartridges, and environmental emissions have been known to be toxic, carcinogenic, and to cause pulmonary/cardiac diseases (National Academies of Sciences, Engineering, and Medicine [NASEM], 2018). The key ingredients found in e-liquid mixtures include solvents such as propylene glycol (PG) or vegetable glycerin (glycerol), a certain percentage of nicotine, concentrated flavors, and water (NASEM, 2018). Despite this initial simple mixture, over 113 chemicals in 50 different brands of e-liquids have been found to exist (Kucharska et al., 2016). More substances can be observed in the aerosol than in the original solution because some chemicals are generated during the vaporization process. For example, an aerosol generated from a single product tested by Herrington and Myers (2015) showed 18 additional compounds observed in this solution. Some of the toxic substances identified in e-liquids and resulting aerosols originate from the following: nicotine, solvents (PG and glycerol), tobacco-specific nitrosamines (TSNAs), carbonyl compounds (aldehydes), metals, silicates, volatile organic compounds (VOCs), phenolic compounds, polycyclic aromatic hydrocarbons (PAHs), flavorings, tobacco alkaloids, and drugs – all of which can be found in an ENDS device (NASEM, 2018).

The most reported short-term symptom from e-cigarette users is dry mouth/throat, most likely due to the water-absorbing property of PG and glycerol (NASEM, 2018). While PG has been generally recognized as safe under conditions of use as a food additive by the FDA, it has not been verified as safe for other routes of absorptions such as through inhalation (NASEM, 2018). PG can also be used for other purposes, such as

artificial smoke and fog used in firefighter training and in theatrical productions (NASEM, 2018). Occupational exposures to PG have been researched by Varughese et al. (2005) in a study of 101 employees who were routinely exposed to these fogs. Measuring the levels of exposure, lung function, and acute/chronic symptoms revealed that theatrical fog exposures were significantly associated with chronic work-related wheezing and chest tightness (Varughese et al., 2005). Various organizations (Health Council of the Netherlands [HCN], National Institute for Occupational Safety and Health [NIOSH], Occupational Safety and Health Administration [OSHA], and World Health Organization [WHO]) have established precautionary guidelines for the recommended exposure limit to PG because of these concerns (NASEM, 2018).

Several other symptoms have been associated with PG use in humans, such as allergic reactions, eye irritation, irritating cough, upper respiratory irritation, and increased development of a pulmonary illness (Choi et al., 2010; McCauley et al., 2012; NASEM, 2018). A systematic literature review conducted by Lim and colleagues (2014) on the toxicity of large doses of PG administered orally or intravenously to humans contributed to the identification of a "PG toxidrome" which results in adverse effects such as hyperosmolarity, lactic acidosis, hemolysis, central nervous system (CNS) toxicity, and cardiac arrhythmia. PG is processed in the body by the kidney, which eliminates 45% of the PG and then the liver metabolizes the remainder of lactic acid, pyruvic acid, or acetone. People with impaired liver or kidney functioning are at a higher risk for developing PG toxidrome following high inhalation doses (Bjur et al., 2017; NASEM, 2018).

The other main solvent in e-liquid mixtures, glycerol, can also be found in food,

nutritional supplements, pharmaceutical products, and oral care products (NASEM, 2018). When glycerol is used at unspecified doses or as a drug, reported adverse effects include mild headaches, dizziness, nausea, vomiting, thirst, and diarrhea. Most of orally administered glycerol is metabolized in about 2.5 hours, with 7% to 14% of eliminated glycerol remaining in urine (NASEM, 2018). There have not been reported glycerol inhalation studies among human samples. In addition to PG and glycerol, ethylene glycol has been identified as another solvent used in e-liquids. Ethylene glycol is commonly used as an industrial solvent, as antifreeze in cooling/heating systems, and in hydraulic brake fluids (NASEM, 2018). While most e-liquid's do not contain this solvent, some ENDS devices do. This is a significant concern as inhalation of ethylene glycol is known to lead to severe eye and respiratory tract infection (Agency for Toxic Substances and Disease Registry [ATSDR], 2010; NIOSH, 2011) and is associated with distinct toxic hazards compared to PG and glycerol (Gomes et al., 2002).

Each ENDS device also creates harmful carbonyl compounds through their heating mechanisms (Jensen et al., 2015; NASEM, 2018). Most ENDS products create temperatures within the range of 150°–350°C from their heating mechanisms and some devices allow users to change the output voltage of their battery to increase aerosol production and thus nicotine delivery. This results in higher heating temperatures of the e-liquid mixtures. The increased battery output voltage has further been reported to affect the quantity of carbonyls created. For example, Kosmider and colleagues (2014) studied the results of altering the voltages in various ENDS devices. The researchers showed that simply increasing the voltage from 3.2 V to 4.8 V resulted in an increase of more than 200 times the levels of formaldehyde, acetaldehyde, and acetone in the aerosolized

vapors (Kosmider et al., 2014). The levels of formaldehyde generated from the high voltage devices were practically identical to those found in combustible cigarette smoke (Kosmider et al., 2014). Other studies have confirmed these results leading to the conclusion that as heating temperatures rise in an ENDS device, so too the levels of formaldehyde will rise, and in a particularly steep manner (Bekki et al., 2014; Flora et al., 2017; Geiss et al., 2016; Jensen et al., 2015).

Even without modification of an ENDS output voltage and controlling for temperatures, the inherent interaction between common solvents found in the e-liquids (PG and glycerol) produce these toxic byproducts (Jenson et al.; 2017; Salamanca et al., 2017). Several harmful compounds are produced even in the absence of nicotine and flavor additives to the e-liquid mixtures (NASEM, 2018). Wang and colleagues (2017) studied this by controlling temperatures and ensuring e-liquid mixtures only contained PG and glycerol but did not contain nicotine and flavorings. The authors detected significant amounts of formaldehyde and acetaldehyde in the vapors, only liquids containing glycerol produced acrolein (Wang et al., 2017). Independent of temperature and complexity of e-liquid mixtures, when e-liquids are heated and aerosolized, they can generate chemical reactions that form harmful carbonyl compounds, which have toxic effects on human health (NASEM, 2018). Therefore, the perceived benefit of using ENDS as a ‘healthier alternative’ appears unsubstantiated.

In addition to the health risks found with the solvents in e-liquid mixtures, there remains notable health risks that exist from nicotine intake, a risk that similarly presents with combustible cigarettes (NASEM, 2018). Nicotine may increase insulin resistance and increase susceptibility to Type 2 Diabetes (USDHHS, 2010). Nicotine can also

damage the cardiovascular system by creating endothelial dysfunction (Bhatnagar, 2016) and affects the endocrine system, particularly contributing to pathogenesis of various endocrine diseases (Tweed et al., 2012). Nicotine also increases blood pressure, constricting coronary blood vessels and promoting acute ischemic events in people who have coronary artery disease (Balakumar & Kaur, 2009; Lippi et al., 2014; Putz-hammer et al., 2016; Sajja, et al., 2015). In addition, some e-liquids may contain concentrations of nicotine large enough to cause seizures, anoxic brain injury, vomiting, and lactic acidosis when inhaled (NASEM, 2018). In fact, calls to poison control centers that involved individuals suffering potentially fatal poisonings of e-liquids increased from an average of 1 call per month in 2010 to an average of over 200 calls per month in 2014 (Chatham-Stephens et al., 2014).

In a meta-analytic publication of 90 peer-reviewed articles analyzing physiological effects of nicotine on human organ systems, Mishra and colleagues (2015) reported that nicotine contributed to several health hazards such as increased risk of cardiovascular, respiratory, and gastrointestinal disorders. Other notable findings included a decreased immune response and negative impacts on reproductive health. Nicotine was also shown to negatively affect cell proliferation, contributing to oxidative stress, apoptosis, and DNA mutation. Significant associations found between nicotine and cancer were also reported and included tumor proliferation, metastasis, and resistance to chemotherapy (Mishra et al., 2015).

Various studies on the inherent toxicity of e-cigarettes have been reported and analyzed and numerous significant findings have emerged. Several hazardous compounds have been found in e-liquids and in the heated aerosol produced by e-cigarettes, including

formaldehyde, acetaldehyde, and acrolein, which are known carcinogenic toxins (NASEM, 2018). The added flavorings that are considered safe for use in food, have not been extensively tested for sensitizing, toxic, or irritating potency though inhalation. There is also evidence that e-cigarettes emit fine particles at high doses that seep into the human respiratory system when PG and glycerol are aerosolized. Given all the considered research, there is substantial evidence that in addition to nicotine, most e-cigarette products contain and produce numerous potentially toxic substances. Other than nicotine, the characteristics of potentially toxic substances emitted from e-cigarettes are highly variable and depend on each ENDS device and how the device is operated by the individual user (NASEM, 2018).

In a review of overall health information linked to vaping, Dr. M.J. Blaha (2021) stated that while vaping may be less harmful in certain circumstances than smoking, it is still not safe. As of February 2020, the CDC reported a total of 2,807 hospitalizations and confirmed 68 deaths due to a national outbreak of E-cigarette or Vaping product use Associated Lung Injury (EVALI). More than just harm to the lungs, growing evidence supports that e-cigarette carry many other health risks including increased likelihood of having a heart attack and cardiovascular disease. Moreover, having Coronavirus Disease 2019 (COVID-19) and being a vaper significantly increased individuals' health risks and complications from the virus, making recovery longer and more intensive for these patients. E-cigarettes can also be just as addictive as traditional cigarettes because of the nicotine content. Users may receive more nicotine than they would have received from a tobacco product if using higher potency cartridges or if the user increases the voltage in their personal ENDS device. Despite being marketed and perceived to be a smoking

cessation aid by many companies, it lacks approval/endorsement from the FDA, CDC, and USDHHS as a smoking cessation tool. Most alarmingly, e-cigarette use is gaining more popularity among those who have never smoked traditional cigarettes (Blaha, 2021). What is concerning here is that individuals who would have never used nicotine products are now initiating this new habit due to the appeal and perceived positive experience associated with using e-cigarettes. This new habit might lead to nicotine addiction and initiation into traditional dual use of smoking products in the future.

E-cigarette flavors also play a role in vaping initiation. In a study conducted by Landry and colleague (2019), most participants reported beginning to use e-cigarettes due to the appeal of various flavors, when otherwise they would not be interested in smoking. The authors analyzed a sample of 1,492 adults, current e-cigarette users drawn from an online quantitative survey. Most e-cigarette users used flavors other than tobacco. Notably, flavors were a common reason for initiating e-cigarette use. Particularly the fruit flavors were more likely to influence young adults (18 to 24 years) to initiate vaping compared to older adults. Those who used flavors also demonstrated higher odds of reporting a high satisfaction from vaping and had higher odds of perceived addiction to vaping than the participants who do not use flavors in their e-cigarettes (Landry et al., 2019). Increases in dual using (use of traditional cigarettes and e-cigarettes) suggested that e-cigarettes are not merely substituting for cigarettes anymore, e-cigarettes are now occurring in individuals who would not otherwise have tried any tobacco product (Barrington-Trimis et al. 2016).

In a meta-analytic review comprised of close to 7,000 studies including over 17,000 adolescents and young adults, Soneji and colleagues (2017), found that

individuals using e-cigarettes at baseline measurements were significantly more likely to initiate use of combustible cigarettes (8%-40%) than individuals not using e-cigarettes at baseline (3%-10%). Specifically, the probability of initiating tobacco cigarette smoking was 23% for baseline ever e-cigarette users compared to the 7% for baseline never e-cigarette users. Similar discrepant probabilities for initiating tobacco cigarette smoking were found between baseline 30-day e-cigarette users and baseline non-users. Overall, results indicated that e-cigarette use was associated with a greater risk for initiating tobacco cigarette smoking later in life (Soneji et al., 2017). This demonstrated a bi-directional influence, in that combustible cigarette smokers will later initiate e-cigarette use and e-cigarette users will later initiate combustible cigarette smoking.

These findings were supported in various other studies. In a longitudinal study following high school students in the UK, Best and colleagues (2017) examined the likelihood of an individual initiating cigarette smoking if they had ever tried an e-cigarette. Results indicated that individuals were more likely to experiment with combustible cigarettes if they had even tried vaping once before. Similar results were reported in another UK study (Conner et al., 2017); findings revealed that ever having used an e-cigarette was robustly associated with initiating cigarette smoking later in life. In another study comprised of 2,558 young adult students in college, Loukas and colleagues (2018) evaluated whether e-cigarette use predicted initiation of cigarette smoking. Findings demonstrated that e-cigarette use in this population was a prominent risk factor for later initiation of cigarette smoking (Loukas et al., 2018). Another longitudinal study showed that dual users were more likely to increase their level of smoking cigarettes compared to those who used fewer e-cigarettes (Doran et al., 2017).

Specifically, occasional cigarette smokers who reported more frequent use of e-cigarettes in their baseline measurements later reported greater increases in cigarette quantity over a 12-month period than cigarette only smokers (Doran et al., 2017). These findings suggest that not only does e-cigarette use potentially lead to cigarette smoking, but it also increases the quantity and frequency of cigarette smoking when dual using.

Respiratory/Pulmonary Health

Before discussing the smoking/vaping health effects on the respiratory system, brief information regarding respiratory health is provided. The World Health Organization (WHO) created the Global Alliance Against Respiratory Diseases (GARD) in 2006 with the purpose of combining knowledge from national and international organizations, institutions, and agencies to address the worldwide health burden which results from chronic and acute respiratory diseases. The Forum of International Respiratory Societies (FIRS, 2017) adopted this challenge and produced an extensive report on lung diseases, environmental precursors, prevalence rates, and other important factors related to respiratory diseases found worldwide. Some of the most common respiratory diseases reported across the globe included the following: acute lower respiratory tract infections, asthma, chronic obstructive pulmonary disease (COPD), lung cancer, occupational lung diseases, pulmonary hypertension, sleep-apnea, and tuberculosis (TB) (FIRS, 2017).

The following are reported prevalence rates for the most common respiratory diseases. An estimated 65 million people have moderate to severe COPD, from which about 3 million die each year, making it the third leading cause of death worldwide

(FIRS, 2017). COPD rates average from 5-7% found among the U.S. adult population according to the National Health Interview Survey (NHIS, 2019) and the Behavioral Risk Factor Surveillance System (BRFSS, 2019). About 334 million people suffer from asthma, which is the most common chronic disease of childhood, affecting 14% of children globally (FIRS, 2017). In the U.S., the rates of ever having asthma were reported at 13.4% and rates of current asthma were recorded as 7.7% (NHIS, 2019). Additionally, African Americans and Puerto Ricans are at a higher risk of developing asthma than people of other races or ethnicities (National Institutes of Health [NIH]-National Heart, Lung, and Blood Institute [NHLBI], 2020). African American and Hispanic children are also more likely to die from asthma-related causes than non-Hispanic white Americans (NIH-NHLBI, 2020). Among children, more boys than girls have asthma; however, in teens/adult populations, asthma is more common among women than men (NIH-NHLBI, 2020).

When any of the functions involved with the respiratory system are not working properly – due to damage, infection, or inflammation – respiratory illness or disease may develop (NIH-NHLBI, 2020). Respiratory diseases are defined as "diseases of the airways and other structures of the lung" by the World Health Organization (2021). There are several terms in the literature used to described respiratory illnesses such as thoracic disease, pulmonary disorder, lung disease, respiratory illness, lung illness, and so on. For this review, any chronic or acute disorder, illness, or disease associated with the respiratory, pulmonary, or lung system will be included in the discussion on respiratory disease.

According to the American Lung Association (ALA, 2021), key symptoms which

demonstrate the presence of a respiratory illness include chronic cough, shortness of breath, phlegm production, wheezing, coughing up blood, or chest pain/tightness. These symptoms occur in over 50 pulmonary diseases, such as acute respiratory distress syndrome (ARDS), asthma, bronchiectasis, bronchiolitis obliterans, chronic obstructive pulmonary disease (COPD) including emphysema or chronic bronchitis, cystic fibrosis, diffuse panbronchiolitis, interstitial lung disease, lung cancer, sleep apnea, pulmonary edema, and tuberculosis (TB), to name a few (ALA, 2021; WHO, 2021).

According to the National Institutes of Health (NIH) U.S. National Library of Medicine (2021), lung diseases can be classified into three main categories: airway disease, lung tissue diseases, and lung circulation disease. Airways diseases affect the tubes in the lungs which carry oxygen into and out of the respiratory system. It involves a narrowing or blockage of the airways and can be seen in asthma, COPD, and bronchiectasis. Individuals with these diseases often report sensations of limited breathing capability (i.e., trying to breathe out of a straw). Lung tissue diseases affect the structures of the lung tissue. Particularly, scarring or inflammation of the lung tissue prevents the lungs from fully expanding, making it harder for the lungs to take in oxygen and release carbon dioxide. As a result, individuals with this condition cannot breathe deeply and may often report chest tightness. This is frequently seen in pulmonary fibrosis, sarcoidosis, and interstitial lung diseases. Finally, lung circulation diseases affect the blood vessels (capillaries) in the lungs and are caused by clotting, scarring, or inflammation of the blood vessels. This affects the lungs' ability to take in oxygen and release carbon dioxide and can also affect heart functioning. A primary example of this disease is pulmonary hypertension; people with this condition often feel very short of

breath when exerting themselves. Many lung diseases incorporate a combination of the above-mentioned factors (NIH-U.S. National Library of Medicine, 2021).

Another primary method of identifying a lung disease is by conducting Pulmonary Function Tests (PFTs), as reported by John Hopkins Medicine (2021) and the American Lung Association (ALA, 2020). These tests measure how well someone's lungs are functioning by defining lung volume, capacity, rates of flow, and gas exchange. The resulting information from PFTs aid healthcare providers in diagnosing and treating various respiratory illnesses. PFTs results reveal two types of disorders in the lung: obstructive or restrictive. Obstructive lung disorders are categorized by a reduction in airflow where air remains inside of the lungs after full exhalation due to airway resistance; this is common in COPD, asthma, bronchiectasis, and cystic fibrosis. Restrictive lung disorders are characterized by a reduction in lung volume and difficulty with breathing air into the lungs, most likely due to lung tissue damage and restriction in chest muscle expansions. These issues are common in interstitial lung diseases (ALA, 2020; John Hopkins Medicine, 2021).

Symptom severity from lung disease can be a costly burden on total healthcare spending (FIRS, 2017). The direct cost of COPD is 6% of total healthcare spending (€38.6 billion annually) in the European Union and accounts for 56% of the total cost of treating respiratory diseases. COPD involves persistent respiratory symptoms and airflow limitation due to bronchioles and alveoli abnormalities (Global Initiative for Chronic Obstructive Lung Disease [GOLD], 2021). Chronic inflammation in the lungs, narrowing of the bronchioles, and destruction of parenchyma (lung tissue) contribute to the loss in alveoli functioning and decreases the lung elasticity in COPD. These changes diminish

the ability of the airways to remain open during exhalation, retaining harmful carbon dioxide within the lungs. Abnormalities in the bronchioles may also contribute to mucociliary dysfunction, preventing the activity in the mucociliary escalator from removing inhaled toxic particles. Along with air pollution and inhaled tobacco smoke, genetic syndromes (such as alpha-1 antitrypsin deficiency), childhood pneumonia, and other diseases that impact the airways (such as chronic asthma and TB) are all risk factors for the development of COPD (GOLD, 2021).

After encouraging smoking cessation, treatment for COPD typically involves immediate and long-term relief of respiratory symptoms, slowing the disease progression, improving exercise tolerance/ability to stay active, preventing medical complications, and improving overall health status (FIRS, 2017; GOLD, 2021; NIH-NHLBI, 2020). Bronchodilators, commonly known as *inhalers*, relax the muscles around the airways. Together with inhaled corticosteroids and other pharmacological interventions, these devices help to relieve and prevent exacerbations of severe airflow obstruction. Furthermore, patients with chronic low blood oxygen levels may require oxygen therapy, which can increase survival rates and improve quality of life. Maintaining physical activity is also highly important because difficulty breathing may lead to decreased activity level and subsequent lung deconditioning. Thus, exercise based pulmonary rehabilitation is another treatment option for individuals with COPD (FIRS, 2017; GOLD, 2021).

Another common respiratory illness is asthma which is a lifelong, uncurable disease. However, treatment with asthma medication can be effective in regulating symptoms (FIRS, 2017). Asthma accounts for frequent preventable hospital visits,

particularly among pediatric populations (FIRS, 2017). Notably, recent data indicates that young children with asthma may develop abnormal lung growth and are therefore at risk for developing lifelong respiratory conditions such as COPD in adulthood, especially with increased health risk factors such as poor lifestyle choices (i.e., smoking) (FIRS, 2017). Asthma is characterized by airway obstructions due to inflammation and narrowing of the bronchioles (NIH-NHLBI, 2020; NIH-U.S. National Library of Medicine, 2021). Asthma affects individuals across all ages although the onset usually begins in childhood. Typical symptoms associated with asthma include wheezing, coughing, chest tightness, and shortness of breath. Symptom severity varies by individual and how often someone is exposed to asthma triggers. Some individuals may experience these symptoms frequently throughout the day with great difficulty, while other individuals may experience these symptoms only a couple of times a year with very minimal difficulty. Asthma symptoms may cause discomfort, functional difficulties, and interfere with daily activities. Overtime, uncontrolled asthma can lead to permanent tissue damage in the bronchioles (NIH-NHLBI, 2020; NIH-U.S. National Library of Medicine, 2021).

Triggers to worsening asthma symptoms vary by person but usually involve tobacco smoke, exercise, allergies, cold air, or hyperventilation from laughing or crying (FIRS, 2017; NIH-NHLBI, 2020; NIH-U.S. National Library of Medicine, 2021). Other asthma triggers include dust mites, outdoor air pollution, pests such as cockroaches or mice, animal dander, and cleaning products (CDC, Common Asthma Triggers, 2020). Additionally, asthma symptoms worsen with infections and are more severe in different times of the day (i.e., early morning and late evening). Asthma attacks, or exacerbations,

involve episodes of severe worsening of asthma symptoms. Asthma exacerbations require immediate rescue inhaler treatment and may require emergency care, as attacks can be life-threatening if untreated (NIH-NHLBI, 2020; NIH-U.S. National Library of Medicine, 2021).

Moving on to other respiratory illnesses, acute lower respiratory tract infections have been among the top three causes of death and disability amongst both children and adults for many decades (FIRS, 2017). Acute lower respiratory tract infections include pneumonia, acute bronchitis, bronchiolitis, influenza, and whooping cough. Acute lower respiratory tract infections in childhood increase the likelihood for the development of chronic respiratory diseases later in life. Respiratory tract infections caused by influenza kill between 250,000 and 500,000 people worldwide and cost between 71 and 167 billion U.S. dollars annually. These infections are particularly prevalent in low- and middle-income countries and kill more people worldwide than human immunodeficiency virus (HIV), TB, and malaria combined. Risk factors for pneumonia include being very young or elderly, crowded living conditions, malnutrition, HIV infection, lack of breastfeeding in infants, lack of immunization, chronic health conditions, and exposure to tobacco smoke or indoor air pollutants (FIRS, 2017).

Interstitial lung disease (ILD) encompasses various pulmonary disorders related to scarred lung tissue, particularly in the lung interstitium. The interstitium is the space where alveoli contact the connective tissue throughout the lungs to exchange oxygen and carbon dioxide (NIH-NBHLI, n.d.). In ILD, the interstitial tissue becomes thick and stiffens, making it harder for oxygen to move out of the lungs and into the bloodstream and equally difficult for carbon dioxide to move out of the bloodstream and into the lungs

to be exhaled. The causes for ILD include genetics factors, certain medications such as chemotherapy drugs, heart medications, and anti-inflammatory drugs, or other medical conditions such as sarcoidosis and autoimmune disorders. Exposures to toxic substances in the environment also contribute to the development of ILD, particularly with asbestos-related lung diseases and hypersensitivity pneumonitis. For some ILDs, such as idiopathic pulmonary fibrosis, the cause of the interstitium scarring is unknown. Typical symptoms include dry cough, shortness of breath, chest discomfort, and fatigue. ILDs are either mild or severe, with the amount of scarring progressively getting worse with time. Treatment usually involves avoiding environmental triggers and managing symptoms with medicines/inhalers, pulmonary rehabilitation, oxygen therapy, or a lung transplant. Untreated ILD can lead to further medical complications such as venous thromboembolism (VTE), lung cancer, pulmonary hypertension, heart failure, and respiratory failure (NIH-NBHLI, n.d.).

Sung and colleagues (2021), examined the cancer burden worldwide based on global estimates of cancer incidence and mortality produced by the International Agency for Research on Cancer. Of the major cancers, lung cancer was the most fatal cancer worldwide. After tobacco smoking, other risk factors for the development of lung cancer included exposure to secondhand smoke, biomass fuel, diesel exhaust, radon, asbestos, and other environmental and workplace carcinogens (FIRS, 2017). Lung cancer treatment varies by stage; early-stage lung cancer is treated with surgery or radiation therapy. Advanced stage lung cancer is not curable, many patients however may experience symptom relief via new forms of treatment. These include molecular targeted therapy against Epidermal Growth Factor Receptor (EGFR) mutations and Anaplastic Lymphoma

Kinase (ALK) re-arrangements, which have reached tumor response rates of around 70%. However, cost may be a major barrier preventing patients from obtaining these forms of treatments (FIRS, 2017).

Respiratory illnesses can affect individuals when asleep as well, particularly with sleep apnea, which involves breathing interruptions while sleeping (Mayo Clinic, 2020). There are three main types of sleep apnea: obstructive, central, and mixed. Obstructive sleep apnea is the most common type and occurs when throat muscles relax, the airways narrow or completely close when breathing in. This results in an inability to get enough air into the lungs which then lowers the oxygen level in the bloodstream. The brain senses the inability to breathe and signals the individual to awaken and resume breathing. At this point an individual might snort, choke, or gasp as they awake, take a breath, and return to sleep. These awakenings are quite brief, and individuals might not recall them. This pattern repeats five to thirty times or more each hour, all night, impairing the ability to reach the deep and restorative phases of sleep. Central sleep apnea occurs when the brain does not send proper signals to the muscles around the lungs to regulate breathing. Individuals with this type usually awaken with shortness of breath or have difficulty getting to sleep and staying asleep. Mixed type occurs when both obstructive sleep apnea and central sleep apnea are present. Symptoms for all three categories overlap and can include loud snoring, brief periods without breathing, gasping for air during sleep, awakening with a dry mouth, morning headaches, insomnia/hypersomnia, difficulty paying attention while awake, and irritability. Risk factors include smoking, excess weight, larger neck circumference, narrow lung airways, alcohol abuse, nasal congestion, and medical conditions such as congestive heart failure, hypertension, type 2 diabetes,

asthma, and Parkinson's disease. Treatment can involve a variety of interventions including adopting a healthier lifestyle (e.g., smoking cessation, losing weight, eating healthier, etc.), utilizing a continuous positive airway pressure (CPAP) machine, or using different mouthpieces and implants to help with breathing at night. For severe cases of sleep apnea, surgical procedures such as a tonsillectomy, maxillary (jaw advancement surgery), or tracheostomy may be considered (NIH-NHLBI, n.d.).

Health Risk Factors Associated with Respiratory Illnesses

The respiratory system ensures daily survival via oxygen intake and carbon dioxide exhalation (gas exchange process in the lungs). Human lungs are exposed to environmental particles and potentially dangerous organisms in the air constantly. As a result, individuals with compromised respiratory systems are at a higher risk for the development of other health conditions, functional difficulties, and higher levels of stress. Cigarette smoking or e-cigarette use may exacerbate the already elevated health risks for this medically compromised population. Due to these vulnerabilities, it is important to evaluate specific health risk factors associated with having a respiratory illness.

Lifestyle impairments from respiratory diseases can be quite severe. Respiratory diseases account for more than 10% of all disability adjusted life years, a measure that estimates the amount of active and productive life lost due to a medical condition (FIRS, 2017). The prevalence of adults with current asthma in the U.S. who also have disability status is 16.5% and 18.7% for those with COPD, compared to 9.2% of the general population, adults aged 18 and over (NCHS, 2019). The National Center for Health Statistics (NCHS, 2019) defines disability status as having considerable difficulty in at

least one of the six functional domains listed: seeing, hearing, mobility, communication, cognition, and self-care. This is notable as those who manage a chronic disease and have low functional capacity are more likely to develop stress and depression, especially as the number of medical conditions increase (Swartz & Jantz 2014; Vancampfort et al., 2017). Furthermore, for those with a chronic medical condition, like a respiratory disease, stress can intensify symptoms by increasing the frequency and severity of respiratory symptoms, and by decreasing overall level of functioning (Prior et al. 2016; Vancampfort et al, 2017). Particularly, high levels of psychological distress can also contribute to worsening progression of chronic medical conditions (Prior et al., 2016; Russ et al., 2012; Vancampfort et al., 2017).

Living with a chronic medical condition like asthma or COPD affects the overall quality of one's life via lowered functioning ability. In one study by Strine and colleagues (2008), researchers found that U.S. adults with chronic illnesses were significantly more likely than those without chronic conditions to report life dissatisfaction due to functional limitations. In addition, adverse health behaviors (such as smoking and physical inactivity) contributed to poorer health-related quality of life (Strine et al., 2008). In another study by Samiei-Siboni and colleagues (2019), the lowest reported level of functioning and quality of life scores came from participants who had respiratory diseases (i.e., asthma and COPD). Furthermore, those with respiratory diseases who smoked had greater functional difficulties than those who do not have a respiratory disease and smoked (Sales et al., 2019). In comparison to smokers with no history of a respiratory disease, smokers with an active respiratory disease had additional difficulties with smoking cessation due to higher levels of nicotine dependence and withdrawal, higher

levels of exhaled carbon monoxide, low motivation and low self-efficacy, and a higher prevalence of anxiety and depression. It is unclear why smokers with an active respiratory disease experienced more difficulties with smoking cessation, however, it is likely that this may be due to the complications of simultaneously managing chronic health conditions. Individuals who had a respiratory disease and smoked also required smoking cessation treatment that involved multidisciplinary intervention and was more intensive/prolonged than the treatments for smokers without a respiratory illness (Sales et al. 2019).

Respiratory symptoms can present differently for each patient and for each specific disease. However, what remains consistent is that with increase in respiratory symptoms and symptom severity, poorer health outcomes are present (Doyle et al., 2013; GOLD, 2021; Miravitlles et al., 2007; Monteagudo et al., 2013; Price et al., 2013; Roche et al., 2013; Tsiligianni et al., 2011). Using the PERCEIVE study (perception of exacerbations of chronic obstructive pulmonary disease) involving random sampling from participants across 6 countries (Germany, France, Italy, Spain, the UK, and the USA), Miravitlles and colleagues (2007) conducted a survey with 1,100 individuals. Notable results included the impact COPD had on a patient's daily-life activities; many participants reported that they could not complete activities they enjoyed due to their COPD symptoms. The second most endorsed functional difficulty reported by participants was sleep disturbances due to their COPD symptoms. A relationship was found between increased symptom severity and difficulty with completing daily functional activities. As the number of respiratory symptom exacerbations and hospital/emergency visits increased, the higher the likelihood that an individual endorsed

that COPD negatively impacted their daily-life activities and overall wellbeing. This was the case as many would have to remain in bed resting or lay down during severe symptom episodes to recover.

Symptom exacerbations also had a strong impact on mood, with many individuals reported feeling frightened or scared and others feeling frustrated and depressed with their physical limitations from increased symptoms. In terms of other notable perceptions endorsed, 17% of participants responded that they were afraid their COPD would cripple them or eventually kill them. Individuals with more negative perceptions related to their COPD were older, had a longer duration of the disease, more severe symptomology, more co-morbidities, and a greater proportion of former smokers. In contrast, 34% responded that their COPD was mainly a nuisance but not too serious. This group consisted of individuals who were significantly younger, had shorter duration of the disease, less severe symptomology, fewer co-morbidities, and a greater proportion of active smokers (Miravitlles et al., 2007).

In a study involving 791 patients with COPD in a primary care clinic, Monteagudo and colleagues (2013) analyzed various factors associated with changes in patients' health-related quality of life. Health-related quality of life was measured at baseline and then at a one-year follow-up visit using the Saint George's Respiratory Questionnaire (SGRQ). Patients with declining scores on their follow-up measure had notably worsened symptoms, including significant increase in coughing and expectoration, and a significant increase in hospital admissions and rehabilitation visits compared to patients whose follow-up scores improved. Among those patients who had improved follow-up health-related quality of life scores, a significant proportion included

former smokers. Factors that were independently and significantly associated with improved follow-up scores included initiation of pulmonology visits, poly-medication, a balanced diet, improved respiratory symptoms, ending rehabilitation, and quitting smoking (Monteagudo et al., 2013).

Price and colleagues (2013) evaluated nocturnal symptom severity and daily functioning level for 2,807 patients with COPD. Outcomes revealed that patients who experienced sleep disturbances due to respiratory symptom exacerbations in the evenings, experienced more respiratory symptoms throughout the daytime and more exacerbations in a 12-month period than those who typically did not experience symptoms throughout the evening. Furthermore, for the patients with increased nocturnal symptoms, they were more likely to have problems in other areas such as daytime breathlessness, frequent exacerbations, functional difficulties with "getting started in the morning," poorer sleep quality, and a poorer quality of life (Price et al., 2013).

In a randomized control trial involving 162 patients with COPD, Doyle and colleagues (2013) examined associations between mental health symptoms and pulmonary-specific symptoms. Results indicated that anxiety and depression were associated with higher levels of fatigue and shortness of breath, and with frequency of respiratory symptoms. In addition, functional capacity was a moderator of anxiety and pulmonary-specific COPD symptoms. The association between anxiety and shortness of breath and the frequency of COPD symptoms was greatest among patients with lower functional capacity (Doyle et al., 2013). Patients with respiratory diseases, particularly COPD and asthma, experienced significantly more stress and psychological issues, such as anxiety and depression, than the general population (Doyle et al., 2013; Miravitlles &

Ribera, 2017; Wagena et al., 2005). Severity of respiratory symptoms and resulting limited level of functioning might be the main contributing factors for this stress (Miravitlles et al., 2007; Miravitlles & Ribera, 2017; Wagena et al., 2005).

Tsiligianni and colleagues (2011) conducted a meta-analytic review on the different factors which affect the health status of individuals with COPD. Notable findings included smoking status whereby current smoking and exposure to secondhand smoke was reported to be associated with poorer health status in patients with COPD. Most published studies suggested that health status was significantly associated with symptom presentation (severity and frequency), especially as the disease progressed to the more severe stages. In fact, one of the most central symptoms in COPD, dyspnea, was found to be significantly negatively associated with health status and had the highest correlations with various health status questionnaires among all other factors. Other typical symptoms, such as sputum production, chronic cough, wheezing, and fatigue, were also negatively associated with health status among patients with COPD. Co-morbidity also had strong associations with negative health status, particularly involving co-morbid heart disease, hypertension, locomotive disorders, diabetes, sleep disturbances, depression, and anxiety. Finally, patient's perception of their illness and overall health was a factor significantly associated with quality of life across many studies (Tsiligianni et al., 2011).

In a review of the biomedical literature describing reported relationships between COPD symptoms and disease burden, Miravitlles and Ribera (2017) identified various factors negatively impacted by COPD. These factors included quality of life, perceived health status, daily activities, physical activity, sleep, comorbid anxiety/depression, as

well as disease prognosis. Overall health status was reported to be significantly lower in patients who experienced more COPD symptoms throughout the day compared to those who experienced no COPD symptoms or less severe symptomology. COPD symptoms progressively compromised a patient's ability to function normally in terms of their day-to-day activities and severely impaired sleep quality when symptoms presented at night (Miravitlles & Ribera, 2017).

Impact of Smoking and Vaping on Respiratory/Pulmonary Health

Health risk factors associated with respiratory illnesses have been described above. How does smoking and vaping impact these health risk factors and ultimately one's respiratory health? Nicotine exposure (from both cigarettes and e-cigarettes) affects pulmonary symptoms and plays a significant role in the development of several respiratory/pulmonary diseases (Grando, 2014; Martin et al., 2016; Mishra et al., 2015; Rowell & Tarran, 2015). E-cigarettes have been reported to negatively affect cardiovascular and pulmonary functioning (Bold et al., 2018). Exposure to nicotine through smoking or vaping is an automatic irritant to lung tissue (Mishra et al., 2015). Nicotine plays a role in the development of emphysema in smokers, by decreasing elastin in the lung parenchyma and increasing the alveolar volume. Nicotine stimulates vagal reflex and parasympathetic ganglia and causes an increased airway resistance by causing bronchoconstriction. Nicotine also transforms respiration through its effects on the CNS. The simultaneous effect of bronchoconstriction and apnea increases the tracheal tension and causes several pulmonary disorders (Mishra et al., 2015). In a study conducted by Jaiswal and colleagues (2013), researchers microinjected nicotine to the preBotzinger

complex and adjacent nuclei in the brain. The firing pattern of the brain signals and breathing pattern were then monitored. Results demonstrated a shallow and rapid rhythm of respiration, indicating strained breathing similar to what is observed with nicotine exposure (Jaiswal et al., 2013).

One of the most common diseases resulting from long-term cigarette smoking is COPD (FIRS, 2017; GOLD, 2021). Outdoor, indoor, and occupational air contamination are major risk factors for the development of COPD. However, the leading contributing risk factor for the development of COPD is smoking (FIRS, 2017; GOLD, 2021; NIH-NHLBI, 2020; NIH-U.S. National Library of Medicine, 2021; WHO, 2021). Up to 75% of individuals who have COPD currently smoke or previously smoked. Tobacco smoke causes destruction of lung tissue (emphysema) and obstruction of the small airways with inflammation and mucus (chronic bronchitis), leading to the development of the main symptoms of COPD – dyspnea (shortness of breath), frequent coughing, wheezing, chest tightness, and sputum production (coughing out phlegm from the respiratory tract). The primary means of prevention for COPD involves complete smoking cessation. After diagnosis, it is imperative that healthcare providers deliver effective FDA-approved smoking cessation interventions (behavioral counseling and pharmacotherapy) to patients and encourage them to quit since symptom severity and disease progression are highly correlated with continued tobacco use (FIRS, 2017; GOLD, 2021).

Another disease associated with tobacco smoking and inhalation of secondhand tobacco smoke is asthma. In a meta-analytic review, Wang and colleagues (2015) reported that children with asthma had worse symptom severity when exposed to secondhand smoke exposure. Specifically, these children were twice as likely to have

been hospitalized than children with asthma who are not exposed to secondhand smoke. Having been exposed to secondhand smoke was also significantly associated with emergency department or urgent care visits, wheezing symptoms, and lower PFT results (Wang et al., 2015). Many other studies have linked secondhand smoke exposure to increased asthma rates, symptom severity, and worsening lung functioning (Awasthi et al. 2012; CDC-pulmonary diseases, 2010; Kanchongkittiphon et al., 2014; Quinto 2013; Schlueter et al., 2011; Van Den Bosch et al., 2012). Despite the lack of exact preventive measures for the development of asthma, there are still vital ways to slow down the progression of debilitating lung function such as reducing cigarette smoking or exposure to secondhand tobacco smoke (FIRS, 2017). Moreover, those with asthma who smoke have significantly more impaired lung functioning than those with asthma who do not smoke (FIRS, 2017; NIH-NHLBI, 2020; NIH-U.S. National Library of Medicine, 2021).

Of the major cancers, lung cancer has been the most diagnosed cancer over the past decades and remains the leading cause of cancer-related death (Sung et al. 2021). Tobacco smoke contributes to more than two-thirds of the cases of lung cancer by damaging DNA and mutating genes in the lung cells (FIRS, 2017). The more years an individual smokes, the higher the risk of developing lung cancer, as it takes time for the DNA-damaged genes to accumulate and create progressive damage. Therefore, even former smokers are at risk for developing lung cancer if they have smoked for many years prior. The simplest and most effective preventative measure of lung cancer is through tobacco control (FIRS, 2017; Sung et al., 2021).

The impact of tobacco smoking on other respiratory conditions is extensive. Cigarette smoking increases the likelihood of developing Interstitial Lung Disease (ILD)

in addition to making the condition worse if smoking is continued once diagnosed (FIRS, 2017). People who smoke cigarettes are three times more likely to have obstructive sleep apnea than those who have never smoked (Mayo Clinic, 2020). Individuals with chronic bronchitis who smoke, worsen lung functioning by deregulating the healing process in lung tissue due to continuous damage caused by inhalation of tobacco smoke (CDC-pulmonary diseases, 2010). A relationship between number of years/packs of cigarettes smoked and severity of emphysema was established in a study evaluating more than 400 lungs removed from patients being treated for lung cancer (Hogg 2004). The more years a patient smoked and the higher number of packs of cigarettes smoked per day, the more severe the pulmonary emphysema was (Hogg 2004).

Many studies report that using e-cigarettes can also damage lung cells and lead to worsening respiratory functioning, contributing to severe respiratory symptoms or even the development of a respiratory illness if not already present (Bhatta & Glantz, 2020; Ghosh et al. 2019; Muthumalage et al., 2019; Xie et al., 2020). A recent study showed that long-term vaping can initiate the same harmful lung changes seen in cigarette smokers (Ghosh et al., 2019). Researchers evaluated bronchoscopies of healthy nonsmokers, cigarette smokers, and e-cigarette users. Results of the comparison showed many similarities between cigarette smokers and e-cigarette users. As with smoking, vaping-induced nicotine dependent protease release from pulmonary immune cells, resulted in disruption of the protease-antiprotease balance by increasing proteolysis (protein breakdown into amino acids) in the lungs. This activity increases the risk of developing chronic lung diseases in comparison to the normal population. Conclusions from the study indicated that e-cigarettes did not appear to have less harmful respiratory

effects than tobacco smoking (Ghosh et al 2019). Furthermore, e-cigarette flavoring pods have been shown to cause significant damage in lung cells and the respiratory system (Muthumalage et al., 2019). Researchers from this study analyzed JUUL and other companies' common pod flavors such as fruit, vanilla, mint, coffee, menthol, etc. with each pod ranging between 5-6% nicotine. Human bronchial epithelial cells were exposed to aerosols of the various pods and then the cells were measured for dysfunction and/or potential damage. Results showed that the substances in flavored pods stimulate oxidative stress, inflammation, epithelial barrier dysfunction, and DNA damage in the lung cells (Muthumalage et al., 2019).

In another recent study, researchers reported associations between e-cigarette use and increased risk for respiratory disease (Xie et al., 2020). Over 20,000 individuals were included in this sample from the Population Assessment of Tobacco and Health (PATH) study. Adjustments were made to control for other variables such as combustible tobacco product use, demographic characteristics, and other chronic health conditions. Results indicated that among former and current e-cigarette users, there was an increased risk of developing respiratory diseases such as asthma, chronic bronchitis, emphysema, and COPD. Another notable result was that those who used e-cigarettes daily and started before the age of 25 had the highest prevalence rates of respiratory disease later in life (Xie et al., 2020).

In a longitudinal analysis of associations between e-cigarette use and respiratory disease, researchers Bhatta and Glantz (2020) found that using e-cigarettes was an independent risk factor for the development of respiratory diseases and later smoking combustible cigarettes. Furthermore, dual use was reported as the most common pattern

and was riskier than sole use of e-cigarettes or smoking cigarette (Bhatta & Glantz, 2020). In studies identifying self-reported negative health symptoms associated with e-cigarette use, the most reported symptoms were those related to what is typically seen in asthma, COPD, pneumonia, and bronchitis (Hua, Alfi, & Talbot, 2013; Hua et al., 2020). Self-reported symptoms included frequent coughing, wheezing, dyspnea, heavy breathing, nasal discharge/congestion, dry cough, and gasping for air (Hua, Alfi, & Talbot, 2013; Hua et al., 2020).

E-cigarettes various flavorings also present several health risks to users when inhaled. Specifically, diacetyl, acetylpropionyl, and acetoin, the major chemicals in e-cigarette products with creamy flavors, were found to be present in more than 90% of tested e-cigarettes available in the U.S. (Allen et al., 2016). These chemicals have been associated with increased incidences of chronic cough, bronchitis, asthma, and bronchiolitis obliterans (Kreiss et al., 2002; NIOSH, 2017). Additionally, cinnamaldehyde (the major chemical in cinnamon and fruit flavors) was found in high concentrations toxic to humans in 50% of e-liquids tested (Behar et al., 2016). Even at low concentrations, cinnamaldehyde can be cytotoxic, genotoxic, and adversely affect cell processes and cell survival (NASEM, 2018).

In addition, harmful carbonyl compounds such as formaldehyde, acetaldehyde, acrolein, and glyoxal are created when e-liquids are heated and aerosolized (NASEM, 2018). Formaldehyde is classified as a human carcinogen by the International Agency for Research on Cancer (IARC) and acetaldehyde is classified as possibly carcinogenic to humans (Bekki et al., 2014; NASEM, 2018). Acrolein causes nasal cavity irritation and damages to the lining of the lungs (ATSDR, 2007). Furthermore, glyoxal and

methylglyoxal show a potential for creating permanent transmissible changes in genetic material of cells (NASEM, 2018). While there is variability in the level of toxicity of each ENDS device due to e-liquid concentrations, puffs inhaled by the user, etc., very high levels of formaldehyde have typically been reported in e-cigarette aerosols almost comparable to levels found in combustible tobacco cigarette smoke (Canistro et al., 2017; Gillman et al., 2016; Kosmider et al., 2014).

EVALI (E-cigarette or Vaping product use Associated Lung Injury) is a term coined by the CDC in response to a multi-state outbreak of severe lung illness associated with using e-cigarettes/vaping products, first identified in the summer of 2019 (CDC-EVALI, 2020). EVALI symptoms can present in otherwise completely healthy individuals and include shortness of breath, dry cough, fever, chills, vomiting, diarrhea, chest pain, headache, dizziness, coughing up blood, weight loss, and fast heartbeat (Awad & Awan, 2020). Because these symptoms can mirror the flu or other respiratory illnesses, diagnosing EVALI can be challenging (Awad & Awan, 2020). As of February 2020, a total of 2,807 EVALI cases and 68 confirmed deaths have been reported in the U.S. (CDC-EVALI, 2020). Despite the steep rise of prevalence in EVALI cases, there has been a gradual decline in deaths since peaking in September 2019. This could be due to increased public awareness of the risk associated with THC-containing e-cigarettes, removal of vitamin E-acetate from products, and/or new law enforcement policies. Notwithstanding the decline in cases, continued use of e-cigarettes still presents a risk factor for the development of EVALI or worse conditions as not enough information is known on the extent of this novel disorder and the potential long term health effects (CDC-EVALI, 2020).

Cigarettes/ENDS Health Perceptions and Influence on Smoking Behaviors

It is known, the harmful effects vaping can have on the respiratory system, especially in those already living with a chronic respiratory condition. Given this reality, how can vaping behaviors be influenced to prevent use and promote healthier behaviors? Evidence suggests that an individuals' values, attitudes, and beliefs can reliably predict their behaviors (Clark et al., 2017; Fishbein & Ajzen, 1975; González-López, & Cuervo-Arango, 2008; Janz & Becker, 1984; Ponizovskiy et al., 2019; Schwartz 1992). Moreover, risk perceptions and perceived self-efficacy are important antecedents to making behavioral changes associated with one's health, as established by the Theory of Planned Behavior (TPB) and the Health Belief Model (HBM) (Ajzenm, 1991; Becker, 1974). According to the TPB, perceived behavioral control, or self-efficacy, together with behavioral intention, can be used directly to predict whether an action will be completed (Ajzenm, 1991). Moreover, the HBM reports that there are key factors influencing health behaviors, such as an individual's perceived threat to illness (i.e., perceived susceptibility), perceived severity of the illness, perceived benefits from taking action, perceived barriers to action, exposure to stimuli that prompt action (i.e., cues to action), and confidence in one's ability to succeed (i.e., self-efficacy) (Becker, 1974; Sheeran & Abraham, 1996; Sutton, 2002). As it relates to vaping behaviors, perceived risks versus perceived benefits of e-cigarette use, have been shown to influence individuals' vaping behaviors. Prevalence rates of ENDS use are higher among those who perceive ENDS as less harmful to their health than combustible cigarettes compared to those who do not hold this perception (Adkison et al., 2013; Choi & Forster, 2013; Cooper et al., 2016; Loukas et al., 2018; Peters et al., 2015). Similarly, individuals who have ever used e-

cigarettes are significantly more likely than those who have never used e-cigarettes to endorse the perception that e-cigarettes should be allowed in public places, presumably due to e-cigarette users' belief that e-cigarettes are not associated with the harmful health effects associated with secondhand cigarette smoke (Peters et al., 2015). In fact, 80% of current e-cigarette users endorsed the perception that e-cigarettes are less harmful to the health of passive bystanders than combustible cigarettes (Foulds et al., 2011). In addition, the perception that e-cigarettes are an effective smoking cessation method is associated with higher rates of e-cigarette use. One of the most cited reasons for e-cigarette use was for smoking cessation, reported by 55-88% of adults in multiple nationally representative samples (Adkison et al., 2013; Rutten et al., 2015; Zhu et al., 2013).

In a study conducted by Popova and colleagues (2018), researchers examined the relationship between affect, perceived risk, and current use for cigarettes versus vaping in a nationally representative sample of 5,398 U.S. adults. Results indicated that negative affect was more highly correlated with cigarettes than with vaping and these associations were mediated by risk perceptions towards smoking and vaping. Moreover, the higher the positive affect associated with vaping, the lower the perceived risk, and the higher the likelihood of being a current vaper. Some methodological limitations of this study, however, involved limited variety in affective cues presented to the participants to illicit emotional reactions and perceptions. Additionally, since this involved a cross sectional survey, all results were correlational and therefore causal inference was limited to the data consistent with the hypothesized mediation model used in the study. The authors have acknowledged that alternative models could have possibly fit the data better (Popova et al. 2018).

Harrell and colleagues (2018) evaluated how flavored vaping preferences among various age groups influenced their vaping behaviors. College students and young adults nationwide reported that their first vaping experience involved a flavor other than tobacco due to the negative health perceptions associated with smoking tobacco. Alternate flavors were an especially motivating reason for high school students to begin vaping. While tobacco flavorings were more preferred among dual users and older adult samples, sweet flavors like fruit and candy dominated preferences for all age groups as they indicated more positive affect from smoking with these fruity flavors. The option to make one's ENDS device taste like something other than tobacco was reported to be a strong motivating factor for individuals to initiate vaping (Harrell et al., 2018).

Other health perceptions that entice users to initiate ENDS use have also been identified. In a cross-sectional study including a sample of 726 adult participants, smoking beliefs of different product users (non-smokers, cigarette smokers, vapers, and dual users) were assessed (Romijnders, Beijaert, Osch, Vries, & Talhout, 2018a). Results indicated that vapers endorsed vaping as less harmful than regular cigarette smoking. Cigarette smokers were significantly more likely to have an intention to start vaping compared to non-smokers. Finally, vapers reported their intention to begin vaping stemmed from perceived safety and perceived social acceptability of vaping among their peers in comparison to cigarette smoking (Romijnders, Beijaert, Osch, Vries, & Talhout, 2018a).

Another study conducted by Chen and colleagues (2016), examined the relationship between risk perceptions and cigarette-smoking behaviors among a nationally representative sample of 1,680 U.S. adults. Findings from this study revealed

that the absolute and relative risk perceptions were significantly correlated with having smoked at least 100 cigarettes in one's lifetime and with the frequency of cigarette smoking. Absolute risk perception was assessed via a question measuring participants' individual belief of developing lung cancer as either 'very low', 'somewhat low', 'moderate', 'somewhat high', or 'very high'. Relative risk perception was assessed via the question: "Compared to the average person your age, would you say that you are more likely, about as likely, or less likely to get lung cancer?" Finally, the frequency of cigarette smoking was measured as 'every day', 'some days', or 'not at all'. Those who responded 'every day' were then asked how many cigarettes they smoked per day on average. Respondents generally had a low absolute risk perception of developing lung cancer; 47% rated their risk as being 'very low' while only 12.1% of respondents rated their risk of getting lung cancer as being 'somewhat high' or 'very high'. Close to 60% of respondents reported that they were less likely to get lung cancer compared to the average person their age, about 30% rated their risk as being similar to that of other people their age, and only 11% of respondents believed their risk of developing lung cancer was higher than others their age (Chen et al., 2016). Although this study evaluated different types of risk perceptions (absolute versus relative), these health perceptions were specifically related to lung cancer. Health perceptions regarding e-cigarette use in relation to lung cancer or other respiratory diseases were not examined. Additionally, health risk factors such as general health status, stress level, and level of functioning were not assessed which could have potentially provided more information on participants' health vulnerability.

In another study evaluating the risk perceptions of lung cancer according to

smoking status, Chen and Kaphingst (2011) revealed that while perceived risk associated with developing lung cancer was higher for never smokers with a family history of lung cancer, it was lower for former and current smokers with a family history of lung cancer. The authors concluded that even when a current or former smoker has a family risk of developing lung cancer, their perceived individual risk was considerably lower compared to those who have never initiated smoking (Chen & Kaphingst, 2011). The finding that those at risk for smoking-related health outcomes continue to smoke may be due to inaccuracies of risk perceptions associated with smoking – when considering one's absolute versus relative risks of smoking (Chen & Kaphingst, 2011; Krosnick et al., 2017).

Current and former smokers may also considerably underestimate their personal health risk associated with smoking to cognitively distance themselves from the possibility of developing negative health consequences from their behaviors (Chen et al., 2016; Chen & Kaphingst, 2011; Krosnick et al., 2017; Weinstein 1998). This may be partially mediated through the mental discomfort associated with cognitive dissonance (Ayanian & Cleary, 1999; Strecher, Kreuter, & Kobrin, 1995; Weinstein 1998). As an attempt to relieve this inconsistency, individuals must distance themselves from the idea that their behaviors are contributing to their negative health outcomes, thus personal risk is perceived to be less intense than the general or absolute risks associated with smoking. When evaluating the absolute risk associated with smoking, individuals are more willing to admit harm from smoking behaviors due to the cognitive distance these questions provide. This may partially account for different outcomes across studies as participants' risk perceptions may depend on the way risk is assessed (i.e., relative, personal, or

absolute risk) (Ayanian & Cleary, 1999; Chen et al., 2016; Chen & Kaphingst, 2011; Hwang et al., 2019; Krosnick et al., 2017; Strecher, Kreuter, & Kobrin, 1995; Weinstein 1998).

Health perception studies among high-risk groups, such as pregnant women, cancer patients, and medically compromised individuals, also indicate strong associations between risk perceptions associated with smoking and smoking behaviors. In a sample of 118 pregnant women (54 smokers, 64 non-smokers), smokers were less likely to endorse that smoking during pregnancy could negatively impact the health of their baby and less likely to view smoking during pregnancy as a risk factor for the baby's development (Bronars et al., 2018). Additionally, out of all the participants, close to three-fourths justified smoking during pregnancy as a method to help manage negative emotions/stress. However, the women in the sample lived in urban areas, thereby limiting generalizability of the results to women living in more rural or other regions in the U.S. (Bronars et al., 2018).

In a meta-analytic review of research conducted between 2006 and 2016 on perceptions and use associated with tobacco smoking and e-cigarette use during pregnancy, McCubbin and colleagues (2017) identified two prevailing perceptions in the literature regarding vaping during pregnancy. The first perception was that e-cigarettes were a safer and potentially healthier alternative (for pregnant woman and fetus) compared to traditional cigarettes. Across all the studies included in this review, the majority of participants viewed e-cigarettes as less harmful than traditional cigarettes in general. The second most common perception was that e-cigarettes may be effectively used as a tool for smoking cessation (McCubbin et al., 2017). In fact, one cross-sectional

study included in this review conducted research with a gynecology population of 194 current and former female tobacco users; more than half the participants were pregnant (Ashford et al., 2016). Notable results showed that majority of the women (88%) were dual users and the top endorsed reason for being a dual user was to "quit cigarette smoking." The majority of women initiated the use of e-cigarettes due to the belief that switching to e-cigarettes would be a safer alternative than cigarette smoking and thus had a lower harm perception associated with vaping, even while pregnant (Ashford et al., 2016).

Reflecting views from cancer patients who smoke, Alton and colleagues (2018) evaluated the risk perceptions of continued smoking among 1,121 patients recently diagnosed with cancer. Patients who were current smokers around the time of diagnosis and who perceived greater health risks associated with continued smoking were two to five times more likely to quit smoking compared with patients who perceived low harm associated with smoking. Those who were current smokers around the time of diagnosis were also less likely to perceive that continued smoking was harmful when compared to former smokers and never smokers. Additionally, perceiving that smoking negatively affected one's quality of life after diagnosis was strongly associated with the initiation of smoking cessation behaviors. Among all the participants, those with a longer smoking history were less likely to believe that smoking was harmful in terms of their quality of life, rates of survival, and fatigue levels (Alton et al., 2018). While this study sample included individuals with various forms of cancer, it did not specifically focus on patients with lung cancer or respiratory diseases. Additionally, other health risk factors that can influence health perceptions such as health status, symptom severity, stress level, and

level of functioning, were not examined.

Similarly, a sample of 105 males, aged 40 years and older, who were current tobacco smokers were involved in a study to measure their perceptions of respiratory health and diseases typically resulting from long-term smoking (Hwang et al., 2019). This particular sample was chosen due to their elevated risk factor of developing COPD (e.g., males, older individuals, current smokers). Out of all participants, approximately 25% knew about COPD, close to 50% of participants did not know what a pulmonary function test (PFT) was, and only about 30% of participants had previously taken a PFT. Most respondents perceived their risk of developing COPD to be equal to their friends' COPD risk or other similarly aged smokers. However, around 40% of the participants perceived their personal COPD risk to be *lower* than their friend's COPD risk and other similarly aged smokers. The authors suggested that this was due to optimistic bias, whereby smokers minimized their personal health risks associated with cigarette smoking by underestimating their risk of developing smoking related conditions (Ayanian & Cleary, 1999; Hwang et al., 2019; Strecher, Kreuter, & Kobrin, 1995). Each participant was then tested with a spirometry breathing test. After receiving their individual results, 60% of the respondents indicated they would obtain PFTs in the future and close to 50% of the participants reported they would quit smoking due to their abnormal spirometry results (Hwang et al., 2019). While this study chose participants based on "at risk" population factors for developing COPD (males, older individuals, current smokers), results were not generalizable to other populations including women, younger individuals, and former smokers.

Demographic/Psychosocial Risk and Protective Factors

Identifying demographic and psychosocial influences related to e-cigarette use is important for predicting future trends in vaping and for developing preventative interventions for vulnerable populations. E-cigarette use in the U.S. has been found to vary significantly based on an individual's sociodemographic characteristics (Levy et al. 2017; Park et al. 2017; Villarroel et al. 2020). Data from the National Health Interview Survey conducted in 2018 reported that men (17.8%) were more likely than women (12.3%) to have ever used an e-cigarette and men (4.3%) were almost twice as likely as women (2.3%) to be current e-cigarette users. The percentage of adults who had ever used an e-cigarette also decreased as age and income increased. The prevalence of adults who had ever used an e-cigarette and were current users was highest among non-Hispanic white males. Moreover, non-Hispanic white adults (16.9%) were more likely than Hispanic (11.5%), non-Hispanic black (10.0%), and non-Hispanic Asian (10.2%) adults to have **ever** used an e-cigarette. Additionally, non-Hispanic white adults (3.7%) were more likely than Hispanic (2.5%), non-Hispanic black (1.6%), and non-Hispanic Asian (2.2%) adults to be **current** e-cigarette users (Villarroel et al. 2020).

In addition, e-cigarette use varies as a function of education level, such that individuals with higher education are less likely to have ever tried ENDS or to be a current ENDS user, compared to individuals with lower levels of education (Huang et al., 2016; Levy et al., 2017; Sharapova et al., 2018; Weaver et al., 2016). Moreover, socioeconomic status (SES) has likewise been implicated as a predictor of ENDS use, although studies assessing this factor are mixed. While some studies have found adults with lower income are more likely to have ever tried ENDS (Regan et al., 2013) or to be

a current ENDS user (Sharapova et al., 2018), other studies have found adults with higher income are more likely to be current ENDS users (Huang et al., 2016). Some studies have found no association between income levels and rates of current or ever ENDS use (King et al., 2015). Although limited studies have investigated the relationship between ENDS use and sexual orientation, research has consistently found that LGBT respondents endorse higher rates of current and ever ENDS use compared to their heterosexual counterparts (Huang et al., 2016; Sharapova et al., 2018). Finally, prevalence rates also vary by marital status, with current ENDS use endorsed by 7.6% of those single/never married/not living with a partner, 5.5% of those widowed, divorced, or separated, and 4.5% of those married or living with a partner (Sharapova et al., 2018), suggesting romantic relationships may serve as a protective factor against ENDS use. Interestingly, many of the same demographic factors that influence smoking/vaping behaviors similarly influence the development and progression of respiratory diseases, such as with asthma and COPD (FIRS, 2017; GOLD, 2021), thereby compounding potential health problems for those who choose to smoke or vape.

Having family members and friends who smoke is also associated with greater use of ENDS (Sutfin et al., 2015). One study found that the second most common reason endorsed for initiating e-cigarettes included that a friend or family member used, gave, or offered them an e-cigarette (Pepper et al., 2014). Mental health status has also been identified as a psychosocial risk factor that influences ENDS use. Individuals with mental health conditions are more likely to have ever used ENDS (34.2%), to currently use ENDS (16.3%) and to currently use ENDS daily (3.3%), compared to individuals without a mental health condition (16.7%, 6.5%, and 1.6%, respectively) (Spears et al., 2019). All

mental health conditions assessed, except for schizophrenia, were associated with a higher likelihood of both lifetime and current ENDS use including bipolar disorder (49.0% lifetime use, 25.4% current use), mood disorders (47.7% lifetime use, 26.3% current use), schizoaffective disorder (39.6% lifetime use, 24.4% current use), anxiety disorders (37.8% lifetime use, 19.1% current use), and depression (35.1% lifetime use, 17.5% current use) (Spears et al., 2019). This is notable as it puts individuals with respiratory illnesses at elevated risk for using ENDS since these populations show an already elevated risk for having co-occurring mood disorders (Hynninen et al., 2007; Miravitlles & Ribera, 2017; Rakofsky & Dunlop, 2019; Yi-Fong et al., 2017). Several studies have also indicated that smoking cigarettes is positively associated with ENDS use (East et al. 2018; Levy et al., 2017; McMillen et al., 2015; Sharapova et al., 2018; Soneji et al. 2017).

Park and colleagues (2017) measured the relationship between smoking status and mental health via assessing psychological distress. Participants were assigned to groups defined by their product use: exclusive cigarette users, exclusive e-cigarette users, ever e-cigarettes and cigarettes user, and current e-cigarettes and cigarettes user. Researchers found a relationship between high levels of psychological distress and a greater likelihood of exclusive e-cigarette use, current e-cigarette and cigarette user, and ever e-cigarette use. Additionally, as level of distress increased, likelihood to initiate e-cigarettes increased as well (Park et al. 2017). Similarly, in a survey conducted with the general population, Spears and colleagues (2019) determined a positive relationship between psychological distress and ever/current ENDS use. Overall, e-cigarette use was strongly associated with increased levels of stress (Spears et al., 2019).

The relationship between e-cigarette use and mental health conditions may be partially mediated by individuals' levels of experienced stress. For example, both episodic and chronic stress have been associated with numerous mental health conditions (Lupien et al., 2009). Similarly, both stress and negative emotional states influence individuals' engagement in negative health-related behaviors such as using e-cigarettes (Ferrer et al., 2016). In fact, severe psychological stress has been found to increase likelihood of lifetime ENDS use (Park et al. 2017; Spears et al., 2019), current ENDS use (Park et al., 2017; Phillips et al., 2017; Spears et al. 2019), and daily ENDS use (Spears et al., 2019). As stress may play a role in the use of e-cigarettes, it puts individuals with respiratory illnesses further at risk due to their already elevated stress levels (Doyle et al., 2013; Miravitlles et al., 2007; Miravitlles & Ribera, 2017; Tsiligianni et al., 2011; Wagena et al., 2005).

Another risk factor that may influence vaping behaviors among those with respiratory illnesses is the advice obtained from medical providers identifying e-cigarettes as a potential harm-reduction strategy for smokers. In the most recent U.S. Surgeons General report on smoking cessation (USDHHS, 2020), key findings stated that more research is required to evaluate whether e-cigarettes are effective for smoking cessation. However, if e-cigarettes should become an effective method for smoking cessation, it would need to be used as a complete substitution for smoking cigarettes or other tobacco products. The eventual treatment goal would be to terminate e-cigarette use to achieve maximum health benefits (USDHHS, 2020). Even though e-cigarettes are not currently approved by the FDA as a smoking cessation tool, perceptions among some medical healthcare providers are that e-cigarettes can be an effective harm-reduction

strategy in smoking cessation (Dewantoro et al., 2018; Franks et al., 2017; Gravely et al., 2019; Kanchustambham et al., 2017; McNeill, 2016). On the other hand, survey results from one study suggested that most family physicians do not endorse or prescribe e-cigarettes to their patients for smoking cessation purposes (Ofei-Dodoo et al., 2017). Also, due to outbreak of EVALI (E-cigarette or Vaping product use Associated Lung Injury), it appears that physician's perceptions of e-cigarettes have changed over the years, moving from neutral to more negative beliefs associated with e-cigarette use for smoking cessation (Ofei-Dodoo et al., 2020). Therefore, it is important to assess whether individuals with respiratory illnesses, who smoke cigarettes, have been informed by their providers of the risks associated with e-cigarettes or have been advised to use e-cigarettes to stop smoking.

Study Rationale and Justification

Research has substantiated that inhalation of ENDS vapors can cause significant damage to an individuals' health. The most notable health effects include reduced pulmonary function, as evidenced by problems with respiration (Kumral et al., 2016; McConnell et al., 2017; Muthumalage et al. 2019; Vardavas et al., 2012), and reduced cardiac function, as evidenced by endothelial dysfunction and oxidative stress (Alzahrani et al., 2018; Antoniewicz et al., 2016; Carnevale et al., 2016; Moheimani et al., 2017). Despite these documented negative health effects, ENDS use is increasing at a substantial rate among adults in the U.S. To date, no published studies have determined vaping rates among those with respiratory and pulmonary illnesses. However, a significant proportion of individuals with a chronic respiratory illness formerly smoked cigarettes or are current cigarette smokers and may be at risk for e-cigarette use. Furthermore, cigarette smokers have a higher risk than the general population of developing a respiratory illness. In addition, managing a chronic respiratory illness can adversely impact one's perceived health, stress levels, and overall functioning. The collective stress of these challenges may place those with respiratory and pulmonary problems at high risk for ENDS use due to the established relationship between stress and increased likelihood of using ENDS (Ferrer et al., 2016; Park et al., 2017; Phillips et al., 2017; Spears et al., 2019).

Research is limited in explaining why those with respiratory illness and chronic lung problems choose to vape. Despite increased vulnerability to the negative health consequences associated with ENDS use, those with a respiratory illness may perceive ENDS to be a safer alternative to smoking cigarettes, aid in smoking cessation, and provide an overall improved smoking experience compared to combustible cigarette

smoking. However, little is known about the demographic, psychosocial, and other health-related factors that shape their risk perceptions regarding ENDS use. Unlike previous studies, this study will add to the literature by examining health risk perceptions associated with ENDS among a vulnerable population of individuals with chronic respiratory illnesses. Understanding what factors contribute to ENDS risk perceptions will help to inform public health policy messaging and improve health related behaviors among this at-risk group. As the development of respiratory illnesses from cigarette smoking can take decades to advance (Gotts et al. 2019), early interventions to reduce smoking and ENDS use may prevent the worsening of respiratory symptoms or even the development of more severe conditions like lung cancer in the future.

Objectives and Hypotheses

- **Objective A:** To describe the rates of past and current use of combustible cigarettes, ENDS use, and dual products (concurrent combustible cigarette and e-cigarette use) among those with respiratory illnesses.
  - **Hypothesis A.1:** The rates of combustible cigarette use, ENDS use, and dual use among those with respiratory illnesses will be comparable to rates reported in other medically compromised samples.
- **Objective B:** To examine health risk perceptions related to ENDS use among those with respiratory illnesses.
  - **Hypothesis B.1:** Individuals with respiratory illnesses will perceive the use of ENDS as less harmful than combustible cigarettes.
  - **Hypothesis B.2:** Individuals with respiratory illnesses will have comparable ENDS health risk perceptions regardless of their smoking/vaping status (i.e., Current Dual Users vs. All Other Users).
  - **Hypothesis B.3:** The majority of participants (>50%) will perceive ENDS use as an effective tool for smoking cessation and stress management.
  - **Hypothesis B.4:** A significant proportion (at least 50%) of participants will report that their healthcare providers have advised the use of electronic cigarettes as a method of smoking cessation or harm reduction strategy.
- **Objective C:** To determine the association between risk factors and ENDS health risk perceptions among those with respiratory illnesses. These include demographic

factors, psychosocial factors, and other health risk factors related to respiratory illnesses.

- **Hypothesis C.1:** Participants who are younger, male, low income, less educated, single, non-Hispanic, from the South/Midwest regions, and Caucasian will report lower ENDS health risk perceptions.
- **Hypothesis C.2:** Participants who have friends who smoke/vape will report lower ENDS health risk perceptions.
- **Hypothesis C.3:** Participants with a higher overall health risk, as measured by these factors (perceived health status, stress level, symptom severity, and level of functioning) will report higher ENDS health risk perceptions.

Methods

Participants and Recruitment

In order to participate, individuals must have met the following criteria: (a) 18 years of age or older, (b) able to read and write English fluently, (c) have been diagnosed with a respiratory illness and still have the diagnosis, (d) be a current/former smoker of any combustible tobacco product (i.e. cigarettes, cigarillos, cigars, blunts, bidis, or any other tobacco product), or a current/former ENDS user (i.e., electronic cigarettes, e-cigarettes, vapes, electronic hookahs, hookah pens, vape pens, electronic pipes, or any other electronic vaping products), or a dual user (i.e. concurrently use cigarettes/combustible tobacco products and ENDS or used both products at some point in time). Participants were recruited through various internet listservs, support groups, and community boards via requests for voluntary participation in an anonymous survey. Approval from the Florida Institute of Technology Institutional Review Board was obtained prior to recruitment. All participants were asked to provide informed consent prior to data collection.

Data Collection Procedures

Participants were directed to the survey through a link provided on the consent form. The online survey consisted of 75 items and took approximately 15-20 minutes to complete. To begin the survey, participants first provided informed consent, following provision of information regarding what the study entailed. Participants verified their eligibility by responding to a set of initial qualifying questions as described in Appendix B. During the survey, participants were able to adjust their answers to previous questions

by using the "back" button and to decline a response to any question. They were also able to withdraw at any time. The data collected from the surveys were entered into a HIPPA-compliant database which de-identified all personal information. Finally, participants were provided the option to enter a drawing to win one out of four $50 gift cards at the completion of the survey.

Measures

Participants accessed the survey through the Qualtrics website. The core components of the survey included the following:

I. **Qualifying Information.** Questions were asked to verify a participant's eligibility for this survey prior to continuing with the full survey. Participants must have been 18 years of age, read and write English fluently, currently have a respiratory illness, and be a current/former smoker or a current/former vaper, or a dual user.

II. **Demographics.** Demographic characteristics obtained included age, sexual orientation, gender identity, race, ethnicity, geographic region, relationship status, education level, income, and occupational status.

III. **Psychosocial.** Physical health and mental health were assessed via questions pertaining to medical and mental health diagnoses. A quality-of-life question relevant to participants' respiratory health was also asked.

IV. **Cigarette Smoking Status and History.** Participants were asked about their past and current smoking status. "Past smokers" were defined as those who have smoked at least 100 cigarettes in their lifetime, but not within the last 30 days (NHIS, 2020). "Current smokers" were defined as those who have smoked at least 100 cigarettes in

their lifetime and currently smoke cigarettes on “some days” or “nearly every day” within the past 30 days as defined in prior studies (USDHHS, 2016). “Ever smokers” were defined as those who endorse smoking in the past or currently (USDHHS, 2016). “Never smokers” were identified as those who have not smoked at least 100 cigarettes in their lifetime and who have not smoked in the past 30 days. “Current dual users” were defined as those who currently smoke cigarettes and who currently use ENDS. Participants who currently use either cigarettes or ENDS products and have used the other product in the past, even if not at the same time, were considered “Ever dual users.” Participants were asked about the number of smokers with whom they are close friends. Responses were categorized into 0 smokers, 1-2 smokers, $\geq$3 smokers. Participants were also asked to complete questions regarding whether their spouse/partner currently smokes. Responses were ‘Yes’, ‘No’, and ‘N/A (No spouse/partner)’ for this question.

V. **ENDS Vaping Status and History.** Participants were asked about their past and current ENDS use status. “Current vapers” were those who reported use of any ENDS product on “some days” or “nearly every day” within the past 30 days. “Past vapers” were those who reported use of any ENDS product at least once in their lifetime but not within the last 30 days. “Ever vapers” included the current and past ENDS users. “Never vapers” were identified as those who have never used any ENDS product in their lifetime, including over the past 30 days. A question regarding the level of nicotine typically used in ENDS devices was included. As this study will include participants who smoke cigarettes and may or may not currently use ENDS, an item assessing future intentions to use ENDS was included. Participants were asked about

the number of vapers with whom they are close friends. Responses were categorized into 0 vapers, 1-2 vapers, ≥3 vapers. Participants were also asked to complete questions regarding whether their spouse/partner currently vapes. Responses were 'Yes', 'No', and 'N/A (No spouse/partner)' for this question.

VI. **Respiratory Health Status and History.** Items in this section assessed participants' respiratory/pulmonary health history and verified participants' diagnoses of respiratory, pulmonary, or lung disease/illness. Participants were described as having a "respiratory illness" if they have been informed by a medical professional of their diagnosis and still currently have the respiratory illness/disease. The proportion of participants who endorsed individual items was also reported and analyzed.

VII. **Health Risk Perceptions Regarding ENDS.** Participants were asked about their perceptions of harm from ENDS use as it relates to their overall respiratory/pulmonary health (14 risk perception items). Items were adapted from the co-investigator's previous smoking research (Tyc, Lensing, Vukadinovich, & Hovell, 2013) for the current study. Items were rated on a 4-point scale ranging from "Strongly Disagree" to "Strongly Agree" or a 3-point scale with options of "less harmful," "as harmful," or "more harmful." A total health risk perception score ranging from 0-38 was computed. Higher health risk perception scores (22 – 38) were indicative of greater perceptions of harm regarding ENDS use. Lower health risk perception scores (0 – 21) were indicative of less perceptions of harm regarding ENDS use. The proportion of participants who endorsed individual items was also reported and analyzed.

VIII. **Smoking Cessation Perceptions.** Participants were asked two questions regarding their perceptions of using e-cigarettes as a smoking cessation or harm reduction strategy. Items were rated on a 4-point scale ranging from "Strongly Agree" to "Strongly Disagree." Total values range from 0 – 6; higher scores indicate a stronger perception that using ENDS use can be an effective method of smoking cessation or harm reduction.

IX. **Healthcare Provider Communication.** Participants were asked four questions regarding smoking and vaping risks/warnings received from their healthcare providers. Additionally, questions were asked regarding what smoking cessation interventions their healthcare providers have advised them to use. Items were rated on a 3-point scale: "Never," "Once or twice," or "Frequently." Scores for the 4th question were reversed. Total values range from 0 – 8; lower scores indicate limited delivery of information about smoking cessation from healthcare providers.

X. **Health Risk Variables**. Overall health risk was examined across four categories: a) health status; b) stress level; c) symptom severity; and d) level of functioning. Individual scores were computed for each category and an overall cumulative health risk score was computed by summing the individual scores across each category. Total cumulative health risk score ranges from 0 to 139, with higher scores indicative of a greater health risk.

    a. **Health Status.** This was assessed using 2 adapted questions from the CDC's Health Related Quality of Life 14-item measure (HRQOL-14). Responses include 'Excellent', 'Good', 'Fair', 'Poor', and 'Terrible'.

Total values range from 0 – 8; higher scores indicate poor overall perceived health status.

b. **Stress Level.** This was measured using the Perceived Stress Scale-4 item questionnaire (PSS-4). This scale is a measurement of global stress which is often used in primary care clinics for individuals with long-term medical conditions. Since the sample included individuals with at least one long-term medical condition (respiratory), it is best suited for measuring stress levels for this population. Responses were measured on a Likert scale including 'Never', 'Almost Never', 'Sometimes', 'Fairly Often', and 'Very Often'. Total values range from 0 – 16; higher scores indicate higher levels of stress.

c. **Symptom Severity.** Participants were asked about the severity of their respiratory/pulmonary symptoms. Items from the Quality-of-Life Respiratory Illness Questionnaire (QOL-RIQ; Maillé et al. 1997) and the BRFSS (2017) were adapted for this measure. Relevant symptoms are defined as the following: chest pain/tightness, coughing, difficulty breathing in, fatigue, frequent need to clear throat, heavy/rapid breathing, itchy/dry throat, phlegm production, recurrent colds, shortness of breath, sleeping issues, stuffed sinus/runny nose, weight loss/gain, and wheezing. Total values range from 0 – 70; higher scores indicate worse symptom severity.

d. **Level of Functioning**. Participants were asked about their level of difficulty/impairment with completing activities of daily living. Items

from the QOL-RIQ (Maillé et al. 1997) were included for this measure. Relevant activities can be defined as bathing/showering, eating/swallowing, getting dressed, going up stairs, lifting a heavy object, running a short distance, sleeping/resting, shopping, and toileting. Total values range from 0 – 45; higher scores indicate significant difficulty with completing many areas of daily functioning.

Research Design and Data Analysis

This study utilized a cross-sectional design. Descriptive statistics, including means, standard deviations, and frequencies, were calculated for participant demographics, primary outcomes (ENDS Health Risk Perceptions), and all covariates. Differences in health risk perceptions between current dual users and those in the 'other smoking/vaping' group were examined using non-parametric Mann-Whitney U tests. Chi Square tests were used to assess for differences between groups for categorical variables. Linear regression analyses were conducted to examine the association between health status, stress level, symptom severity, level of functioning and ENDS Risk Perceptions. Preliminary analyses were conducted to examine the relationship between variables and primary outcomes and tests for assumptions of normality and multicollinearity were conducted for selected analyses. The data was analyzed using the Statistical Package for the Social Sciences (SPSS) –version 28. All analyses were considered significant at the $p < .05$ level.

Results

Participants

Demographic Variables: A total of 305 participants agreed to participate in the study. Of those, 35 were not eligible to take the survey due to not having any respiratory conditions and not being a smoker or vaper. The final sample consisted of 270 participants, including 146 men, 101 women, 19 transwomen, 3 transmen, and one individual who identified as gender fluid. Most participants were in the age range of 25-34 years old (*n* = 95, 35%) and most identified as Heterosexual (*n* = 209, 77%). The majority of participants were male (*n* = 146, 54%), identified as White/Caucasian (*n* = 204, 76%), were Non-Hispanic/Latino (*n* = 150, 56%), and lived in Urban/City areas (*n* = 209, 77%). The most frequently endorsed U.S. geographic region of residence was the South (*n* = 79, 29%). A total of 23 participants (8.52%) endorsed living outside of the US, specific counties of residence included United Kingdom, Ireland, Kenya, Qatar, Canada, New Zealand, and South Africa. In terms of relationship status, the most prevalent category was Married (*n* = 117, 43%). The most endorsed level of education was a Technical Degree/Certificate (*n* = 72, 27%). Most participants were in the income level of $20,000-$39,000 (*n* = 76, 28%) and more than half were employed full-time (*n* = 148, 55%).

Psychosocial Variables: In reference to participants' health conditions, arthritis (*n* = 96, 36%), chronic pain (*n* = 60, 22%), and hypertension (*n* = 57, 21%) were the top three most frequently endorsed chronic medical conditions. Regarding mental health conditions, anxiety (*n* = 126, 47%), depression (*n* = 78, 29%), and sleep disorders (n = 61, 23%) were the top three most frequently identified mental health conditions. Quality

of life in relation to living with a respiratory condition was evaluated. The majority of participants (*n* = 200, 74%) endorsed that their respiratory illness negatively impacted/worsened their quality of life. See Table 1 for additional health diagnosis information.

Smoking/Vaping Status: Smoking and vaping status of participants were categorized into 7 groups to account for all participants. Current Smoker (*n* = 7, 3%) consisted of those who smoked at least 100 cigarettes in their lifetime including over the past 30 days and have never used a vaping product. Current Vaper (*n* = 2, 1%) included those who have not smoked 100 cigarettes in their lifetime and have not smoked within the past 30 days but have vaped in the past 30 days. Current Dual User (*n* =190, 70%) included those who have vaped and smoked within the past 30 days regardless of if they smoked 100 cigarettes in their lifetime or not. Past Smoker (*n* = 21, 8%) included those who have smoked at least 100 cigarettes in their lifetime but have not smoked within the past 30 days and have never vaped. Past Vaper (*n* = 5, 2%) includes those who have not smoked at least 100 cigarettes, have not smoked or vaped within the past 30 days, but have vaped at least once in their lifetime. Past Dual User (*n* = 18, 7%) includes those who have smoked at least 100 cigarettes in their lifetime and have vaped at least once in their lifetime but have not smoked or vaped within the past 30 days. Ever Dual User (*n* = 27, 10%) includes individuals who did not meet criteria for any other group. For comparative purposes and due to the limited number of participants in some groups, these groups have been merged to categorize participants into two groups: the 'Current Dual Users' versus 'All Other Users' combined.

Respiratory Illness Variables: The top three most frequently identified respiratory illnesses among participants included Asthma (*n* =111, 41%), Chronic Obstructive Pulmonary Disease (COPD; *n* = 88, 33%), and Bronchiectasis (*n* = 78, 29%). In terms of sequence for the onset of illness in comparison to smoking/vaping initiation, more than half of participants endorsed smoking or vaping prior to receiving a diagnosis for their respiratory condition (*n* = 149, 55%). A little over three-fourths of participants (*n* = 205, 76%) endorsed having been given a Pulmonary Function Test (PFT) to assess breathing concerns. Similarly, majority of participants endorsed currently using a medically prescribed inhaler (*n* = 191, 71%) and experiencing an episode of severe symptom exacerbation during the past 12 months (*n* = 149, 58%). During the past 12 months, 168 participants (62%) have visited an emergency room or urgent care center due to their respiratory illness and 212 participants (78%) have seen a medical professional for a routine checkup regarding their respiratory illness. See Table 2 for further information.

ENDS Health Risk Perception Variables: The health risk perceptions regarding ENDS were assessed via 14 questions (i.e., question 48-61). The responses to each question were totaled to obtain a 'ENDS Risk Perception Score' for each participant. The minimum score was 0 and the maximum score was 38 (*Md* = 21). Higher scores indicated a greater perception of harm from ENDS devices. Lower scores indicated less perception of harm from ENDS devices.

Health Risk Variables: These factors included health status, stress levels, symptom severity, and level of functioning as measured by difficulty/impairment with completing daily activities. Total scores for each variable were computed as well as an

‘Overall Health Risk Score’ composed of health status, stress level, symptoms severity, and level of functioning. For the Overall Health Risk, range of scores were from 8 to 107. Higher Overall Health Risk scores indicated a greater health risk for the participant and Lower Overall Health Risk scores indicated less of a health risk for the participant. The mean Overall Health Risk score was 57 (*SD* = 21.65, *Md* = 61) indicating a moderate overall health risk status for those with respiratory illness among this sample. See Table 3 for data on the responses to the Health Risk Variables and Table 4 for summary statics of each Health Risk factor.

Hypotheses

Hypothesis A.1: *The rates of combustible cigarette use, ENDS use, and dual use among those with respiratory illnesses will be comparable to rates reported in other medically compromised samples.*

Within the current study, it was found that 2.6% of the sample were current smokers (*n* = 7), 0.7% were current vapers (*n* = 2), and 70.4% were current dual users (*n* = 190). Similarly, 7.8% of the sample were past smokers (*n* = 21), 1.9% were past vapers (*n* = 5), and 6.7% were past dual users (*n* = 18). Since there were not any individual studies which evaluated cigarette use, ENDS use, and dual use within a single medical population, multiple studies were used to analyze the rates obtained in the current study to comparison samples. In a nationally representative sample (Behavioral Risk Factor Surveillance System survey [BRFSS], CDC, 2019), current and past cigarette smoking rates for those who endorsed having a chronic medical condition were reported. Of those who endorsed having any type of cancer, the current cigarette smoking rate was 1.7%, while the past cigarette smoking rate was 4.6%. Likewise, of those who endorsed having coronary heart disease or myocardial infarction, the current cigarette smoking rate was 1.3%, while the past cigarette smoking rate was 2.6%. In an analysis of the Population Assessment of Tobacco and Health (PATH) Study, authors Salloum and colleagues (2019) evaluated the vaping rates of cancer survivors. Current vaping rates among cancer survivors were reported at 3.8%, past vaping rates were reported at 0.7%, and dual current use rates (cigarettes and vaping) were reported at 25% (Salloum et al., 2019).

Results of chi square goodness of fit tests demonstrated that current cigarette smoking rates among individuals with respiratory illnesses in this study (2.6%) were not

significantly different than the published rates among cancer patients (1.7%), $\chi^2(1) = 1.29$, $p > .05$, and among cardiac patients (1.3%), $\chi^2(1) = 3.51$, $p > .05$ found in the BRFSS. However, results of chi square goodness of fit tests demonstrated that past cigarette smoking rates among individuals with respiratory illnesses in this study (7.8%) were significantly different than the published rates among cancer patients (4.6%), $\chi^2(1) = 6.21$, $p < .05$, and among cardiac patients (2.6%), $\chi^2(1) = 28.58$, $p < .001$ found in the BRFSS.

Results of chi square goodness of fit tests demonstrated that current vaping rates among individuals with respiratory illnesses in the current sample (0.7%) were significantly different than the published rates among cancer survivors (3.8%), $\chi^2(1) = 6.91$, $p < .05$ found in the PATH Study. Results of chi square goodness of fit tests also demonstrated that past vaping rates among individuals with respiratory illnesses in the current sample (1.9%) were significantly different than the published rates among cancer survivors (0.7%), $\chi^2(1) = 5.15$, $p < .05$ found in the PATH Study. Finally, results of chi square goodness of fit tests demonstrated that current dual user rates among individuals with respiratory illnesses in the current study (70.4%) were significantly different than the published rates of current dual use among cancer survivors (25%), $\chi^2(1) = 296.42$, $p < .001$ found in the PATH Study.

Hypothesis B.1: *Individuals with respiratory illnesses will perceive the use of ENDS as less harmful than combustible cigarettes*.

The frequency of responses to the survey item ("Use of e-cigarettes is: ___") were reviewed. Most participants endorsed the response "As harmful to me as regular

cigarettes" (*n* = 129, 48%). The response "Less harmful to me than regular cigarettes" was endorsed by 41% of participants (*n* = 112), and 11% of participants (*n* = 29) endorsed the use of e-cigarettes as "More harmful to me than regular cigarettes."

Hypothesis B.2*: Individuals with respiratory illnesses will have comparable ENDS health risk perceptions regardless of their smoking/vaping status (i.e., Current Dual Users vs. All Other Users).*

For this analysis, Current Dual Users were compared to all other smoking/vaping groups combined due to the limited number of participants in some groups and because the Dual Users were currently using both a smoking and vaping product while participants in the other groups used only a single product at a time. Kolmogorov-Smirnov and Shapiro-Wilk tests were conducted to determine whether the distribution of total ENDS health risk perception scores was significantly different from a normal distribution. Results from both tests showed that this distribution was not normally distributed ($D = 0.14$, $p < .001$) and ($W = 0.96$, $p < .001$), respectively. Therefore, a non-parametric Mann-Whitney *U* test was conducted to test for differences in ENDS risk perception scores between the Current Dual Users and 'Other Smoking/Vaping' groups. The Mann-Whitney *U* Test indicated that the ENDS risk perception scores were significantly greater for the 'Other Smoking/Vaping' group ($Md = 27.50$, $n = 80$) than for the Current Dual Users group ($Md = 20.00$, $n = 190$), $U = 3988$, $z = -6.18$, $p < .001$.

Hypothesis B.3: *The majority of participants (>50%) will perceive use of ENDS as an effective tool for smoking cessation and stress management*.

In order to evaluate this hypothesis, the frequency of responses to specific survey items (i.e., questions 62 and 63 for smoking cessation and question 36 for stress management) were reported. More than half of the sample responded "Yes" (*n* = 146, 54%) to the question, "Do you feel that you use e-cigarettes/vaping products to manage or cope with stress?"

Regarding smoking cessation perceptions, 66% (*n* = 179) 'agreed' or 'strongly agreed' with the statement "E-cigarette/vaping products could help me, or others quit smoking regular cigarettes". Similarly, 76% of the sample (*n* = 206) 'agreed' or 'strongly agreed' with the statement "E-cigarette/vaping products could help me, or others reduce the number of cigarettes smoked." These collective results support the hypothesis that majority of this sample agreed that ENDS use is an effective stress management coping method and an effective tool for smoking cessation/harm reduction.

Hypothesis B.4: *A significant proportion (at least 50%) of participants will report that their healthcare providers have advised the use of electronic cigarettes as a method of smoking cessation or harm reduction strategy*.

This hypothesis was evaluated by examining the frequency of responses to a specific survey item (question 67) "Have any of your health care providers advised the use of e-cigarettes/vaping products to quit cigarette smoking or reduce the number of cigarettes smoked?" More than half of the respondents answered 'Never' (*n* = 159, 59%), 33% responded 'Once or Twice' (*n* = 90), and 8% responded 'Frequently' (*n* =21) to this question. The hypothesis that a significant proportion of participants were advised by

their healthcare providers to use electronic cigarettes as a smoking cessation or harm reduction strategy was not supported.

Hypothesis C.1: *Participants who are younger, male, low income, less educated, single, non-Hispanic, from South/Midwest regions, and Caucasian will report lower ENDS health risk perceptions.*

A Chi-square Test of Independence was conducted using Yates continuity correction values to examine whether age, gender, income, education, relationship status, ethnicity, geographic region, and race were associated with ENDS Health Risk Perceptions. For this analysis, high and low health risk perception groups were determined using the median value of the health risk perception scores *(Md* = 21). The first group consisted of the **higher** risk perception scores (*n* = 123, 46%) and included those who obtained a risk perception score between 22 and 38. The **lower** risk perception scores (*n* = 147, 54%) consists of those who obtained a risk perception score between 0 and 21. Age groups were divided into two categories: 18-34 years old (*n* = 131, 49%) and 35 years and older (*n* = 139, 51%). Income level groups were categorized as those who endorsed making $39,000 and below (*n* = 107, 40%) and those who endorsed making $40,000 and above (*n* = 163, 60%). Two groups were created for education level. 'More Education' consisted of Associates Degree, Bachelor's degree, Master's Degree, and Doctoral Degree (*n* = 104, 39%) and 'Less Education' consisted of all other responses (*n* = 166, 61%). Relationship status was divided into two groups: Single group consisted of single, divorced, and widowed (*n* = 91, 34%) and Relationship group consisted of married and in a relationship (*n* = 179, 66%). The results of the Chi-square tests showed

no significant association between ENDS Health Risk Perceptions and age, income level, education level, and relationship status. Chi Square values are presented in Table 5.

Gender groups were divided into two categories: female, transwoman, and gender fluid (n = 121, 45%) in one category and male and transman (n = 149, 55%) in the other category. The results of the Chi-square test showed a significant association between ENDS Health Risk Perceptions and gender, $\chi^2(1) = 6.50$, $p = .011$. Those in the higher risk perception group were more likely to be Female while those in the lower risk perception group were more likely to be Male. There were two groups created for ethnicity: Hispanic/Latino (n = 120, 44%) and Non-Hispanic/Latino (n = 150, 56%). The results of the Chi-square test showed a significant association between ENDS Health Risk Perceptions and ethnicity, $\chi^2(1) = 4.03$, $p = .045$. Those in the higher risk perception group were more likely to be Non-Hispanic/Latino while those in the lower risk perception group were more likely to be Hispanic/Latino. Geographic region of residence was divided into two groups: South/Midwest (n = 151, 56%) and all other regions, including outside of the U.S., (n = 119, 44%). A Chi-square test indicated a significant association between ENDS Health Risk Perceptions and geographic region, $\chi^2(1) = 4.16$, $p = .041$. Participants in the lower risk perception group were more likely to be from the South and Midwest regions while those in the higher risk perception group were more likely to be from other regions. Race groups were divided into two categories: Caucasians (n = 204, 76%) and all other minorities (n = 66, 24%). Race and ENDS health risk perceptions were significantly associated, $\chi^2(1) = 7.40$, $p = .007$ showing that those in the higher risk perception group were more likely to be White/Caucasian while those in the lower risk perception groups were more likely to be of another race. In summation,

ENDS risk perception scores were significantly associated with gender, ethnicity, geographic region, and race. Chi Square values are presented in Table 5.

Hypothesis C.2*:* *Participants who have friends who smoke/vape will report lower ENDS health risk perceptions*.

A Chi-square Test of Independence was conducted using Yates continuity correction values to examine whether having friends who smoke and vape were associated with ENDS Risk Perceptions. The High and Low ENDS Risk Perception groups, as defined above using the median scores to divide the groups, were used in this analysis. Number of friends who smoke were divided into two groups: none (n = 39, 14%) and one or more friend who smokes (n = 231, 86%). The results of the Chi-square test indicated no significant association between the number of friends who smoked and ENDS Risk Perceptions,

Likewise, number of friends who vape were divided into two groups: none (n = 39, 14%) and one or more friend who vapes (n = 231, 86%). A Chi-square test showed a significant association between the number of friends who vape and ENDS Risk Perceptions, $\chi^2(1) = 13.92$, $p < .001$. Participants with higher ENDS risk perceptions were more likely to have no friends who vape while those with lower ENDS risk perceptions were more likely to have one or more friends that vape. See Table 5 for Chi Square values.

Hypothesis C.3: *Participants with a higher overall health risk, as measured by these factors (health status, stress level, symptom severity, and level of functioning) will report higher ENDS health risk perceptions.*

A Chi-square Test of Independence using Yates continuity correction values was conducted to examine whether overall health risk was associated with ENDS Health Risk Perception Scores. The High and Low ENDS Risk Perception groups, as defined above, were used in this analysis. Similarly, high and low overall health risk groups were determined using the median of the overall health risk scores *(Md* = 61). The first group consisted of the **higher** overall health risk scores (*n* = 131, 49%) and included those who obtained a total score between 62 and 107. The **lower** overall health risk scores (*n* = 139, 51%) consisted of those who obtained a total score between 8 and 61. The results of the Chi-square test were not significant, $\chi^2(1) = 0.48$, $p = .490$, suggesting no significant association between overall health risk and ENDS risks perceptions. See Table 5 for Chi Square values.

A linear multiple regression analysis was conducted to assess whether Health Status, Stress Level, Symptom Severity, and Level of Functioning significantly predicted ENDS Risk Perception Scores. Preliminary analyses indicated no violation of the assumptions of normality and multicollinearity. The results of the linear regression model were significant, $F(4,265) = 4.01$, $p = .004$, $R^2 = 0.06$, indicating that approximately 6% of the variance in ENDS Risk Perception Scores was explained by Health Status, Stress Level, Symptom Severity, and Level of Functioning. Of the variables in the model, Health Status significantly predicted ENDS Risk Perceptions, $B = 0.70$, $t(265) = 3.42$, $p < .001$. This indicates that on average, a one standard deviation-unit increase in Health

Status score will increase the value of ENDS Risk Perception scores by 0.70 standard deviation units. Stress Level did not significantly predict ENDS Risk Perception scores, $B = -0.01$, $t\ (265) = -0.06$, $p = .956$. Symptom Severity also did not significantly predict ENDS Risk Perception scores, $B = 0.03$, $t\ (265) = 0.78$, $p = .437$. Level of Functioning was not a significant predictor of ENDS Risk Perception scores, $B = -0.03$, $t\ (265) = -0.56$, $p = .578$. Table 6 summarizes the results of the regression model.

Discussion

Extensive literature has conclusively demonstrated the harmful effects of smoking on individuals' health while research investigating the net public health effect of ENDS has been somewhat more controversial (National Academies of Sciences, Engineering, and Medicine, 2018). Nonetheless, the increasing popularity of ENDS has contributed to a surge in research resulting in increased evidence supporting ENDS use as significantly damaging to users' health, especially related to cardiovascular and pulmonary functioning (Bold et al., 2018). Moreover, even second-hand exposure to nicotine through vaping is an immediate irritant to the lung tissue (Mishra et al., 2015). Despite notable respiratory concerns and susceptibility to further negative health effects from vaping, 70% of individuals with respiratory illnesses from this study indicated being a current dual user. Current dual use compounds the negative health effects that is associated with combustible cigarette smoking and vaping. The high rates of multiple product use among individuals with respiratory illnesses suggest an at-risk population that warrants interventions to address their smoking and vaping behaviors.

A comparison of current cigarette smoking rates in the study sample were similar to those reported in prior studies (BRFSS-CDC, 2019; PATH Study-Salloum et al., 2019) with other medically compromised groups (*i.e.,* those with cancer and cardiac conditions). However *past* cigarette smoking rates were significantly higher among this sample compared to the other medically compromised groups. This finding may have several explanations. While the BRFSS and the PATH studies were published in 2019, the timing of when participants answered the survey most likely occurred years prior. Participants in the current study responded in 2021, amidst the COVID-19 pandemic. The

significant difference in past cigarette smoking rates between the two studies may be accounted for by the fact that participants in our study had respiratory concerns during a respiratory pandemic and may have elected to quit smoking because of COVID-19 concerns. The different rates of vaping between the two samples may also be due to the fact that as rates of vaping increase as smokers attempt to quit smoking, failed smoking cessation attempts while concurrently vaping may contribute to dual product use.

The reasons that individuals with respiratory illnesses use ENDS products at high rates may be explained, in part, by their perceived benefits of ENDS use. Our study found, for example, that 54% of the sample used ENDS to manage their stress. Additionally, two-thirds of this sample agreed that e-cigarettes were an effective method to stop smoking while over three-fourths of this sample agreed that e-cigarettes could assist a smoker in reducing the number of cigarettes smoked. Additionally, when participants were asked the reasons, they might use or consider using e-cigarettes, the most frequently endorsed item was “Help with quitting other tobacco products, such as cigarettes.” These findings, combined with the fact that the majority of the sample perceived use of e-cigarettes ‘as harmful’ or ‘less harmful’ than combustible cigarettes, suggests that individuals who smoke and view e-cigarettes as a safer alternative, may initiate vaping to quit smoking, and instead become nicotine dependent on two products. This conclusion may account for the high rate of dual use in our sample. However, based on the nature of our data, it is difficult to determine which product use came first. Future longitudinal studies could better address the trajectory of smoking and vaping initiation and track the course of product use.

Relatedly, a little more than half of the participants responded that they have never been advised by their healthcare provider to use an ENDS product to quit cigarette smoking or reduce the number of cigarettes smoked. However, one-third of participants indicated they have been advised at least once or twice from their healthcare providers to use an ENDS product to quit smoking. More alarmingly, 8% of participants endorsed being advised **frequently** by their healthcare providers to use an ENDS product to quit smoking. This is despite that fact that there is limited data about the effectiveness of ENDS as a cessation tool and numerous health agencies do not recommend ENDS use as a cigarette smoking cessation aid. Instead, patients should be directed by their providers to implement evidence-based approaches and FDA-approved medications to quit smoking. If e-cigarettes are used by patients, they should be used as a bridge off of combustible cigarettes with the patient ultimately quitting all products as an end goal.

When examining health perceptions, results showed that current dual users had significantly lower risk perceptions (*i.e.*, lower perceptions of harm associated with e-cigarette use) than the "all other users" group. This finding is consistent with previous research that suggests that those who have less perceived health risks will engage in more risky behaviors (Ayanian & Cleary, 1999; Strecher, Kreuter, & Kobrin, 1995; Weinstein 1998) such as concurrent dual use of ENDS products and combustible cigarettes (Chen et al., 2016; Chen & Kaphingst, 2011; Hwang et al., 2019; Krosnick et al., 2017; McCubbin et al., 2017). It is important to note that the participants in the "all other users" group were also current or past smokers/vapers and yet significant differences in ENDS health risk perceptions between them and the current dual users were found. The differences in ENDS risk perceptions between the current dual users and the "all other users" group in

our sample are likely of a lower magnitude than what would be expected if one were to compare current dual users to never smokers/vapers on risk ratings. Future studies that compare larger samples of dual users versus exclusive smokers/vapers and never users would help to better assess the relationship between smoking/vaping status and health perceptions.

Interestingly, there was no significant association between perceptions of health risk associated with ENDS use and overall health risk scores. However, examination of the individual components of the overall health risk indicated that perception of one's health status was a significant predictor of ENDS risk perceptions. These findings are consistent with the Health Belief Model (HBM) of health behavior which states that perceptions regarding risks of getting seriously ill and the ability to overcome illness can influence the practice of health behaviors (Becker, 1974). Such findings suggest that providers who can capitalize on the patient's sensitivity to their health status may be able to shape the patient's health risk perceptions and prompt behavior change.

Based on the results from this study, medical practitioners can be more mindful in discussing the negative health outcomes of dual using among those who have a chronic respiratory condition and currently smoke and vape. Since this population often requires frequent medical care and hospital visits, it would be worthwhile to implement change in respiratory medical standards, whereby patients should be routinely asked about their vaping habits and educated about the negative health effects of vaping, specific to their illness. The association between health perceptions and smoking/vaping status demonstrated in our study and the fact that health perceptions are modifiable, suggests that provider advice about smoking/vaping-related health risks may influence behavioral

change. Although increasing patient knowledge about the adverse health consequences associated with ENDS use may not be sufficient by itself to change patient behavior, understanding that one's respiratory symptoms and health risks can be magnified by smoking and using ENDS products is a first step in making healthy behavioral choices.

Finally, this study sought to examine demographic and psychosocial risk factors associated with ENDS health risk perceptions. Results indicated that gender, ethnicity, geographic region of residence, race, number of friends who vape, and smoking/vaping status were all significantly related to ENDS Risk Perceptions. However, age, income level, education level, relationship status, and number of friends who smoked were not significantly associated with ENDS Risk Perceptions. These findings suggest that study participants who identified as male/transman, Hispanic/Latino, from the South and Midwest, and of a minority race were more likely to report lower risk perceptions associated with ENDS use. Social influences were also important in determining health risk perceptions. Participants who had one or more friends who vaped were more likely to perceive ENDS use as being less harmful to their health. These higher risk groups should be targeted for messaging about the health risks associated with ENDS use.

Clinical Implications

As discussed above, the clinical implications that can be extrapolated from this study relate to how smoking and vaping is addressed in medical settings among patients with chronic respiratory conditions. The results from this study and previous studies have established that this population is in frequent contact with medical providers to manage their respiratory symptoms. Given this increased contact, it is critical that vaping behaviors be regularly addressed with the patient during routine medical visits. Along with the warnings against cigarette smoking, providers should also discuss the dangers of vaping. Likewise, it would be prudent for medical providers to **not** advice the use of e-cigarettes as a form of smoking cessation aid at this time without an explicit plan to eventually quit all forms of smoking and vaping. These recommendations can be put into action by first identifying patients at risk of initiating ENDS use and then providing these patients with educational pamphlets on the negative health effects of vaping and/or dual use to prompt discussion about ENDS use. As health risk perceptions can be modified, and perceptions of risk are associated with smoking/vaping behaviors, increasing patient awareness of their health risks is an important step in promoting abstinence from ENDS and tobacco products.

As it relates to psychotherapeutic interventions, mental health practitioners can utilize this information to bolster smoking cessation psychoeducation by sharing the negative health effects of dual using for smoking cessation. Since it is suggested that individuals are more likely to begin using ENDS as a method of smoking cessation, but often end up continuing to use both cigarettes and ENDS products, it is vital to provide education about the FDA approved behavioral and pharmacological methods of smoking

cessation. Motivational interviewing techniques may also be helpful in reducing patient ambivalence about quitting and increasing motivation for behavioral change. In addition, practitioners should emphasize that ENDS initiation while smoking cigarettes may be counterproductive not only to quitting but also in creating worse respiratory effects for the patient.

Limitations and Directions for Future Research

There are some methodological issues inherent to the current study, which limit the definitiveness of the conclusions drawn. First, the study is cross-sectional in design, such that the directionality of the relationship between many of the participants' pulmonary-specific characteristics and their health risk perceptions associated with ENDS cannot be entirely established. Future research should include a longitudinal approach to better understand directionality of these relationships. Another limitation to the current study was that the primary outcomes were based on self-reports. Although the validity of self-reported smoking measures appears to be valid (Caraballo et al., 2004; Japuntich et al., 2009; Ramo et al. 2011; Wetter et al., 1994;), the validity of self-reported vaping measures has yet to be investigated. Moreover, only current or former smokers/vapers who have a respiratory illness were included in this study to examine perceptions related to ENDS use in this high-risk sample. This eligibility criteria resulted in a less than desirable sample size, preventing the more in-depth assessment of the risk and protective factors of ENDS use among those with respiratory illnesses. Likewise, the subsamples of smoker/vaper groups were unexpectedly small which contributed to the grouping of all but one group into a heterogeneous group for the purposes of analysis.

The findings from this current study move us toward a better understanding of smoking and vaping among individuals with respiratory illnesses. Nonetheless, future research should seek to obtain further information via a nation-wide survey that includes individuals with respiratory illnesses who do not smoke or use ENDS products. Likewise, it would be worthwhile to explore the reasons for why individuals believe vaping is an acceptable method of smoking cessation and ways to alter this perception.

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Table 1

Frequency for Psychosocial Variables

Variable	*n*	*%*
Medical Health Condition		
Arthritis	96	35.56%
Cancer	42	15.56%
Chronic fatigue syndrome	44	16.30%
Chronic pain	60	22.22%
Diabetes	42	15.56%
Gastrointestinal (GI) disorder	46	17.04%
Heart Disease	34	12.59%
HIV Disease (AIDS)	3	1.11%
Hypertension (high blood pressure)	57	21.11%
Kidney Disease	20	7.41%
Multiple Sclerosis	13	4.81%
Parkinson's Disease	6	2.22%
Stroke	13	4.81%
Traumatic brain injury or other brain-related injury	8	2.96%
Any physical disability (e.g., quadriplegia, paraplegia, etc.)	4	1.48%
Other Medical Condition	2	0.74%
Eczema	1	0.37%
High cholesterol	1	0.37%
Mental Health Condition		
Anxiety	126	46.67%
Bipolar Disorder	55	20.37%
Depression (including dysthymia)	78	28.89%
Obsessive Compulsive Disorder (OCD)	33	12.22%
Post-Traumatic Stress Disorder (PTSD)	27	10.00%
Personality Disorder	15	5.56%
Schizophrenia	12	4.44%
Sleep Disorder (e.g., insomnia)	61	22.59%
Developmental Disability (ADHD, Learning Disorder, etc.)	19	7.04%
Neurocognitive Disorder (Dementia, MCI, etc.)	9	3.33%
Alcohol abuse	25	9.26%
Drug abuse	9	3.33%
Health-Related Quality of Life (QoL)		
Respiratory illness has negatively impacted (worsened) QoL	200	74.07%
Respiratory illness has not impacted QoL (no change)	56	20.74%

Respiratory illness has positively impacted (improved) QoL	14	5.19%

Table 2

Frequency of Respiratory Illness Variables

Variable	*n*	*%*
Respiratory Condition		
Acute Respiratory Distress Syndrome (ARDS)	47	17.41%
Asthma	111	41.11%
Bronchiectasis	78	28.89%
Bronchiolitis Obliterans	34	12.59%
Chronic Obstructive Pulmonary Disease (COPD)	88	32.59%
Coronavirus Disease 2019 (COVID-19)	12	4.44%
Cystic Fibrosis	18	6.67%
Diffuse Panbronchiolitis	32	11.85%
E-cigarette or Vaping product use Associated Lung Injury (EVALI)	26	9.63%
Interstitial Lung Disease (ILD); including Pulmonary Fibrosis	22	8.15%
Lung Cancer	15	5.56%
Sleep Apnea (central, obstructive, or mixed)	29	10.74%
Pulmonary Edema	5	1.85%
Pulmonary Embolism	12	4.44%
Pulmonary Hypertension	15	5.56%
Severe Acute Respiratory Syndrome (SARS)	10	3.70%
Tuberculosis	5	1.85%
Onset of Illness		
Illness diagnosed before smoking/vaping	96	35.56%
Smoking/vaping before illness was diagnosed	149	55.70%
Don’t know / Not sure	25	9.26%
Pulmonary Function Test (PFT)		
Yes	205	75.93%
No	50	18.52%
Don’t know / Not sure	15	5.56%
Currently Use Prescribed Inhaler		
Yes	191	70.74%
No	79	29.23%
Severe attack over past 12 months		

Yes	149	55.19%
No	121	44.81%
ER/Urgent Care Visit over past 12 moths		
Yes	168	62.22%
No	102	37.78%
Routine Medical Visit for Resp. Illness over past 12 months		
Yes	212	78.52%
No	58	21.48%

Table 3

Frequency of Health Risk Variables

Health Status	*n*	*%*
General Health		
Excellent - Good	127	47.04%
Fair - Terrible	143	52.96%
Respiratory Health		
Excellent - Good	111	41.11%
Fair – Terrible	159	58.89%
Perceived Stress Level	*n*	*%*
How often have you felt unable to control the important things in your life?		
Never - Almost Never	123	45.56%
Sometimes	114	42.22%
Fairly Often - Very Often	33	12.22%
How often have you felt confident about your ability to handle personal problems?		
Very Often - Fairly Often	74	27.41%
Sometimes	104	38.52%
Almost Never - Never	92	34.08%
How often have you felt things were going your way?		
Very Often - Fairly Often	64	20.71%
Sometimes	103	38.15%
Almost Never - Never	103	38.15%
How often have you felt difficulties were so high you could not overcome them?		
Never - Almost Never	122	45.18%

Sometimes	95	35.19%
Fairly Often - Very Often	53	19.63%
Symptom Severity	*n*	*%*
Chest pain/tightness		
None - Mild	182	67.41%
Moderate - Severe	88	32.59%
Coughing		
None - Mild	143	52.96%
Moderate - Severe	127	47.04%
Difficulty breathing in		
None - Mild	167	61.85%
Moderate - Severe	103	38.15%
Fatigue		
None - Mild	135	50.00%
Moderate - Severe	135	50.00%
Frequent need to clear throat		
None - Mild	156	57.78%
Moderate - Severe	114	42.22%
Heavy/rapid breathing		
None - Mild	155	57.41%
Moderate - Severe	115	42.59%
Itchy/dry throat		
None - Mild	169	62.59%
Moderate - Severe	101	37.41%
Phlegm production		
None - Mild	147	54.44%
Moderate - Severe	123	45.56%
Recurrent colds		
None - Mild	196	72.59%
Moderate - Severe	74	27.41%
Shortness of breath		
None - Mild	154	57.04%
Moderate - Severe	116	42.96%
Sleeping issues		
None - Mild	149	55.19%
Moderate - Severe	121	44.81%
Stuffed sinus/runny nose		
None - Mild	157	58.15%
Moderate – Severe	113	48.85%
Weight loss/gain		
None - Mild	183	67.78%
Moderate - Severe	87	32.22%
Wheezing		
None - Mild	170	62.96%
Moderate - Severe	100	37.04%

Difficulty/Impairment with Daily Activities (Functioning)	*n*	*%*
Bathing/Showering		
None - Mild difficulty	199	73.70%
Moderate - Severe difficulty	71	26.30%
Eating/Swallowing		
None - Mild difficulty	188	69.63%
Moderate - Severe difficulty	82	30.37%
Getting Dressed		
None - Mild difficulty	212	78.52%
Moderate - Severe difficulty	58	21.48%
Going Up Stairs		
None - Mild difficulty	174	64.44%
Moderate - Severe difficulty	96	35.56%
Lifting a Heavy Object		
None - Mild difficulty	166	61.48%
Moderate - Severe difficulty	104	38.52%
Running a Short Distance		
None - Mild difficulty	135	50.00%
Moderate - Severe difficulty	135	50.00%
Sleeping/Resting		
None - Mild difficulty	184	68.15%
Moderate - Severe difficulty	86	31.85%
Shopping		
None - Mild difficulty	182	67.41%
Moderate - Severe difficulty	88	32.59%
Toileting		
None - Mild difficulty	197	72.96%
Moderate - Severe difficulty	73	27.04%

Table 4

Summary Statistics for Health Risk Factors & Overall Health Risk

Variable	*M*	*SD*	*n*	SE_M	Min	Max	Skewness	Kurtosis
Health Status	3.56	1.94	270	0.12	0.00	8.00	0.47	-0.47
Stress Level	7.46	2.61	270	0.16	0.00	16.00	-0.37	1.21
Symptom Severity	30.01	12.17	270	0.74	0.00	60.00	-0.36	-0.32
Level of Functioning	15.97	10.14	270	0.62	0.00	40.00	0.02	-1.16
Overall Health Risk	57.00	21.65	270	1.32	8.00	107.00	-0.16	-0.54

Table 5

Demographic and Psychosocial variables according to ENDS Health Risk Perceptions

	ENDS Health Risk Perceptions				
	Higher Risk *n (%)*	**Lower Risk** *n (%)*	χ^2	*df*	*p*
AGE			1.04	1	.307
Older	68 (25.2%)	71 (26.3%)			
Younger	55 (20.4%)	76 (28.1%)			
GENDER			6.50	1	.011*
Female	66 (24.4%)	55 (20.4%)			
Male	57 (21.1%)	92 (34.1%)			
INCOME			2.07	1	.150
High Income	68 (25.2%)	95 (35.2%)			
Low Income	55 (20.4%)	52 (19.3%)			
EDUCATION			0.05	1	.826
More educated	46 (17.0%)	58 (21.5%)			
Less educated	77 (28.5%)	89 (33.0%)			
RELATIONSHIP STATUS			1.70	1	.192
Relationship	76 (28.1%)	103 (38.1%)			
Single	47 (17.4%)	44 (16.3%)			
ETHNICITY			4.03	1	.045*
Hispanic	46 (17.0%)	74 (27.4%)			
Non-Hispanic	77 (28.5%)	73 (27.0%)			
GEOGRAPHIC REGION			4.16	1	.041*
Other Regions	63 (23.3%)	56 (20.7%)			
South/Midwest	60 (22.2%)	91 (33.7%)			
RACE			7.40	1	.007*
Minority	20 (7.4%)	46 (17.0%)			
White	103 (38.1%)	101 (37.4%)			
FRIENDS WHO SMOKE			2.71	1	.100
0	23 (8.5%)	16 (5.9%)			
1 or more	100 (37.0%)	131 (48.5%)			
FRIENDS WHO VAPE			13.92	1	< .001*
0	29 (10.7%)	10 (3.7%)			
1 or more	94 (34.8%)	137 (50.7%)			
OVERALL HEALTH RISK			0.48	1	.490
Lower	60 (22.2%)	79 (29.3%)			
Higher	63 (23.3%)	68 (25.2%)			

Note. * Indicates significance at $p < .05$

Table 6

Results for Linear Regression with Health Risk Factors

Variable	*B*	*SE*	95% CI	β	*t*	*p*
(Intercept)	19.15	1.42	[16.34, 21.95]	0.00	13.46	< .001
Health Status	0.70	0.20	[0.30, 1.10]	0.22	3.42	< .001
Stress Level	-0.01	0.15	[-0.31, 0.29]	-0.00	-0.06	.956
Symptom Severity	0.03	0.04	[-0.05, 0.12]	0.06	0.78	.437
Level of Functioning	-0.03	0.05	[-0.13, 0.07]	-0.05	-0.56	.578

Note. Results: F (4, 265) = 4.01, p = .004, R^2 = 0.06

APPENDIX A
LETTER OF INFORMATION AND INFORMED CONSENT

Primary Investigator:
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Purpose of the Study
The purpose of this study is to learn more about Electronic Nicotine Delivery System (ENDS) (i.e., e-cigarettes, vapes) use among individuals with chronic respiratory illnesses (asthma, COPD, etc.). ENDS are battery-operated devices that usually resembles a cigarette, but do not involve the burning of tobacco. They are also known as e-cigs, e-cigars, vapes, vape pens, and other names. If you do not use e-cigarettes, we will ask for your opinions about them. This information will help us to better understand factors related to e-cigarette use among those with respiratory illnesses.

Eligibility
In order to participate, you must be 18 years of age or older, be able to read and write English fluently, have been diagnosed with a respiratory illness by a medical professional, and be a current or past smoker of any combustible tobacco product (i.e., cigarettes, cigarillos, cigars, blunts, bidis, or any other tobacco product), and/or a current or past ENDS user. Participants who use ENDS devices with or without nicotine are eligible to participate; those who **only** use ENDS devices containing cannabis products (e.g., THC, CBD oil, etc.) are not eligible for this study.

Procedures of the Study
If you are eligible, you will be asked to complete a survey online. The survey will consist of questions that ask about your past and current smoking and vaping behaviors, as well as your medical and mental health history. You will be able to adjust any of your responses by pressing the "Back" button to return to the previously completed page. We estimate that the questionnaire will take **approximately 15 minutes** to complete.

Compensation
At the end of the survey, you will be given the choice to provide your email address to be entered into a drawing to win one of four $50 gift cards.

Potential Risks and Benefits
The risks of participating in this study are minimal and unlikely. However, you will be asked questions about your smoking and vaping behaviors as well as your respiratory health which you may find stressful. You may choose not to respond to any question that

makes you feel uncomfortable and are free to discontinue your participation **at any point** during the study. While it is unlikely, there is also a risk of loss of privacy. We will keep your study records private and confidential, and all data will be de-identified and kept in a database that only researchers have access to. There will be no direct benefits to you by taking part in this study. However, the information obtained from this study may be used to help other smokers and vapers in the future.

Discontinuation of the Study
Participation in this study is **voluntary**. You are under no obligation to participate in this study, and you are free to discontinue the study at any time without consequences to you. There is no penalty for not participating. You may refuse to answer any questions that we ask you. If you decide to withdraw from the study, the information provided by you will not be retained.

Confidentiality
Your responses will be kept confidential. No identifying information will be collected during this survey. All data collected will be entered into a HIPAA-compliant database and stored on a password-protected server located in the Department of Psychology at Florida Institute of Technology. Only authorized researchers will have access to this information.

Questions?
Any questions about study participation may be directed to Sarah A. Sebban (Principal Investigator) at SSebban2018@my.fit.edu.

This study has been reviewed and approved by the Florida Institute of Technology's Institutional Review Board. If you have any ethical questions or concerns about the study, these may be directed to:
Dr. Jignya Patel, Chair for the Institutional Review Board
Institutional Review Board Office, School of Psychology
150 W. University Blvd
Melbourne, Florida, 32901
Phone: 321-674-7347
Email: FIT_IRB@fit.edu

Consent
In order to keep your information confidential, your name and signature are not required. Please indicate your choice below. Should you choose to participate, you will be directed automatically to the survey.

- o I have read the information presented above about a study being conducted by Sarah A. Sebban (Principal Investigator) of the School of Psychology at Florida Institute of Technology. I am 18 years or older, and I understand that I may withdraw from the study at any time. I agree to participate in this study.
- o I have read the information presented about this study and I do not wish to participate.

APPENDIX B
Survey

Qualifying Information:

1. Are you 18 years of age or older?
    a. Yes
    b. No
2. Are you able to read and write English fluently?
    a. Yes
    b. No
3. Have you ever been told by a doctor, nurse, or other health professional that you have a respiratory, pulmonary, or lung disease/illness (e.g., asthma, COPD, emphysema, chronic bronchitis, interstitial lung disease, sleep apnea, etc.)?
    a. Yes
    b. No
4. Do you still have this respiratory, pulmonary, or lung disease/illness?
    a. Yes
    b. No
5. Have you smoked at least 100 cigarettes (including cigarillos, cigars, blunts, biddies, or any other tobacco products) in your lifetime? 1 pack = 20 cigarettes, thus 5 packs = 100 Cigarettes
    a. Yes (score=1)
    b. No (score=0)
6. Have you ever used an electronic nicotine delivery system (ENDS) product (including electronic cigarettes, e-cigarettes, e-cigs, vapes, e-hookahs, hookah pens, or vape pens) even once in your lifetime? **NOTE**: If you have **only** used ENDS devices containing cannabis products, please select 'No'
    a. Yes (score=1)
    b. No (score=0)
7. Did you answer 'Yes' to **either** question 5 **or** 6 above?
    a. Yes
    b. No
8. Within the last 30 days, how often have you smoked cigarettes?
    a. Nearly Every Day (score=1)
    b. Some Days (score=1)
    c. I have not smoked any cigarette product within the last 30 days (score=0)
9. Within the last 30 days, how often have you used an electronic nicotine delivery system (ENDS)/vaping product?
    a. Nearly Every Day (score=1)
    b. Some Days (score=1)
    c. I have not used any ENDS product within the last 30 days (score=0)

Demographics:

10. What is your current age?
    a. 18-24 years old

b. 25-34 years old
c. 35-44 years old
d. 45-54 years old
e. 55-64 years old
f. 65-74 years old
g. 75 years or older

11. What sexual orientation do you identify with?
    a. Heterosexual (i.e., attracted to other sex)
    b. Homosexual (i.e., attracted to same sex)
    c. Bisexual
    d. Asexual
    e. Pansexual
    f. Other: _____
12. What gender do you identify with?
    a. Female
    b. Male
    c. Transwoman (MTF)
    d. Transman (FTM)
    e. Gender Fluid
    f. Other: _____
13. What is your race?
    a. White/Caucasian
    b. Black/African American
    c. Asian
    d. American Indian/Alaskan Native
    e. Hawaiian Native/Other Pacific Islander
    f. Biracial/Multiracial
    g. Other: _____
14. What is your ethnicity?
    a. Hispanic/Latino
    b. Non-Hispanic/Latino
15. How would you describe the area you currently live in?
    a. Urban/City
    b. Rural/Country
16. What geographic region do you currently reside in?
    a. **Northeast**: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, and Pennsylvania.
    b. **Midwest**: Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, and Kansas.
    c. **South**: Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Kentucky, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, and Texas.
    d. **West**: Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, Washington, Oregon, California, Alaska, and Hawaii.
    e. N/A, I live outside of the United States:
        *__What country do you currently live in? _____**

17. What is your current relationship status?
    a. Single
    b. In a relationship
    c. Married
    d. Divorced
    e. Widowed
18. What is your highest level of education completed?
    a. I did not graduate high school
    b. High School Diploma/GED
    c. Technical Degree/Certificate
    d. Associate Degree
    e. Bachelor's Degree
    f. Master's Degree
    g. Doctoral Degree
19. What is your approximate individual total annual income (before taxes)?
    a. $0-$19,000
    b. $20,000-$39,000
    c. $40,000-$59,000
    d. $60,000-$79,000
    e. $80,000-$99,000
    f. $100,000-$119,000
    g. $120,000 and over
20. What is your current occupational status?
    a. Employed full-time
    b. Employed part-time
    c. On disability
    d. Retired
    e. Unemployed
    f. Student

Psychosocial:

21. Has a doctor, nurse, or other healthcare professional **EVER** told you that you had any of the following chronic medical health conditions? *[Please select all that apply]*
    a. Arthritis (rheumatoid arthritis, gout, lupus, fibromyalgia, etc.)
    b. Cancer
    c. Chronic fatigue syndrome
    d. Chronic pain
    e. Diabetes
    f. Gastrointestinal (GI) disorder (Crohn's disease, ulcerative colitis, irritable bowel syndrome, or bowel incontinence)
    g. Heart Disease (heart attack, congestive heart failure, angina, etc.)
    h. HIV Disease (AIDS)
    i. Hypertension (high blood pressure)
    j. Kidney Disease
    k. Multiple Sclerosis

l. Parkinson's Disease
m. Stroke
n. Traumatic brain injury or other brain-related injury
o. Any physical disability (e.g., quadriplegia, paraplegia, amputation, etc.)
p. Other: _____

22. Have you **EVER** been informed by a health professional that you have any of the following mental health conditions? *[Please select all that apply]*
    a. Anxiety
    b. Bipolar Disorder
    c. Depression (including dysthymia)
    d. Obsessive Compulsive Disorder (OCD)
    e. Post-Traumatic Stress Disorder (PTSD)
    f. Personality Disorder
    g. Schizophrenia
    h. Sleep Disorder (e.g., insomnia)
    i. Developmental Disability (ADHD, Learning Disorder, Autism Spectrum Disorder, etc.)
    j. Neurocognitive Disorder (Dementia, MCI, etc.)
    k. Alcohol abuse
    l. Drug abuse
    m. Other: _____
23. Please rate the impact that your respiratory illness has had on the quality of your life.
    a. My respiratory illness has negatively impacted (worsened) my quality of life
    b. My respiratory illness has not impacted my quality of life (no change)
    c. My respiratory illness has positively impacted (improved) my quality of life

Cigarette Smoking Status and History:

24. For how many years have you smoked cigarettes?
    a. Years: _____
    b. N/A, I have never smoked cigarettes
25. Does your spouse/partner currently smoke cigarettes?
    a. Yes
    b. No
    c. N/A (No spouse / partner)
26. How many of your close friends currently smoke cigarettes?
    a. 0
    b. 1-2
    c. 3 or more
27. Do you feel that you smoke cigarettes to manage/cope with stress?
    a. Yes
    b. No
    c. N/A, I have never smoked cigarettes
28. Do you feel that your smoking habits have changed since/due to COVID-19?
    a. No, my smoking habits have not changed since COVID-19
    b. Yes, I started smoking cigarettes since the start of COVID-19

c. Yes, I smoke more since COVID-19
d. Yes, I smoke less since COVID-19
e. N/A, I have never smoked cigarettes

ENDS Smoking Status and History:

29. If you use or have ever used e-cigarettes/vaping products, how much nicotine is typically in your e-liquid?
    a. Nicotine amount: _____
    b. None, my e-cigarettes/vaping product does not contain any nicotine
    c. Not sure
    d. N/A, I have never used e-cigarettes/vaping products
30. Have you ever used an e-cigarette/vaping product to inhale other substances, such as CBD oil, alcohol, etc.?
    a. Yes
    b. No
    c. N/A, I have never used e-cigarettes/vaping products
31. For how many years have you used e-cigarettes/vaping products?
    a. Years: _____
    b. N/A, I have never used e-cigarettes/vaping products
32. What are the reasons you have used, **or might consider using,** e-cigarettes/vaping products? *[Please select all that apply]*
    a. Friend or family member used
    b. Help with quitting other tobacco products, such as cigarettes
    c. E-cigarettes cost less than other tobacco products, such as cigarettes
    d. E-cigarettes are easier to get than other tobacco products, such as cigarettes
    e. Famous people on TV or in movies use e-cigarettes
    f. E-cigarettes are less harmful to my health than cigarettes
    g. E-cigarettes are available in a variety of flavors, such as mint, candy, fruit, chocolate, etc.
    h. E-cigarettes can be used discreetly in areas where other products, such as cigarettes, are not allowed
    i. E-cigarettes do not leave a bad smell or taste like cigarettes do
    j. It is more socially acceptable to use e-cigarettes in my environment
    k. Some other reason: _____
    l. N/A, I would never consider using e-cigarettes
33. For those who **do not** currently vape, do you intend to start using e-cigarettes/vaping products?
    a. Yes, within the next month
    b. Yes, within the next 6 months
    c. Yes, within the next year
    d. Yes, sometime in the future
    e. No, I do not have any intentions to start using e-cigarettes/vaping products
    f. N/A, I already currently use e-cigarettes/vaping products
34. Does your spouse/partner currently use e-cigarettes/vape?
    a. Yes
    b. No

c. N/A (No spouse/partner)

35. How many of your close friends currently use e-cigarettes/vape?
    a. 0
    b. 1-2
    c. 3 or more
36. Do you feel that you use e-cigarettes/vaping products to manage or cope with stress?
    a. Yes
    b. No
    c. N/A, I have never used e-cigarettes/vaping products
37. Do you feel that your use of e-cigarettes/vaping products have changed since/due to COVID-19?
    a. No, my vaping habits have not changed since COVID-19
    b. Yes, I started using e-cigarettes since the start of COVID-19
    c. Yes, I vape more since COVID-19
    d. Yes, I vape less since COVID-19
    e. N/A, I have never used e-cigarettes/vaping products

Respiratory Health Status and History

38. Please select the respiratory, pulmonary, or lung disease/illness you have been diagnosed with. *[Select all that apply]*
    a. Acute Respiratory Distress Syndrome (ARDS)
    b. Asthma
    c. Bronchiectasis
    d. Bronchiolitis Obliterans
    e. Chronic Obstructive Pulmonary Disease (COPD); including emphysema or chronic bronchitis
    f. Coronavirus Disease 2019 (COVID-19)
    g. Cystic Fibrosis
    h. Diffuse Panbronchiolitis
    i. E-cigarette or Vaping product use Associated Lung Injury (EVALI)
    j. Interstitial Lung Disease (ILD); including Pulmonary Fibrosis
    k. Lung Cancer
    l. Sleep Apnea (central, obstructive, or mixed)
    m. Pulmonary Edema
    n. Pulmonary Embolism
    o. Pulmonary Hypertension
    p. Severe Acute Respiratory Syndrome (SARS)
    q. Tuberculosis
    r. Other: _____
39. Was your respiratory illness diagnosed **before** you started smoking or vaping?
    a. Yes
    b. No, I smoked/vaped first
    c. Don't know / Not sure
40. Have you ever been given a breathing test (Pulmonary Function Test) to assess your breathing problems?

a. Yes
b. No
c. Don't know / Not sure

41. During the past 12 months, have you visited an emergency room or urgent care center because of your respiratory, pulmonary, or lung disease/illness?
    a. Yes
    b. No
42. During the past 12 months, have you seen a doctor, nurse, or other healthcare professional for a routine checkup of your respiratory, pulmonary, or lung disease/illness?
    a. Yes
    b. No
43. Do you currently take/use medication for your respiratory, pulmonary, or lung disease/illness?
    a. Yes
    b. No
44. Do you currently use any type of medically prescribed inhaler?
    a. Yes
    b. No
45. During the past 12 months, have you had an episode of severe symptom exacerbation/attack?
    a. Yes
    b. No
46. <u>During the past 3 months</u>, have you used the kind of PRESCRIPTION inhaler that gives QUICK relief from symptoms during an exacerbation/attack?
    a. Yes
    b. No
47. <u>During the past 30 days</u>, how many days did you take a preventative medication (i.e., maintenance inhaler) to PREVENT a symptom exacerbation/attack from occurring?
    a. Never
    b. 1 to 14 days
    c. 15 to 24 days
    d. 25 to 30 days

ENDS Health Risk Perceptions

***Please complete the following questions regardless of if you smoke **OR** vape.*

48. E-cigarettes are harmful to one's health.
    a. Strongly Agree (score=3)
    b. Agree (score=2)
    c. Disagree (score=1)
    d. Strongly Disagree (score=0)
49. Do you believe the use of e-cigarettes/vaping is less harmful, equally harmful, or more harmful for people with pulmonary/respiratory problems than smoking regular cigarettes?
    a. Less harmful (score=0)
    b. As harmful (score= 1)

c. More harmful (score=2)

50. Compared to people your age **without** pulmonary/respiratory problems, do you believe it is less harmful, equally harmful, or more harmful for people **with** pulmonary/respiratory problems to use e-cigarettes?
    a. Less harmful (score=0)
    b. As harmful (score= 1)
    c. More harmful (score=2)
51. Using e-cigarettes would lead to serious health problems for someone like me in the next few months.
    a. Strongly Agree (score=3)
    b. Agree (score=2)
    c. Disagree (score=1)
    d. Strongly Disagree (score=0)
52. Using e-cigarettes would lead to serious health problems for someone like me, down the road (in the long-term future).
    a. Strongly Agree (score=3)
    b. Agree (score=2)
    c. Disagree (score=1)
    d. Strongly Disagree (score=0)
53. People with pulmonary/respiratory problems should not use e-cigarettes.
    a. Strongly Agree (score=3)
    b. Agree (score=2)
    c. Disagree (score=1)
    d. Strongly Disagree (score=0)
54. E-cigarettes are a safer alternative to regular cigarettes.
    a. Strongly Agree (score=0)
    b. Agree (score=1)
    c. Disagree (score=2)
    d. Strongly Disagree (score=3)
55. Do you believe that breathing in second-hand vapors from e-cigarettes is less harmful, equally as harmful, or more harmful than breathing in second-hand cigarette smoke?
    a. Less harmful (score=0)
    b. As harmful (score= 1)
    c. More harmful (score=2)
56. Inhaling vapors from e-cigarettes can harm one's health.
    a. Strongly Agree (score=3)
    b. Agree (score=2)
    c. Disagree (score=1)
    d. Strongly Disagree (score=0)
57. Use of e-cigarettes is:
    a. Less harmful to me than regular cigarettes (score=0)
    b. As harmful to me as regular cigarettes (score=1)
    c. More harmful to me than regular cigarettes (score=2)
58. I am hesitant to use e-cigarettes because of possible health risks.
    a. Strongly Agree (score=3)

b. Agree (score=2)
c. Disagree (score=1)
d. Strongly Disagree (score=0)

59. My respiratory/pulmonary symptoms will worsen if I use e-cigarettes.
    a. Strongly Agree (score=3)
    b. Agree (score=2)
    c. Disagree (score=1)
    d. Strongly Disagree (score=0)
60. The benefits of using e-cigarettes far outweigh the risks.
    a. Strongly Agree (score=0)
    b. Agree (score=1)
    c. Disagree (score=2)
    d. Strongly Disagree (score=3)
61. My risk of becoming ill from using e-cigarettes is low.
    a. Strongly Agree (score=0)
    b. Agree (score=1)
    c. Disagree (score=2)
    d. Strongly Disagree (score=3)

Smoking Cessation Perceptions Regarding ENDS

62. E-cigarettes/vaping products could help me **OR** others quit smoking regular cigarettes (i.e., e-cigarettes are an effective method of smoking cessation).
    a. Strongly Agree (score=3)
    b. Agree (score=2)
    c. Disagree (score=1)
    d. Strongly Disagree (score=0)
63. E-cigarettes/vaping products could help me **OR** others reduce the number of cigarettes smoked.
    a. Strongly Agree (score=3)
    b. Agree (score=2)
    c. Disagree (score=1)
    d. Strongly Disagree (score=0)

Healthcare Provider Communication:

64. Have any of your healthcare providers ever discussed the risks of smoking with you?
    a. Never (score=0)
    b. Once or Twice (score=1)
    c. Frequently (score=2)
65. Have any of your healthcare providers ever discussed the risks of vaping with you?
    a. Never (score=0)
    b. Once or Twice (score=1)
    c. Frequently (score=2)
66. Have any of your healthcare providers advised you to use typical smoking cessation interventions, such as **Nicotine Replacement Therapy** (patch, lozenge, gum, nasal

spray), **Non-Nicotine Replacement Therapy** (Chantix, Wellbutrin, Elavil), or **Behavioral Counseling** (therapy) to quit smoking or reduce the number of cigarettes smoked?

a. Never (score=0)
b. Once or Twice (score=1)
c. Frequently (score=2)

67. Have any of your healthcare providers advised the use of e-cigarettes/vaping products to quit cigarette smoking or reduce the number of cigarettes smoked?

a. Never (score=2)
b. Once or Twice (score=1)
c. Frequently (score=0)

Health Risk Variables:

(A) Health Status

68. Would you say your general health is:

a. Excellent (score=0)
b. Good (score=1)
c. Fair (score=2)
d. Poor (score=3)
e. Terrible (score=4)

69. Would you say your respiratory health is:

a. Excellent (score=0)
b. Good (score=1)
c. Fair (score=2)
d. Poor (score=3)
e. Terrible (score=4)

(B) Stress Level

70. In the last month, how often have you felt that you were **unable** to control the important things in your life?

a. Never (score=0)
b. Almost Never (score=1)
c. Sometimes (score=2)
d. Fairly Often (score=3)
e. Very Often (score=4)

71. In the last month, how often have you felt confident about your ability to handle your personal problems?

a. Never (score=4)
b. Almost Never (score=3)
c. Sometimes (score=2)
d. Fairly Often (score=1)
e. Very Often (score=0)

72. In the last month, how often have you felt things were going your way?
    a. Never (score=4)
    b. Almost Never (score=3)
    c. Sometimes (score=2)
    d. Fairly Often (score=1)
    e. Very Often (score=0)
73. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?
    a. Never (score=0)
    b. Almost Never (score=1)
    c. Sometimes (score=2)
    d. Fairly Often (score=3)
    e. Very Often (score=4)

(C) Respiratory Symptom Severity

74. Thinking about your respiratory illness symptoms, please rate the frequency/severity of each symptom listed below:

	None	Slight	Mild	Moderate	Moderately Severe	Severe
Chest pain/tightness	0	1	2	3	4	5
Coughing	0	1	2	3	4	5
Difficulty breathing in	0	1	2	3	4	5
Fatigue	0	1	2	3	4	5
Frequent need to clear throat	0	1	2	3	4	5
Heavy/rapid breathing	0	1	2	3	4	5
Itchy/dry throat	0	1	2	3	4	5
Phlegm production	0	1	2	3	4	5
Recurrent colds	0	1	2	3	4	5
Shortness of breath	0	1	2	3	4	5
Sleeping issues	0	1	2	3	4	5
Stuffed sinus/runny nose	0	1	2	3	4	5
Weight loss/gain	0	1	2	3	4	5
Wheezing	0	1	2	3	4	5

(D) Level of Functioning

75. As it pertains to your respiratory illness, please rate your typical level of difficulty/ impairment with completing each activity below.

	No difficulty	Slight difficulty	Mild difficulty	Moderate difficulty	Moderately Severe difficulty	Severe difficulty
Bathing/showering	0	1	2	3	4	5
Eating/swallowing	0	1	2	3	4	5
Getting dressed	0	1	2	3	4	5
Going up stairs	0	1	2	3	4	5
Lifting a heavy object	0	1	2	3	4	5
Running a short distance	0	1	2	3	4	5
Sleeping/resting	0	1	2	3	4	5
Shopping	0	1	2	3	4	5
Toileting	0	1	2	3	4	5