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Electronic nicotine delivery systems (ENDS) use and its association with

low academic achievement among 9th-12th grade students in the US –

2017 Youth Risk Behavior Survey (YRBS)

By

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Master of Public Health

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B.S., Georgia College and State University, 2012

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An abstract of
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Abstract

Electronic nicotine delivery systems (ENDS) use and its association with
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By: Olivia Russell

Objective. In 2018, the United States (US) Surgeon General declared adolescent electronic nicotine delivery systems (ENDS) use an epidemic and called for aggressive steps to reduce ENDS use among adolescents. There is ample evidence how tobacco smoking impacts academic achievement among adolescents; however, there is a need to explore the association of ENDS use with low academic achievement in high school students in the US, to guide translational research on ENDS use and its prevention programs.

Methods. We used self-administered questionnaire response data from the 2017 Youth Risk Behavior Survey (YRBS), a nationally representative cross-sectional survey of 14,765 US high school adolescents (9th-12th grade). Low academic achievement was defined as receiving mostly Cs, Ds, and Fs in the previous 12 months. Multiple logistic regression was performed to estimate crude and adjusted prevalence odds ratios (cPOR and aPOR, respectively) and associated 95% confidence intervals (CI) to examine the association. Adjusted analyses were stratified by gender, and controlled for year in school, race/ethnicity, and cigarette use.

Results. In 2017, 13.2% of adolescents reported current ENDS use in the past 30 days of YRBS survey, 21.5% reported past use, and 65.2% never used ENDS. Our stratified adjusted analysis showed that among females, current ENDS users had 2.3-times (95% CI: 1.5 – 3.4) higher odds for low academic achievement compared to never ENDs users, and among males, past ENDS users had 1.3- times (95% C.I.: 1.1 – 1.5) higher odds of low academic achievement, relative to those who reported never ENDS use.

Conclusions. In our study examining a nationally representative sample of high school adolescents in the US, ENDS use was positively associated with lower academic achievement in both genders, however the association was stronger in females. Prevalence of ENDS use fluctuates in the adolescent population, and hence knowledge of gender's differential effect on the association between ENDS use and academic achievement should be examined in future analyses.

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CHAPTER 1: Literature Review

PUBLIC HEALTH SIGNIFICANCE

Academic achievement in school has lasting effects on adolescents and is an important social determinant of health [1]. Despite numerous educational reforms and a large investment in spending, little progress has been observed in advancing student's academic achievement in the United States (US) over the past few decades [2]. While some progress has been made in terms of increasing graduation rates and closing achievement gaps, academic achievement in terms of math, science, and reading test scores do not compare favorably to other industrialized countries [3, 4]. One theory proposed to explain this lack of progress is health related barriers to learning, that can pose significant threats to students' motivation and ability to learn [2].

Tobacco use is the leading cause of preventable morbidity and mortality in the US, and accounts for roughly 8.7% of all annual healthcare spending in the US (~170 billion USD per year) [5, 6]. Most tobacco usage is initiated in adolescence. By the age of 18, 88% of smokers have smoked their first cigarette, and 99% of first use occurs by the age of 26 [7]. While cigarette usage has steadily declined among adolescents over the past two decades, tobacco usage has been recently increasing due to the introduction and growing popularity of electronic nicotine delivery systems (ENDS). In 2014, ENDS became the most commonly used tobacco products among adolescents [8]. By, 2018 the US ranked number one in terms of the global market share of ENDS products at roughly 7 billion USD; in second place, was the United Kingdom at roughly 2.5 billion USD [9].

ENDS contain nicotine, a highly addictive chemical present in tobacco products that can have significant and lasting effects on the developing brain and can lead to sustained tobacco product use [10]. Furthermore, multiple studies suggest that adolescents

who use ENDS are more likely to subsequently initiate cigarette smoking [11, 12]. As a result, many of the strategies employed in tobacco prevention and control should be utilized to discourage the initiation of nicotine addiction facilitated via ENDS among adolescents [13-15]. In 2018 the US Surgeon General declared adolescent electronic nicotine delivery systems (ENDS) use an epidemic and called for aggressive steps to reduce ENDS use among adolescents [16].

ELECTRONIC NICOTINE DELIVERY SYSTEMS (ENDS)

ENDS. The term "electronic nicotine delivery systems" (ENDS) is used in the scientific literature to describe a range of products that are designed to deliver aerosolized nicotine and other additives, including a wide variety of flavorings, to the user [17]. There are several types and designs of these battery powered devices available on the market including e-hookahs, hookah pens, vape pens, e-cigars, e-pipes, and most commonly, e-cigarettes [18]. These devices are often referred to using a variety of terms including, vapes, pod systems, tanks, and mods as well as by their brand names, such a JUUL [17]. ENDS differ from traditional combustible tobacco products such as cigarettes, cigarillos, cigars, pipe tobacco, and hookahs, which involve the burning of tobacco leaf for inhalation [8, 17, 19].

ENDS Design. Commonly, ENDS consist of the following components: a mouthpiece, a sensor or button used to activate the heating coil, a battery, a heating coil or atomizer, and a reservoir or tank [20]. When users inhale from the mouthpiece, the heating coil is activated to aerosolize the liquid from the reservoir tanks that is then inhaled by the user [17]. This solution often contains varying levels of nicotine (up to 5%), a humectant

(most often propylene glycol (PG) and vegetable glycerin (VG)), and a variety of fruit and candy flavors such as mango, cucumber, mint, and crème brulee [18].

ENDS Emissions. While the emissions produced by ENDS are often referred to as vapor, it is more accurately descried as an aerosol, as it is made up of a suspension of particles in gas. The term secondhand aerosol refers to the emission of an ENDS product exhaled by the user that bystanders are exposed to. Thirdhand aerosol refers to the nicotine and toxicants that are present in the environment, predominantly on surfaces, from the emissions an ENDS user exhales, that can be absorbed through contact [17].

History of ENDS. Beginning in the 1960s, tobacco companies became aware of the addictive nature of nicotine, and its usefulness in ensuring a loyal customer base. As research began to point to an association between cigarettes and cancer, the need for a product that could deliver nicotine to the user without burning tobacco spurred British American Tobacco (BAT) to covertly launch Project Ariel [18, 21]. The project's objective was to create a product that could delivery nicotine to the user, without any tar or carbon monoxide, that would look and feel like a cigarette. After a few years of research and development, the first functional aerosol-smoking device had been created, and patents were filed under the name Battelle (its creator) in order to disguise its association with BAT. Due to the drawbacks of the design (throat irritation and poor taste of smoke), lack of anticipated tobacco industry regulation, and insurance that no other company could put similar devices out on the market until 1984 when their patents would expire, BAT decided not to bring the products to market [21]. Nearly 25 years later, Phillip Morris invested in similar research and developed the "Premier" Capillary Aerosol Generator. While this

product also failed to make it to market, its technology is similar to their subsequent electronic cigarette patent from 2009 [22].

Invention of the e-cigarette is attributed to Chinese pharmacist, Hon Lik (former deputy director of the Institute of Chinese Medicine in Liaoning Province) in 2003. It first appeared on the market in China in 2004 under the company name Ruyan and gained attention as a potential alternative cigarette or smoking cessation device. In 2007, after obtaining a US patent, the product came to the US market [10]. Although marketed as a smoking cessation device, to date, no FDA approval has been granted for that indication. Further meta-analysis of 26 studies found that adults who use ENDS for the purpose of cessation are 27% less likely to quit smoking traditional cigarettes than smokers who do not use ENDS [17].

Despite its short lifetime on the market, ENDS devices have gone through several changes in terms of design, and are often referred to as first-, second-, third-, and fourth-generation devices. First-generation ENDS are often referred to as cigalikes, are small and meant to resemble cigarettes. They are often disposable or have refillable cartridges. Second-generation devices are commonly known as vapes or vape pens and contain a refillable reservoir for e-liquid. Third generation devices, or "mods" or tank systems, are named because of their modifiable wattage and voltage capabilities that can alter the size, distribution, and amount of aerosol particles as well as nicotine content. Their reservoirs also tend to hold a larger volume of e-liquid. Fourth-generation devices are the most recent products to enter the market, and do not resemble cigarettes, or previous ENDS devices. They are sold under the same JUUL, Suorin, and SMPO. They were designed to resemble a flash drive, can be charged using a USB port, come with prefilled, non-modifiable

cartridges of flavored e-liquid called pods, and are easily concealable [17]. Their trendy, hi-tech design furthers their appeal, as they are often referred to as the "iPhone of e-cigarettes" [23]

JUUL was first sold in 2015, and quickly began to dominate the ENDS market. In the beginning of 2017, JUUL sales represented 13.6% of the US ENDS market, and by August 2018, represented 72.1% of the market [17, 24]. Because of their popularity among adolescents, the act of using an ENDS device is often referred to by adolescents as "JUULing," and previous studies are thought to have underreported adolescent ENDS usage if surveys did not use the brand name JUUL or the term JUULing to refer to ENDS usage [25, 26]. Starter kits include a JUUL device, charging dock, and four flavored pods. These kits cost $49.99. Replacement pods come in packs of four and cost $15.99. Each pod contains roughly 200 puffs, the equivalent of a pack of traditional cigarettes. These products are available for purchase online and in multiple retail stores including vape shops, gas stations, and convenience stores [17]. One of the draws of JUUL which has been cited in media reports and surveys is that the devices can be used covertly inside school classrooms [8].

JUUL comes in two nicotine strengths: 1.8% (18 mg/mL) and 5% (59mg/mL) [18], however some research has shown the nicotine content labeling can be incorrect, and actual levels can be more than 50% greater than advertised [20]. At present, JUUL products have the highest nicotine content on the market and have a formulation that allows for a more pleasant user experience. This is achieved through the addition of a protonated salt, as opposed to the free-base nicotine found in earlier generations of ENDS devices, which makes the product more pleasant to inhale, especially for users who have never

smoked combustible tobacco products like cigarettes [18, 27]. Additionally, this formulation can deliver a nicotine peak more quickly giving an experience more equitable to traditional cigarettes[18]. In fact, ENDS usage may expose the user to higher levels of nicotine than conventional cigarette usage. One study found that urinary cotinine (nicotine exposure level indicator) was higher in adolescent ENDS users than cigarette users [27]. This more potent and palatable formula makes JUUL attractive to both adolescent and adults who have and have not smoked traditional cigarettes [23].

Health Effects of ENDS. Nicotine is well known to be a highly addictive substance [10]. Adolescents are particularly susceptible to these effects, even with sporadic and infrequent use [18]. Addiction is caused by nicotine's primary psychoactive actions. Nicotine binds to cholinergic receptors in the brain, which releases dopamine as a part of the pathway involved in drug-induced rewards, which creates dependence [28]. Withdrawal symptoms are marked by affective (irritability and anxiety), behavioral (sleep disturbances and increased appetite) and cognitive (difficulty concentrating) symptoms [10]. Nicotine addiction is known to affect the areas of the brain controlling executive function, memory, and mood, and can have lasting effects on the developing adolescent brain [17]. Further, there are distinct differences in the response to nicotine between the two genders. Females metabolize nicotine and cotinine faster than males, due the presence of estrogen. They are also less sensitive to the rewarding effects of nicotine, and are more likely to report subjective adverse reactions [29].

Data exists suggesting the inhalation of ENDS aerosols has potential short- and long- term health effects, in part due to the unregulated contents of e-liquid. Both propylene glycol (PG) and vegetable glycerin (VG) are common forms of humectants in most e-liquid

formulations, which give the aerosol its smoke like appearance. While both are classified as "generally recognized as safe" for ingestion or dermal application, neither have been deemed safe for inhalation. PG is known to cause respiratory and eye irritation, and VG forms acrolein, which is a known respiratory irritant [18, 30].

There is a growing concern regarding the toxicity profile of flavor compounds included in e-liquid. While these flavorings are recognized as safe for consumption in foods, there is little data suggesting that inhalation of these compounds are safe [10]. In fact, some *in-vitro* studies have observed significant toxicity of flavoring compounds in relevant lung cell lines suggesting potential health effects on long term *in-vivo* exposure [31]. Further, some flavorings are known to contain several toxic compounds (such as diacetyl and acetyl propionyl) in concentrations exceeding the National Institute of Occupational Safety and Health's recommendations [20]. Exposure to these compounds are associated with the development of bronchiolitis obliterans, or "popcorn lung" [30].

While manufacturers of ENDS promote the safety of the devices due to the claim that the vapor contains only water, nicotine, PG or VG, and flavorings, studies have found varying levels of heavy metals such as chromium, nickel, tin, silver, cadmium, mercury, and aluminum in the vapor. Additionally, carcinogens have also been identified such as formaldehyde and acetaldehyde, especially when the heating element of an ENDS device is operated at a high voltage [20].

E-liquid also poses a poisoning risk, in cases of transdermal exposure or oral ingestion. In 2011, 271 cases of e-liquid associated poisoning was reported, compared to 3,783 cases in 2014, half of which involved exposures among children [10]. Data from Texas poison control show a similar trend, with two cases attributed to e-liquid exposure

in 2009, to 123 reported in 2013[20]. As a result of this trend, the Child Nicotine Poisoning Prevention Act of 2015, enacted in 2016, requires all e-liquid containers to child-proof for children under the age of five [10].

There is a growing concern that ENDS usage may be serving as a gateway to nicotine addiction and subsequent initiation of traditional cigarette smoking. One study using pooled NYTS data from 2015 to 2017 examined this association, and found that ENDS usage was significantly associated ($p < 0.05$) with subsequent initiation and continued use of traditional cigarettes [32]. Another study looking at 3 waves of the PATH study (2013-2016) found similar results. ENDS users were more than 4 times as likely to ever use cigarettes, and nearly 3 times more likely to be a current cigarette user when compared to never tobacco users. Of note, this association was also observed in low-risk adolescents when analysis was stratified at baseline for risk-taking behaviors [33]. A systematic review and meta-analysis was also conducted on the issue that included 9 longitudinal studies of 17,389 adolescents confirming the odds ratios reported in the PATH study [11].

TOBBACO USE PREVALENCE

Prevalence of adolescent ENDS usage, particularly of high school students in the US, is monitored by several surveillance studies including the *Youth Risk Behavioral Surveillance System* (YRBSS), *National Youth Tobacco Survey* (NYTS), *Population Assessment of Tobacco and Health* (PATH), and the *Monitoring the Future Project (*MTF*)*.

Youth Risk Behavior Survey (YRBS). In 1991 the Centers for Disease Control and Prevention (CDC) developed the YRBS to collect data on six categories of health-risk behaviors associated with the leading causes of morbidity and mortality among adolescents

in the US on a biannual basis. The six categories include: 1) unintentional injuries and violence; 2) sexual risk behaviors, sexually transmitted diseases, and unintended pregnancies; 3) tobacco use; 4) alcohol and substance use; 5) dietary behaviors; and 6) physical activity. The system was designed to provide information on the prevalence of health-risk behaviors, as well as to assess trends in health risk behaviors over time [34]. While the YRBS has included questions pertaining to tobacco use since 1991, the 2015 survey is the first year when ever or current ENDS use was assessed [35]. Current ENDS use is defined as having used an ENDS product for a day or more within the past 30 days. Ever use is defined as having ever tried an ENDS product, even if only for one or two puffs [35-38]. Dual use describes the use of ≥ 2 tobacco products [8].

The 2017 data set includes survey data for 14,765 students from 144 schools utilizing a three stage cluster design to produce a nationally representative sample of 9-12th grade students who attend public and private schools in the US (including all 50 states and the District of Columbia) [37]. In 2015 the YRBS found that 44.9% of students reported ever ENDS use, compared to 44.2% of students in 2017 [35, 37]. In 2015, 24.1% of students were current ENDS users [35, 37]. In 2017, only 13.2% of students reported current ENDS use [37].

National Youth Tobacco Survey (NYTS). The NYTS is a cross-sectional, school based, self-administered questionnaire designed to collect data on tobacco-related beliefs, attitudes, behaviors, and exposure to pro- and anti- tobacco influences among adolescents [38]. Like the YRBS, the NYTS utilizes a three-stage cluster procedure to generate a nationally representative sample of public and private middle (grades 6-8) and high (grades 9-12) school students in the US [19]. This data helps to evaluate various short-term,

intermediate, and long-term effects of various tobacco prevention and control measures. The survey was first conducted in 1999 and has continued on biannual or annual basis since. Data is available on current adolescent ENDS usage since 2011 [19].

The 2019 NYTS provides data on 10,097 high school students [36]. In 2019, 46.9% of students reported ever using ENDS products, while 27.5% of students reported current ENDS usage. Among current ENDS users, 18.0% reported ENDS usage on 20 or more days in the past 30, and 72.2% of current ENDS users reported current use of flavored ENDS products [36]. Current flavored ENDS users most commonly reported using fruit (66.1%), menthol or mint (57.3%), or candy, dessert, or other sweets flavors. Current ENDS user also overwhelmingly reported using JUUL (59.1%) as their usual brand [38].

Population Assessment of Tobacco and Health (PATH). After congress gave the US Food and Drug Administration (FDA) the authority to regulate tobacco products in 2009, the FDA partnered with the National Institute of Health (NIH) to create the PATH study. This study is a nationally representative longitudinal cohort study of adolescents and adults (age 12 and older) in the US that began in 2013 and is on-going. Because of its design, the study is able to collect information on tobacco use patterns including initiation, cessation, relapse, and transition between products, as well as risk perceptions and attitudes on varying tobacco products. In addition to the survey aspect of the PATH study, bio specimens are collected from consenting adults (18 years and older) to allow for the measurement of tobacco related biomarkers and exposures. As of 2016, 45,971 individuals are enrolled in the study [39].

Monitoring the Future (MTF). The MTF project has been measuring drug use and related risk factors in a national sample of 12th graders in the US since 1975, and has since

expanded the sample to include 8th and 10th graders on a wider variety of health related risk behaviors [34]. In 2017, the study assessed ENDS usage and found that 16% of 10th graders, and 19% of 12th graders had used a ENDS product in the previous year while 8.2% of 10th graders and 11.0% of 12th graders reported current ENDS usage [40]. In 2018, current ENDS usage was reported as 16.1% for 10th graders, and 20.9% of 12th graders [41].

Reasons for Use. Understanding why adolescents are initiating ENDS use is crucial in order to determine where to focus prevention and intervention strategies. One longitudinal study found that adolescents most commonly cited curiosity, flavors, and "family and friends were using them", as to why they tried ENDS [42]. Other reasons cited included easy concealability, "can use anywhere", and perceived as "being safer than traditional cigarettes". This is consistent with previous studies done on smaller focus groups [43]. Studies conducted using 2016 NYTS data also found similar results. Among middle and high school ENDS users, reasons for usage was most often cited as "friends or family members use them," "they are available in flavors, such as mint, candy, fruit, or chocolate," and "they are less harmful then other forms of tobacco, such as cigarettes" [44]. Data from the 2015 MTF study also examined adolescents' reasons for ENDS usage and found the most common reasons cited were experimentation/curiosity, taste, and boredom [45]. Adolescents, however, do not cite smoking cessation as a primary reason for ENDS usage [10].

TRENDS IN TOBACCO USE AMONG ADOLESCENTS

ENDS Use. According to the YRBS, ever usage of ENDS products did not significantly change between 2015 and 2017, however, current usage of ENDS products

significantly decreased from 2015 to 2017 [35, 37]. The NYTS provides more trend data. From 2011 (when ENDS was first introduced into the survey) – 2015, current ENDS usage increased from 1.5% to 16.0%, however, ENDS usage significantly decreased to 11.3% in 2016. This trend quickly reversed, as current ENDS usage rose significantly from 2016-2019 [8, 38]. By 2018, 20.8% of high school students were current ENDS users, which increased to 27.5% in 2019 [8, 36]. Similarly, the MTF project found that from 2017-2019 current ENDS usage significantly increased among 10th and 12th graders in the US, translating into approximately 1.3 million additional adolescents who reported current ENDS usage in 2018, when compared to 2017. This observed increase represents the largest ever recorded by the MTF in the 44 years since its inception monitoring substance use [41].

Cigarette Use. The YRBS found that in 2017, 28.9% of students reported ever usage of cigarettes. From 1991 – 2017 (the entire life of the survey), significant linear decrease in ever cigarette use has occurred from 70.1% - 28.9%, however this decrease in prevalence occurred after 1999. No significant change in ever cigarette usage was detected from 2015-2017 (32.3% - 28.9%). Regarding current cigarette usage, 8.8% of students reported usage in 2017. This reflects a significant, but nonlinear trend in current usage from 1991-2017. From 1991-1997 prevalence of current cigarette use rose from 27.5% to 36.4%, before steadily decreasing every year from 1997-2017. Current cigarette usage among students did not significantly change from 2015 – 2017 (10.8% - 8.8%) [35, 37].

The NYTS found similar trends. From 2011-2018 current usage of combustible tobacco significantly decreased from 21.8% to 13.9% [8]. In 2019, the NYTS found the prevalence of current cigarette smoking to be 5.8% among high school students, the lowest

it has ever been reported since the survey began in 1999 [8, 36]. While only 5.8% of students report current cigarette use in 2019, 22.6% report having ever tried traditional cigarettes [36].

Tobacco Dual Use. Dual use describes the use of $\geq$ 2 tobacco products [8]. According to the 2017 YRBS, 19.5% of students reported current usage of tobacco products. As this questions was first added to the survey in 2017, no trend data is available [37]. The NYTS however, offers trend data on overall tobacco and dual usage. From 2011-2018, the NYTS found no significant trend in the overall use of tobacco products, however significant changes were observed regarding the combined use of $\geq$ 2 tobacco products. From 2011-2018, current dual usage significantly decreased in a non-linear trend from 12.0% to 11.3% [8]. However, from 2017-2018, dual use significantly increased from 9.2% to 11.3%, and rose again in 2019 to 33.9% [8]. The 2019 NYTS survey indicates that 53.3% of high school students in the US had ever tried a tobacco product, and 31.2% reported being current users of a tobacco product. [36]. Multiple tobacco product use during adolescents is a known to increase the risk of developing a nicotine dependence that results in chronic use extended into adulthood [5, 7]. While the 2019 data suggests that most adolescent tobacco product users are not daily users, even infrequent use (1-5 days in the preceding month) can lead to nicotine dependence [46].

ENDS RISK FACTORS

Understanding both the demographic and individual risk behaviors associated with ENDS usage offers the unique opportunity to tailor intervention measures to the most vulnerable populations and individuals. Because ENDS usage has been associated with cigarette usage by many studies [11, 32, 33, 47], three hypotheses to explain the

relationship have been proposed by the 2018 National Academies of Science, Engineering and Medicine Report. First is the *diversion hypothesis*, which states that high-risk adolescents who may normally have been traditional cigarette smokers are using ENDS products instead. Second, is the *common liability hypothesis,* which states that the positive association between ENDS and cigarette smoking is due to shared risk factors. Third, is the *catalyst hypothesis,* which states that low-risk adolescents, who would otherwise not use traditional cigarettes, are susceptible to ENDS usage, which in turn makes then susceptible to traditional cigarettes [47]. Over the past several decades a great deal of research into risk behavior associated with cigarette usage has been reported on; however, few studies have examined such a wide array of risk factors associated with ENDS use. Examining the different demographic and individual behavior risk factors for ENDS use can provide evidence for the different hypotheses, which will help inform prevention measures.

Age/grade. The 2017 YRBS data shows that the prevalence for ever and current usage of ENDS devices increases with grade in school. 32.7% of 9th graders, 41.0% of 10th graders, 48.0% of 11th graders, and 48.6% of 12th graders have ever tried ENDS products, compared to 9.5% of 9th graders, 11.4% of 10th graders, 14.1% of 11th graders, and 18.3% of 12th graders who reported being current ENDS users. Ever and current usage of traditional cigarettes showed the same prevalence trend among 9th, 10th, 11th, and 12th grade students, 20.9%, 26.1%, 33.1%, 37.1%, and 5.2%, 7.6%, 9.5%, 13.4%, respectively [37, 48]. Further, longitudinal studies (PATH) have found that older students are more likely to be susceptible to ENDS usage than younger adolescents, as indicated by their willingness to try ENDS among non-users [48].

Gender. According to the 2017 YRBS data, ENDS use is more prevalent among males than females. 44.9% of males reported ever use of an ENDS device compared to only 39.7% of females. This prevalence trend extends to current ENDS use (15.9% of males compared to 10.5% of females), as well as ever and current use of traditional cigarettes (30.7% and 27.3%, and 9.8% and 7.8%, respectively) [37, 48]. Other studies have identified a similar significant trend, with one finding males to be twice as likely as females to report current ENDS use [49]. Further, longitudinal studies have found that males are significantly more likely to be susceptible to ENDS use, as indicated by their willingness to try ENDS among non-users [48].

Race/Ethnicity. 2017 YRBS data found that Hispanic adolescents showed the highest prevalence of ever ENDS use while white adolescents reported the highest prevalence of current ENDS use. 48.7% of Hispanic students, 41.8% of white students, and 36.2% of black students reported ever ENDS use compared to 15.6% of white students, 11.4% of Hispanic students, and 8.5% of black students who reported current ENDS use. Regarding traditional cigarettes, white adolescents report the highest prevalence of ever and current use, followed by Hispanic and then black adolescents: 29.1%, 27.5%, 21.2% and 11.1%, 7.0%, 4.4%, respectively [37, 48].

Socioeconomic Status (SES). A 2016 systematic review of longitudinal studies identified 6 publications on SES and smoking onset among never tobacco using adolescents, and found a significant inverse association between SES and smoking onset [50].

Academic Achievement. One study using MTF data, examined current ENDS use and academic performance and school truancy, and found that adolescent ENDS users were

significantly more likely than non-tobacco users to report lower academic performance (grade point average of C or lower) and truancy, when controlling for age, sex, race/ethnicity, school geographic region, metropolitan area, parental education, and college plans. This significant association held up when looking at adolescents who engaged in either experimental, occasional, and frequent ENDS usage when compared to non-users. [51]. Additionally, data from the 2013-2014 PATH study found committed never tobacco users were significantly less likely to report low academic achievement than ENDS users when controlling for age, sex, and race/ethnicity. They also found that adolescents susceptible to future ENDS use were significantly more likely to report lower academic achievement than committed never users controlling for age, sex, and race/ethnicity [47].

Alcohol Use. Looking at 2017 YRBS data, current ENDS, cigarette, and dual use was significantly associated with consuming alcohol for the first time before the age of 13, consuming alcohol in the past 30 days, binge drinking, and having driven a car while drunk in the past 30 days [48]. Studies looking at the MTF data also found that students who were current ENDS users were significantly more likely to have engaged in current alcohol use and binge drinking when compared to non-users ($p < 0.001$) [51].

Substance Use. Analysis of the 2015 YRBS showed that current ENDS use as well as current cigarette and dual use was significantly associated with current marijuana use, nonmedical use of prescription drugs, and "other illicit drugs" [52]. 2017 YRBS data was subsequently analyzed regarding a wider variety of substance abuse risk factors and found similar results. The 2017 study found significant association between current ENDS, cigarette, and dual use and ever and current marijuana use, and ever nonmedical use of prescription drugs, cocaine, ecstasy, and hallucinogens [48]. Studies looking at the MTF

data found similar results. Current ENDS users were significantly more likely than non-users ($p < 0.001$) to report current marijuana, illicit drugs, and nonmedical use of prescription drugs [51]. These results were further replicated in a study done on a population of 9th graders in California, where the authors observed the highest risk of substance abuse among dual users, followed by cigarette users, and ENDS users when compared to non-users [53].

Mental-Health. A study looking at 2015 and 2017 YRBS data examined the association between current ENDS users with depression and suicide ideation using the questions, "During the past 12 months, did you ever feel so sad or hopeless almost every day for two weeks or more in a row that you stopped doing some usual activities?" and "During the past 12 months, did you ever seriously consider attempting suicide?"[54]. Results indicated that ENDS users were significantly more likely to experience depression and suicide ideation than non-users. Additionally, earlier cross-sectional studies conducted in California on population of 9th graders, found similar results. Current ENDS use, as well as cigarette and dual use was significantly associated with depressive symptoms when compared to non-user. Further, as seen in other risk factors, the strongest associations were seen in dual users, then cigarette users, then ENDS users, suggesting that current ENDS users represent a "lower-risk" subset of the population, adding evidence to the catalyst hypothesis. [53]. This trend in tobacco usage and mental health has also been observed in adolescents in other countries with a high prevalence of depression and suicide such as South Korea [55]. Another study using data from waves 1 and 2 of the PATH study found that adolescents with high past year internalizing problems such as anxiety and depression as determined by GAIN-SS scores, were at a significant increased risk for e-cigarette

initiation while controlling for age, gender, race, alcohol, marijuana, and parental education level [56].

Sexual Activity. 2015 YRBS data showed that current ENDS, cigarette, and dual users were significantly more likely than non-users to be sexually active and to have reported > 4 sexual partners [52].

Violence and Injury. Current ENDS users, as well as cigarette and dual users from the 2015 YRBS were significantly more likely than non-user to engage in a fight, while only current ENDS and dual users were significantly more likely to text and drive than non-users [52].

Diet and Physical Activity. 2015 YRBS data revealed that current ENDS, cigarette, and dual users where significantly more likely to drink ≥ 3 sodas per day when compared to non-users, and that current ENDS users were significantly less likely to have engaged in daily physical activity when compared to non-users [52].

Psychosocial Characteristics. Certain psychosocial characteristics such as peer or household use of cigarettes, as well as the perception of smoking as acceptable or normal, are known to be strong predictors of cigarette use in adolescents [7]. One study examined whether these risk factors were significantly associated with ENDS use in adolescents and found that the presence of an ENDS or traditional cigarette user at home were significant predictors of adolescent ENDS use. For example, current adolescent ENDS users were 7 times more likely to have another ENDS user living in their home and almost 3 times as likely to live with a current cigarette user, compared to adolescents who have never used an ENDS product. Additionally, almost half (49.5%) of current adolescent ENDS users had 3 or 4 friends who were ENDS users compared to 3.4% of never users. Further, results

suggest that ENDS are perceived as being significantly less harmful than cigarettes among all adolescents, but especially among ENDS users [49].

Susceptibility to ENDS use. Longitudinal studies using the 2013-2014 PATH study dataset found that ENDS susceptibility, as determined by the following two questions, "If one of your best friends offered you an e-cigarette, would you smoke it?" and "Do you think in the future you might experiment with e-cigarettes?" was a significant and independent predictor of ENDS use initiation within the following 6 months [48, 51, 57]. Susceptibility to ENDS was also found to be significantly associated with ever use of alcohol and marijuana when compared to never uses of alcohol and marijuana. Further, beliefs on the perceived addictiveness and harmfulness of ENDS was significantly associated with ENDS susceptibility. For example, students who viewed ENDS as addictive and harmful were less likely to be susceptible to ENDS use [57].

Flavorings. Looking further into the issue of ENDS flavors, previous studies and tobacco industry documents have shown that flavored (sweet) tobacco products disproportionately attract young and inexperienced users [58, 59]. As such, non-traditional flavors have been banned in traditional cigarettes in the United States since 2009 [60]. ENDS devices, however, are available in over 7,000 flavors [61]. Studies utilizing longitudinal data from the 2013-2015 PATH study, found that the majority of adolescents (71.9%) who had initiated tobacco use in the past year were using flavored products [58]. Similarly, a report of the surgeon general cited 85% of adolescent ENDS users use flavored ENDS products [10]. Further, longitudinal data from a different study conducted in California found that adolescents who used flavored ENDS products were significantly more likely to continue using ENDS devices after 6 months, and to take more puffs per

session than adolescents who used traditional (tobacco, mint, menthol, or flavorless) ENDS products [62].

ENDS Marketing. Exposure to ENDS marketing is also a concerning issue. Adolescent exposure to ENDS advertisements is associated with a higher odds of ENDS usage [63]. The CDC examined data from the 2014-2016 NYTS and found that overall, exposure to ENDS advertisement from at least one source has been increasing every year, starting at 68.9% or 18.3 million adolescents in 2014, to 78.2% or 20.5 million adolescents in 2016 [36, 64]. In 2019, this rose to 86.3% of students [36]. The most common sources of advertisement exposure were retail stores (68%), internet (40.6%), television (37.7%), and newspapers and magazines (23.9%) [36, 64]. Similarly, 2014-2015 and 2015-2016 PATH study found that 70.7% adolescents who have never used ENDS reported past month exposure to ENDS marketing. This study also found that adolescents who were exposed to ENDS marketing were significantly more likely to have initialed ENDS usage within the next six months than adolescents who were not exposed to ENDS marketing [65]. To compound this issue, ENDS devices are being marketed in ways that are illegal for traditional cigarettes, including television, sports and music event sponsorships [64]. It is hypothesized that exposure to this marketing may influence adolescent's perception about the safety of ENDS products [65].

Perceived Addictiveness and Harmfulness. Beliefs on the perceived addictiveness and harmfulness of ENDS were significantly associated with ENDS susceptibility and use. A study that consisted of adolescent focus groups further examined this issue, by asking participants (both ENDS users and non-users) about different compounds in ENDS vapor. Students were generally familiar with nicotine, but were unfamiliar with acetaldehyde and

acrolein, and their presence in ENDS vapor. All participants in the study wanted more information about the discussed compounds and their associated health effects [66]. Further, a study conducted using the 2013-2014 PATH data found that adolescents who believed ENDS were addictive were significantly less susceptible to ENDS usage than those who believed ENDS were unlikely to be addictive. Similarly, adolescents who perceived ENDS as more harmful than traditional cigarettes were significantly less likely to be susceptible to ENDS use compared to those who did not think ENDS were more harmful than cigarettes [57].

Data from several studies provide evidence in support of the common liability hypothesis between shared risk factors for ENDS and cigarette usage, especially in regard to substance abuse. Risk factors for ENDS use appear to clusters with other risk activities creating a "risk behavior syndrome" in adolescents, which is also observed in adolescent cigarette use [51, 52]. Further, a trend emerged in studies evaluating risk comparing current ENDS, cigarette, and dual users with non-tobacco users, suggesting a gradient of risk for tobacco users. Dual users typically displayed the highest risk, followed by cigarette users, followed by ENDS users [51-53, 67]. This trend is concerning considering the high likelihood of ENDS users subsequently initiating cigarette use [11, 32]. Further, many of the risk factors remained significant no matter the frequency of current ENDS use (1 or 2 times a month), suggesting that even infrequent use is associated with other substance abuse [48, 51].

ACADEMIC ACHIEVEMENT TREND DATA

Data regarding a variety of academic outcomes of elementary and secondary students in the US is collected and reported by the National Center for Education Statistics

(NCES) of the U.S. Department of Education. The outcomes measured include academic achievement, college admission tests, enrollment, retention, attendance, and drop- out rates. Academic achievement in particular is addressed by the Nations Report Card, which is periodically published by the National Assessment of Educational Progress (NAEP) project, by congressional authorization. This report communicates to the public the findings of the NAEP on student performance and long-term trend assessment in reading, mathematics, science, US history, geography, and other subjects of students at age 9, 13, and 17 since 1971. These reports are used as an assessment on the condition and progress of education in the US. [3]

Academic Achievement. Since 1971, no significant increase has been made in reading scores for 17-year-old students in the US. While average scores increased in the late 80s and early 90s, they once again fell by the early 2000s to today's current levels [3, 68]. Gains in reading scores were seen however, among lower performing (10th and 25th percentile) 17-year-olds from 1971 – 2012 [3]. Average mathematics also did not change significantly between 1971 – 2012 for the same age group; however, long-term gains were seen for students at the 10th, 25th, and 50th percentile [3, 69]. Science scores remain unchanged between 2009 – 2015 as a whole, and at every level [70]. US history saw no change on average or at any level from 1994-2010 [71]. Likewise, no change in geography scores was observed in between 1994-2010 for 12 grade students [72].

SAT Scores. The average critical reading SAT scores of college-bound high school seniors has decreased since the late 60s. In the 1966-1967 school year, the average critical reading score was a 543. By the 2015-2016 school year, average scores had fallen to 494. In contrast, average SAT scores in mathematics have changed significantly in the past 50

years, with both observed increases and decreases. In the 1966-1967 school year, the average mathematics score was a 516. Scores subsequently dropped where they hit an all-time low in the 1979-1980 school year at 492, until they began to rise again in the late 90s. Mathematics SAT scores reached an all-time high during the 2004-2005 school year at 520 but have again fallen slightly to 508 in the 2015-2016 school year [73].

Drop-out Rates. According to the National Center for Education Statistics, the drop-out rate among 16 to 24 year-olds in the US has been steadily declining since 2006 from 9.7% to 5.3% in 2018 [4].

ACADEMIC ACHIEVEMENT RISK FACTORS

One explanation for the lack of progress made in improving academic achievement for adolescents in the US despite education reform and large investment of resources is the failure to address health related barriers to learning [74]. Identifying both the demographic and individual risk behaviors associated with low academic achievement is crucial in order to determine where prevention and intervention measures should focus.

Gender. While males are often reported as having higher standardized test score then females in math and science subjects [3], a meta-analysis published in 2014 based on 502 effect sizes drawn from 369 studies found that females showed significantly better academic outcomes in terms of average and course specific GPA than males [75]. This is not a newly observed phenomenon. Since 1976 females have outnumbered males in terms of enrollment in gifted and advanced placement courses and are also less likely to be held back to repeat grades in schools [76]. Further, in the US, females have had consistently lower drop-out rates than males. In 2017, only 4.4% of 16-24 year old's were high school

dropout, compared to 6.4% of males [4]. In terms of higher education, females also outnumber males in enrollment in post-secondary degrees [76].

Race/Ethnicity. A study conducted using data from the cross-sectional Minnesota Student Survey (MSS) from 1998-2010 including data on 351,510 adolescents in Minnesota public high schools examined whether academic achievement disparities existed among different races/ethnicities. The study found that at every time point examined (1998, 2001, 2004, 2007, and 2010), statistically significant racial/ethnic disparities in academic achievement as determined by grade point average (GPA) existed. While average GPA was observed to increase over time, since 2001, white students exhibited the highest average GPA, followed by Asian or pacific island students, black students, Hispanic or Latino students, American Indian, followed by mixed race students [77]. In terms of high school dropout rates, in 2017 only 1.9% of Asian 16-24-year-olds were high school dropouts, followed by 4.2% of white adolescents/young adults. In contrast, 6.4% of blacks, and 8.0% of Hispanic 16-24-year-olds were high school dropouts [4].

SES. Data from the MSS study mentioned previously found that in 2007 and 2010, students receiving free and reduced lunch had significantly lower GPAs than those students who were not on free and reduced lunch [77]. This confirms the trend noted in the National Center for Education Statistics 2009 report, which found that high school drop-out rates for students from low-income families (7.4%) were five times greater than students from high-income families (1.4%) [78]. Interestingly, the Education Longitudinal Study of 2002 (ELS) of 15,240 10th grade high school students found that parental involvement was

particularly beneficial for students in terms of academic achievement (GPA) from lower-income families when compared to students from higher-income families [79, 80].

Tobacco Use. A systematic review conducted in 2013 on the association between tobacco use and academic achievement found that 100% of the 28 studies examined reported a significant association. The studies consistently found that students with higher academic achievement (as measured through GPA, standardized test scores, or grade level retention) were significantly less likely to use tobacco products when compared to students with lower academic achievement. Longitudinal studies examined in this review also found that cigarette users reported fewer years of education completed than non-users [74]. A more recent systematic review conducted in 2016 identified 12 longitudinal studies that examined academic performance and the onset of tobacco product use. 10 of the 12 studies reported a significant inverse relationship between academic performance and smoking onset [50].

Alcohol Use. A morbidity and mortality weekly report (MMWR) looking at 2015 YRBS academic achievement over the previous year found that students with higher academic achievement (making mostly As, Bs, or Cs) were significantly less likely to report drinking alcohol in the past 30 days when compared to students with lower academic achievement (mostly Ds and Fs) while controlling for grade, gender, and race/ethnicity [81]. Additionally, a 2013 systematic review that specifically looked at alcohol consumption and academic achievement identified 6 cross-sectional and 3 longitudinal studies that specifically differentiated heavy drinking from more moderate alcohol consumption. These studies found that students who engaged in heavy drinking (binge drinking or drinking to get drunk) were significantly associated with lower academic

performance than students who did not drink. Students who engaged in more moderate alcohol consumption however, were not significantly associated with lower academic achievement outcomes compared to students who did not drink however [74]. Further, a prospective cohort study of 9th-12 graders conducted in Canada (COMPASS) found that students who engaged in binge drinking were less likely to attend class and achieve and value high grades when compared to students who did not engage in binge drinking [82, 83].

Substance Use. The same 2013 systematic review mentioned previously included 35 studies that reported a significant inverse association between the use of marijuana, inhalants, illicit drugs, or prescription drugs and academic achievement. Some of the longitudinal studies identified in the review specifically examined the negative antecedent effect of drug use at age 13 on years of educational attainment reported by the age of 25 [84]. A MMWR report looking at 2015 YRBS data found that students with higher academic achievement were significantly less likely to be current marijuana users, or ever users of cocaine, heroin, methamphetamine, injection drugs, or prescription drug use without a doctor's prescription, when compared to students with lower academic achievement [81].

Mental-Health. An analysis of 2015 YRBS data found that students with higher academic achievement were significantly less likely to seriously have considered suicide, made a plan of how to attempt suicide, or have made a suicide attempt than students with lower academic achievement [81].

Sexual Activity. In regard to sexual debut, age at first instance of sexual intercourse, 10 studies identified in a 2013 review found that younger age at sexual debut was

significantly associated with lower academic achievement as measured by grades, standardized test scores, and grade level retention [74]. A study examining 2015 YRBS data found that students with higher academic achievement were significantly less likely to have ever engaged in sexual intercourse, had sexual intercourse with more than four partners, currently be sexually active, had sexual intercourse without a condom or any form of birth control than students with lower academic achievement [81].

Violence and Injury. A 2013 systematic review on health-related behaviors and academic outcomes identified 32 studies that examined the association between violence related behaviors and academic outcomes. Of the 19 cross sectional studies identified, all found that students with higher academic performance (as indicated by GPA, letter grades, standardized test scores, grade retention, and years of education completed) were significantly less likely to engage in or be victims of violence. Of the 14 longitudinal studies identified (follow-up ranging from 1 to 10 years) showed similar results [74]. In particular, one 10 year study found that students who experience violence during adolescents had a significant negative effect on GPA at age 18, as well as the number of years of education obtained [85]. An MMWR report examining 2015 YRBS data found that students with higher academic achievement were significantly more likely to experience intimate partner violence (IPV), bullying (both online and in school), or stay home due to safety concerns compared to students with lower academic achievement [81].

TV and Device Usage. 2015 YRBS data found that students with higher academic achievement were significantly less likely to watch more than 3 hours of television per day or used a device for something other than school work such as gaming or social media for

more than 3 hours per day when compared to students with lower academic achievement [81].

Diet. Results from the 2015 YRBS indicate that students with higher academic achievement were significantly more likely to eat breakfast everyday as well as a one or more servings of fruit or vegetables every day when compared to students with lower academic achievement. This trend also extended for no soda consumption in the past 7 days [81]. In 4 longitudinal studies lasting from 4 months to 10 years examining the effect of school breakfast and lunch program participation on academic achievement, significant improvements in GPA, grades, or standardized test scores were observed. Further, 5 cross sectional studies examining the relationship between the daily consumption of fruits and vegetables with academic achievement found that inadequate quantities of fruits and vegetables in students' diets were significantly associated with lower grades, standardized test scores, or the increased likelihood of grade level retention [74].

Physical Activity. Further, 2015 YRBS data showed that students with higher academic achievement were significantly more likely to be physically active for at least an hour 5 or more days a week or to play on a sports team than students with lower academic achievement [81]. Results from a 2013 systematic review identified 13 studies that examined the relationship between physical activity levels and academic achievement. 5 of the 7 longitudinal studies, and 4 of the 6 cross sectional studies identified a significant inverse relationship between physical activity and academic achievement [74].

STUDY RATIONALE

There is no shortage of studies linking academic outcomes with health-related behaviors. A 2013 systematic review of the literature from 1985 to 2010 identified 122

original research papers that addressed academic outcomes such as grade point average (GPA), letter grades in specific subjects, standardized test scores, grade level retention, years of schooling completed, and high school graduation and their relationships with health-related behaviors. While many of the associations identified in these studies did not indicate causation in either direction, a reciprocal pattern was established that can greatly alter the life trajectory of adolescents [74].

In 2017, an MMWR paper was published by the CDC that examined 30 health-related behaviors and their associations with academic achievement using 2015 Youth Risk Behavior Survey (YRBS) data. The study reported significantly higher prevalence estimates for protective health behaviors (like eating breakfast everyday), and significantly lower prevalence estimates for health related risk behaviors (such as drinking alcohol) among students with higher academic achievement (mostly As, Bs, and Cs) when compared with students with lower academic achievement (mostly Ds and Fs) in 29 of the 30 behaviors. Tobacco use in any form, however, was not assessed in the analysis [81]. While previous studies have established a strong association between cigarette use and low academic achievement as measured through GPA, standardized test scores, grade level retention, and education level attainment, very little has been published on electronic nicotine delivery systems (ENDS) use and academic achievement suggesting a gap in the literature [74] [50].

The merit in addressing this gap lies not only in the significance of low academic achievement on adolescents' future life trajectory, but also in the profound effect of ENDS use on adolescents' current and future health. As the vast majority of tobacco usage is initiated in adolescents, the time an adolescent spends in high school is a crucial time for

tobacco prevention [7]. While two studies have been conducted looking at the association between ENDS use and academic achievement using MTF and PATH study data, none to date have stratified by gender, been published using YRBS data, or data that was collected after 2014 [47, 51]. Due to the change in adolescent ENDS use prevalence every year, there is a need to understand whether ENDS use, like many other health-related behaviors, is associated with academic achievement. The purpose of this study is to evaluate the association between ENDS use and academic achievement among 9 - 12th grade students in the United States from a nationally representative cross-sectional survey.

CHAPTER 2: Manuscript

Electronic nicotine delivery systems (ENDS) use and its association with
low academic achievement among 9th-12th grade students in the US –
2017 Youth Risk Behavior Survey (YRBS)

ABSTRACT

Objective. In 2018, the United States (US) Surgeon General declared adolescent electronic nicotine delivery systems (ENDS) use an epidemic and called for aggressive steps to reduce ENDS use among adolescents. There is ample evidence how tobacco smoking impacts academic achievement among adolescents; however, there is a need to explore the association of ENDS use with low academic achievement in high school students in the US, to guide translational research on ENDS use and its prevention programs.

Methods. We used self-administered questionnaire response data from the 2017 Youth Risk Behavior Survey (YRBS), a nationally representative cross-sectional survey of 14,765 US high school adolescents (9th-12th grade). Low academic achievement was defined as receiving mostly Cs, Ds, and Fs in the previous 12 months. Multiple logistic regression was performed to estimate crude and adjusted prevalence odds ratios (cPOR and aPOR, respectively) and associated 95% confidence intervals (CI) to examine the association. Adjusted analyses were stratified by gender, and controlled for year in school, race/ethnicity, and cigarette use.

Results. In 2017, 13.2% of adolescents reported current ENDS use in the past 30 days of YRBS survey, 21.5% reported past use, and 65.2% never used ENDS. Our stratified adjusted analysis showed that among females, current ENDS users had 2.3-times (95% CI: 1.5 – 3.4) higher odds for low academic achievement compared to never ENDs users, and among males, past ENDS users had 1.3- times (95% C.I.: 1.1 – 1.5) higher odds of low academic achievement, relative to those who reported never ENDS use.

Conclusions. In our study examining a nationally representative sample of high school adolescents in the US, ENDS use was positively associated with lower academic achievement in both genders, however the association was stronger in females. Prevalence of ENDS use fluctuates in the adolescent population, and hence knowledge of gender's differential effect on the association between ENDS use and academic achievement should be examined in future analyses.

INTRODUCTION

Academic achievement in high school has lasting effects on adolescents and is an important social determinant of health [1]. Low academic achievement is described in the literature as a failure to meet an expected standard and is most commonly measured through letter grades, grade point average (GPA), and standardized test score in the US [86]. Low academic achievement can have significant effects on the psychological wellbeing of adolescents, in terms of self-efficacy, motivation, and stress [87]. Further, poor academic performance can lead to fewer years of schooling completed, which is associated with future earning potential [88].

Research on academic outcomes in relation to health-related behaviors is extensive. A 2013 systematic review of the literature from 1985 to 2010 identified 122 original research papers that addressed academic outcomes such as grade point average (GPA), letter grades in specific subjects, standardized test scores, grade level retention, years of schooling completed, and high school graduation and their relationships with health-related behaviors. While many of the associations identified in these studies did not indicate causation in either direction, a reciprocal pattern was established that can greatly alter the life trajectory of adolescents. While previous studies have established a strong association between cigarette use and low academic achievement, very little has been published on electronic nicotine delivery systems (ENDS) use and academic achievement suggesting a gap in the literature [74].

While cigarette usage has steadily declined among adolescents over the past two decades, tobacco use has recently been increasing due to the introduction and growing popularity of ENDS. In 2014, ENDS became the most commonly used tobacco products

among adolescents [8]. By 2019, 46.9% of high school students in the US reported ever using ENDS, with 27.5% of students reporting use in the previous 30 days [36].

ENDS contain nicotine, a highly addictive chemical present in tobacco products that can lead to sustained tobacco product use [10]. Adolescents are particularly susceptible to these effects, even with sporadic and infrequent use [18]. Nicotine addiction is known to affect the areas of the brain controlling executive function, memory, and mood and can have lasting effects on the developing adolescent brain [17]. There are distinct differences in the response to nicotine between the two genders. Females metabolize nicotine and cotinine faster than males, due the presence of estrogen. They are also less sensitive to the rewarding effects of nicotine, and are more likely to report subjective adverse reactions [29]. Furthermore, multiple studies suggest that adolescents who use ENDS are more likely to subsequently initiate cigarette smoking [11, 12].

Two US studies have been conducted looking at the association between current ENDS use (defined as use within the last 30 days) and academic achievement. One study using 2014 Monitoring the Future (MTF) data examined current ENDS use and academic performance among high school seniors (12th grade). The authors found that ENDS users were significantly more likely than non-tobacco users to report lower academic performance (grade point average of C or lower) when controlling for age, sex, race/ethnicity, school geographic region, metropolitan area, parental education, and college plans [51]. Another study using 2013-2014 Population Assessment of Tobacco Health (PATH) data on 12 – 17 year-olds and found committed never tobacco users were significantly less likely to report low academic achievement than current ENDS users when controlling for age, sex, and race/ethnicity [47]. Neither study stratified results by gender

or utilized data representative of all high school students in the US collected after 2014 [47, 51].

Due to the change in adolescent ENDS use prevalence every year, there is a need to understand whether ENDS use, like many other health-related behaviors, is associated with academic achievement. The purpose of this study is to conduct a secondary data analysis examining the association between ENDS use and academic achievement among 9 - 12th grade students in the United States using the most recent nationally representative cross-sectional survey data. We conducted gender-specific analysis to understand the association as it relates to males and females, while controlling for several important confounding variables. Findings from this study will guide translational research on ENDS use and its prevention programs.

METHODS

Study Design and Sample. The YRBS was developed by the US Centers for Disease Control and Prevention (CDC) in 1991 as a cross-sectional study in order to collect data on six categories of health-risk behaviors associated with the leading causes of morbidity and mortality among adolescents in the US on a biannual basis. The six categories include: 1) unintentional injuries and violence; 2) sexual risk behaviors, sexually transmitted diseases, and unintended pregnancies; 3) tobacco use; 4) alcohol and substance use; 5) dietary behaviors; and 6) physical activity. The system was designed to provide information on the prevalence of health-risk behaviors, as well as to assess trends in health risk behaviors over time [34]. While the YRBS has included questions pertaining to tobacco use since 1991, the 2015 survey is the first year when ever or current ENDS usage was assessed [35].

The YRBS utilizes a three-stage cluster design (county, school, class) to produce a nationally representative sample of 9-12th grade students who attend public and private schools in the US (including all 50 states and the District of Columbia). All surveys were anonymous and voluntary in order to protect participant's privacy. The surveys were self-administered and completed during a single class period using computer scannable answer sheets. Weights were applied to each response based on student grade, sex, and race/ethnicity to adjust for school and student non-response and oversampling of black and Hispanic students. Overall weights were scaled so that the total sample size of responses remained unchanged and proportions of each grade level remained consistent with national population proportions [37]. Response rates are typically $\geq 75\%$ for schools and $\geq 60\%$ for students. Surveys that do not have an overall response rate of $> 60\%$ are not weighted, and only represent the students participating in the survey [34].

Outcome Variable. Academic achievement was assessed by asking students to describe their grades in school over the past 12 months. Response options included: mostly As, mostly Bs, mostly Cs, mostly Ds, mostly Fs, none of these grades, and not sure. Responses were subsequently dichotomized into high academic achievement (mostly As or Bs) and low academic achievement (mostly Cs, Ds, or Fs) [51].

Exposure Variable. ENDS use was determined using participant responses to the following two survey questions: "Have you ever used an electronic vapor product?" and "During the past 30 days, on how many days did you use an electronic vapor product?" [37]. Responses to the first question were limited to "Yes" and "No" and the following options for the second question: 0 days, 1 or 2 days, 3 to 5 days, 6 to 9 days, 10 to 19 days, 20 to 29 days, and All 30 days. ENDS use was subsequently coded into three levels: never

(for those who had never used an ENDS product), past (for those who indicated use, but not in the past 30 days), and current (for those who indicated use in the past 30 days).

Covariables. In terms of demographics, year in school is assessed by asking students their grade level. Responses were coded as 9th, 10th, 11th, or 12th. All other responses (ungraded or other grade) were set to missing for the analysis. As gender identity is not addressed by the YRBS, sex was coded as either male or female. Race/ethnicity is addressed by two questions on the survey, and was coded as white, black, Hispanic, or other [37].

Cigarette use was coded as "never", "past", and "current", in accordance with literature standards [35-38]. All subsequent individual behavior risk factor variables were dichotomized as "Yes" and "No". Alcohol Risk was coded as "Yes" for any responses that indicated first drinking alcohol before the age of 13 or drinking in the past 30 days [48, 51, 74, 81-83]. Substance use risk was considered to be present for any positive response for marijuana use in the past 30 days, marijuana initiation before the age of 13, or ever use of cocaine, heroin, methamphetamines, ecstasy, synthetic marijuana, steroids, non-prescribed prescription pain pills, or illegal IV drug use [48, 51-53, 81, 84]. Sexual activity risk was coded as "Yes" for students who indicated sexual intercourse with ≥ 4 partners, last sexual encounter under the influence of alcohol or drugs, or last sexual intercourse without the use of a condom or other form of birth control [48, 52, 74]. Mental health risk was assessed and deemed positive for students who reported depressive symptoms lasting for longer than two weeks in the previous year or who reported seriously considering or attempting suicide in the past year [48, 53, 54]. Violence risk was measured for responses indicating engaging in a physical fight in the previous year, and injury risk was considered for students who

reported texting or emailing while driving in the past 30 days [48, 52, 74, 85]. Diet risk was considered for responses indicating consuming less than 1 serving of fruit per day, ≥ 3 sodas per day, or failing to eat breakfast in the past 7 days [48, 52, 74]. Physical inactivity risk was measured for students who reported at least 60 minutes of physical activity for < 5 days in the previous week or who were on 0 sports teams in the previous year [52]. Screen time risk was coded as "Yes" for any response reporting ≥ 3 hours of television, gaming, or social media use on an average school day [81].

Statistical Analysis. All analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC) utilizing sample survey procedures in order to account for the YRBS's complex survey design. Descriptive statistics were performed to compare the difference between the groups of academic achievement using Rao-Scott chi-squares test for significance. Bivariate and multivariate analysis was performed to estimate crude and adjusted odds ratios for the association between ENDS use and academic achievement. Potential confounding was determined for covariables if the crude and adjusted odds ratios were meaningfully different (by greater than 10%) when the covariable entered and left the statistical model. Multicollinearity was assessed among covariables. In order to avoid over-fitting, the model, the individual behavior risk factor with the strongest association with academic achievement as determined in the crude analysis (cigarette use) was selected to be included in model. Interaction was assessed between ENDS use and all other risk factors. Multiple logistic regression models were stratified by gender. The Emory University Institutional Review Board determined that this research was exempt from review, as the data was deidentified and publicly available.

RESULTS

The 2017 YRBS data set includes data from 14,765 9th – 12th grade students in the US from 144 public and private schools. The 2017 survey had a 75% school and 81% student response rate, with an overall response rate of 60% [37]. Out of all responses to the 2017 YRBS survey, 3,533 (24%) responses were missing data for academic achievement, and 1,944 (13%) were missing data for ENDS use, resulting in 5,026 (37%) observations being excluded in subsequent analysis due to missing data. A total of 9,288 student responses were included in the analytic sample.

Overall, 21% of high school students reported low academic achievement, with males showing a higher prevalence than females. Regarding ENDS use, 12.7% of students indicated current ENDS use, while 21.6% reported past use. Current ENDS use was more prevalent among males. Unweighted frequency and weighted percent demographics of the population sample are reported in Table 1.

The distribution of all demographic and individual behavior risk factors was significantly different between adolescents who reported low and high academic achievement (Table 2). With the exception of physical inactivity risk, the distribution of all other demographic and individual behavior risk factors was significantly different for all covariates evaluated between current, past, and never ENDS use (Table 3). Race/ethnicity, cigarette use, alcohol, substance use, sexual activity, violence, and injury risk were associated with both exposure and outcome (Table 2 and Table 3). As gender has the strongest biological basis, subsequent multiple logistic regression models were stratified based on gender.

Our first multivariable model showed that current and past ENDS users were significantly more likely to report low academic achievement when compared to never

users in both genders, controlling for year in school and race/ethnicity; however, a stronger effect was observed in females than males. When cigarette use is introduced as an additional covariable in the multivariable model, the strength of the association between ENDS use and academic achievement was slightly reduced but significant for both past and current ENDS use in females and past ENDS use in males, but did not change the direction of the association. Among females, those who reported past ENDS use were 1.7-times (95% CI: 1.3 – 2.2) more likely to indicate they were low academic achievers relative to those who reported never ENDS use. Current female ENDS users showed an even stronger association (aPOR: 2.3, 95% CI: 1.5 – 3.4). Among males, those who reported past ENDS had 1.3-times (95% C.I.: 1.1 – 1.5) higher odds for low academic achievement, relative to those who reported never ENDS use. Current males ENDS users showed no significant association (aPOR: 1.3, 95% CI: 0.9 – 2.0) (Table 4).

DISCUSSION

Our results are novel, as these reflect findings on data collected post 2014, when ENDS became the most common tobacco products used by adolescents; additionally, they are the first to report gender-specific effect estimates. In our nationally representative sample of US high school students participating in 2017 YRBS, we found that over 1/3 of high school students in the US reported ever having used an ENDS product, with 13% reporting ENDS use in the past month. In terms of academic performance, 1 out of every 5 students reported low achievement. Both past and current ENDS use among females was significantly associated with low academic achievement when compared to never ENDS use. The effect size of this association was stronger in females than in males. While past

ENDS use was significantly associated with low academic achievement among males, current ENDS was not, relative to never ENDS use.

While two studies have been conducted looking at a potential association between current ENDS use and academic achievement using 2014 MTF project and 2013-2014 PATH study data, none to date have been published using a nationally representative sample of high school students [47, 51]. In the analysis published by Sawdey et al. 2019, using 2013-2014 PATH data examining a nationally representative population of 12-17-year-old adolescents, 3.9% of respondents reported ENDS use, 6.9% cigarettes use, and 7.7% claimed dual use of both tobacco products in the past 30 days. The study also included data measures regarding respondent's susceptibility to future tobacco use. The findings of this analysis found that in 2014, 7.2% were susceptible to ENDS, 10.1% to cigarettes, and 18.5% to dual use. Multinomial logistic regression was performed examining the association between academic achievement and susceptibility to future tobacco use, controlling for age, sex, and race/ethnicity. Compared to committed never users, those susceptible to current ENDS use, were 1.5- (95% C.I.: 1.1 – 2.0) times more likely to report lower academic achievement (mostly Cs, or Cs and Ds) than higher academic achievement (mostly As, or As and Bs). Multinomial logistic regression was also performed to examine the association of academic achievement and tobacco product use, while controlling for age, sex, and race. Compared to current ENDS users, committed never tobacco users were 0.5- (95% C.I.: 0.3-0.7) times as likely to report low academic achievement [47]. In the second study, published by McCabes et al. 2017, using 2014 MTF data on a nationally representative population of high school seniors (12th grade), 9.9% of students reported current ENDS use, 6.0% reported current cigarette use, and 7.3% reported dual use. In this

study multiple logistic regression was used to examine the association between tobacco use and various individual risk behaviors including academic achievement and truancy. They found ENDS users were 1.5 (95% CI: 1.2, 2.0) times more likely to report a grade point average of a C or lower when compared to non-users, while controlling for age, sex, race/ethnicity, school geographic region, metropolitan area, parental education, and college plans. The analysis also examined the frequency of ENDS use in the past month and its association with the same academic outcomes. All levels of use were significantly associated with low academic achievement when compared to non-users, but frequent/daily users exhibited the highest adjusted odds for academic risks [51].

The findings of this analysis are strengthened by several factors. First, this study is the first to examine the association between ENDS use and low academic achievement in a nationally representative sample of high school students. The two previous studies examined the association in a nationally representative sample of 12-17-year old adolescents and high school seniors. Second, our study is the first to examine the association utilizing YRBS data. Third, our study is the first to examine the association between ENDS and academic achievement utilizing data collected after 2014, when ENDS became the most used tobacco product among adolescents. Fourth, our study is the first to examine the association between past ENDS use and low academic achievement. Previous studies have exclusively reported on the association between current ENDS use and academic achievement. Finally, our study is the first to report on the differential effect of gender on the association between ENDS use and academic achievement and report gender-specific effect estimates.

The results of this study are limited by several factors. Selection bias is possible, as adolescents who responded to the survey may be different from those that did not respond. While the YRBS is a nationally representative sample of 9th-12th grade high school students in the US, it does not represent all adolescents of the same age group, as students who have dropped out of school are excluded from participating [35]. In 2018, 2.2% of 16 year-olds, 3.2% of 17 year-olds, and 4.5% of 18 year-olds were not enrolled in high schools [4]. Second, information bias may also be present, as both ENDS use and low academic achievement are associated with a level of stigma and social desirability. Despite the confidentiality of the survey, respondents misreporting, or underreporting ENDS use or low academic achievement, cannot be excluded. While validation of ENDS use or academic achievement was not undertaken, however YRBS survey questions have previously demonstrated good test reliability [34, 89]. Third, the results of this analysis do not lead to any conclusion on directionality or causality regarding the association between ENDS use and academic achievement among high school students, as the survey design is cross-sectional, however, previous studies suggest a strong reciprocal relationship between health risk behaviors and low academic performance [74]. Fourth, there is a potential for residual confounding even though we examined and controlled for several covariables in our multivariable models.

Because 2017 represents a year when current ENDS use prevalence decreased from previous years, and subsequently increased after, future studies should re-examine the association between ENDS use and low academic achievement, especially among current male users, who showed a marginal association in the current analysis, when there is a larger sample size. Further, in order to address potential information bias, future studies

should examine biomarkers and academic records to validate self-report measures of ENDS use and academic achievement, respectively.

The conclusions of our analysis are important as they are the first to report on the difference of association of ENDS use and a low academic outcome between the two genders in high school students in the US. In 2018, the NYTS estimated 4.0 million high school students were current ENDS users, and this number is only increasing [38]. In light of this data, the US Surgeon General declared adolescent ENDS use an epidemic, and called for aggressive steps to reduce ENDS use among youth [16]. In terms of prevention many population initiatives at the policy level are being suggested in order to curb adolescent ENDS use, such as the inclusion of ENDS into current tobacco legislation like smoke-laws, flavor bans, and marketing/advertisement restrictions. While these measures are likely to be highly effective, as they were for cigarette smoking prevention among adolescents over the past 20 years, targeted education and prevention programs are needed that focus on the specific risks of ENDS use [17-19, 36]. The results of this analysis suggest that public health messages and prevention efforts should be developed that target high school females and highlight the harmful effects of ENDS use on academic achievement.

TABLES

Table 1. **Description and coding structure for relevant risk behaviors - 2017 Youth Risk Behavior Survey**

Variable Label	Survey Question	Variable Description	Coding Structure		n	%
ENDS Use	*Q34, Q35*	Ever use: even one or two puffs	"0"	Never	8406	65.20%
			"1"	Past	2749	21.50%
		Current use: past 30 days	"2"	Current	1666	13.20%
			" "	missing	1944	-
Academic Achievement	Q89	Self-reported grades in school during past 12 months	"0"	Low: Mostly Cs, Ds, Fs	2588	22.30%
			"1"	High: Mostly As, Bs	8644	77.70%
			" "	missing	3533	-
Year in School	Q3	Students grade level	"0"	9th	3921	27.30%
			"1"	10th	3715	25.70%
			"2"	11th	3602	23.90%
			"3"	12th	3383	23.10%
			" "	missing	144	-
Gender	Q2	Sex	"0"	Female	7526	50.70%
			"1"	Male	7112	49.30%
			" "	missing	127	-

n   unweighted frequency
%   weighted percent

Variable Label	Survey Question	Variable Description	Coding Structure		n	%
Race/Ethnicity	Q4, Q5		"0"	White	6261	53.50%
			"1"	Black	2796	13.40%
			"2"	Hispanic	3647	22.80%
			3	Other	1724	10.30%
			" "	missing	337	-
Cigarette Use	Q30, Q32	Ever use: even one or two puffs	"0"	Never	8596	71.90%
			"1"	Past	2185	18.90%
		Current use: past 30 days	"2"	Current	1223	9.30%
			" "	missing	2761	-
Alcohol Risk	*Q41, Q42*	Drinking in past 30 days, first drink before 13	"0"	No	7985	62.10%
			"1"	Yes	4772	37.90%
			" "	missing	2008	-
Substance Use Risk	*Q46, Q47, Q48, Q49, Q51, Q52, Q53, Q54, Q55, Q56, Q57*	Current marijuana use, ever prescription or "illicit" drugs use	"0"	No	8312	69.30%
			"1"	Yes	4277	30.70%
			" "	missing	2176	-
Sexual Activity Risk	*Q61, Q63, Q64, Q65*	> 4 partners, under influence of drugs or alcohol, or w/o condom or birth control	"0"	No	10089	77.50%
			"1"	Yes	2896	22.50%
			" "	missing	1780	-

n   unweighted frequency

%   weighted percent

Variable Label	Survey Question	Variable Description	Coding Structure		n	%
Mental Health Risk	Q25, Q26	Depression or serious suicidal thoughts or attempt in past 12 months	"0"	No	9379	65.20%
			"1"	Yes	5160	34.80%
			" "	missing	226	-
Violence Risk	Q17	Physical fight in past 12 months	"0"	No	9239	77.70%
			"1"	Yes	2646	22.30%
			" "	missing	2880	-
Injury Risk	Q11	Texting or emailing while driving in past 30 days	"0"	No	10753	75.40%
			"1"	Yes	3049	24.60%
			" "	missing	963	-
Diet Risk	Q71, Q76, Q78	< 1 serving fruit per day, inconsistent breakfast, ≥ 3 sodas per day	"0"	No	1617	13.40%
			"1"	Yes	12188	86.60%
			" "	missing	960	-
Physical Inactivity Risk	Q79, Q83	Physically active (60 min per day) < 5 days in past week, 0 sports teams in past year	"0"	No	8796	65.10%
			"1"	Yes	5497	34.90%
			" "	missing	472	-
Screen Time Risk	Q80, Q81	≥3 hours of TV, social media, or gaming on school days	"0"	No	6470	47.80%
			"1"	Yes	7363	52.20%
			" "	missing	932	-

n   unweighted frequency
%   weighted percent

Table 2. **Characteristics of 9th-12 graders in the United States by academic achievement-2017 Youth Risk Behavior Survey**

Characteristic	Low Academic Achievement: Mostly Cs, Ds, Fs			High Academic Achievement: Mostly As, Bs			
	n = 2140	% = 21.2	Column %	n = 7599	% = 78.8	Column %	*p-value**
ENDS Use							
Never	1156	*10.7%*	*50.3%*	5336	*55.0%*	*69.8%*	
Past	603	*6.1%*	*28.6%*	1550	*15.5%*	*19.7%*	
Current	381	*4.5%*	*21.1%*	713	*8.2%*	*10.5%*	*< 0.0001*
Year in School							
9th Grade	464	*5.2%*	*24.8%*	2027	*21.8%*	*27.7%*	
10th Grade	558	*5.4%*	*25.6%*	1850	*19.6%*	*24.9%*	
11th Grade	597	*5.9%*	*28.1%*	1820	*17.9%*	*22.7%*	
12th Grade	494	*4.5%*	*21.5%*	1858	*19.5%*	*24.7%*	*0.0021*
missing (71)	27			44			
Gender							
Female	870	*8.7%*	*41.2%*	4163	*42.7%*	*54.2%*	
Male	1249	*12.5%*	*58.8%*	3387	*36.1%*	*45.8%*	*< 0.0001*
missing (70)	21			49			

* = Rao-Scott Chi-square test
n = unweighted frequency
% = weighted percent

Characteristic	Low Academic Achievement: Mostly Cs, Ds, Fs			High Academic Achievement: Mostly As, Bs			
	n = 2140	% = 21.2	Column %	n = 7599	% = 78.8	Column %	*p-value**
Race/Ethnicity							
White	680	*8.9%*	*41.9%*	3619	*47.8%*	*60.6%*	
Black	435	*3.4%*	*16.2%*	1140	*8.1%*	*10.2%*	
Hispanic	785	*7.0%*	*33.2%*	1709	*14.4%*	*18.3%*	
Other	189	*1.8%*	*8.6%*	1000	*8.6%*	*10.9%*	*< 0.0001*
missing (182)	51			131			
Cigarette Use							
Never	1246	*12.0%*	*57.4%*	5840	*61.5%*	*77.7%*	
Past	505	*5.3%*	*25.3%*	1122	*12.1%*	*15.2%*	
Current	300	*3.6%*	*17.2%*	479	*5.6%*	*7.1%*	*< 0.0001*
missing (247)	89			158			
Alcohol Risk							
No	1003	*10.8%*	*53.3%*	4650	*54.5%*	*68.4%*	
Yes	785	*9.4%*	*46.7%*	2100	*25.2%*	*31.6%*	*< 0.0001*
missing (1434)	352			849			
Substance Use Risk							
No	1270	*12.1%*	*57.5%*	5849	*62.2%*	*78.9%*	
Yes	832	*9.0%*	*42.5%*	1667	*16.7%*	*21.1%*	*< 0.0001*
missing (121)	38			83			

* = Rao-Scott Chi-square test

n = unweighted frequency

% = weighted percent

Characteristic	Low Academic Achievement: Mostly Cs, Ds, Fs			High Academic Achievement: Mostly As, Bs			
	n = 2140	% = 21.2	Column %	n = 7599	% = 78.8	Column %	*p-value**
Sexual Activity Risk							
No	1342	*14.4%*	*67.5%*	5661	*64.5%*	*82.0%*	
Yes	597	*7.0%*	*32.5%*	1292	*14.1%*	*18.0%*	*< 0.0001*
missing (847)	201			646			
Mental Health Risk							
No	1253	*12.3%*	*58.0%*	5089	*54.1%*	*68.6%*	
Yes	861	*8.9%*	*42.0%*	2448	*24.7%*	*31.4%*	*< 0.0001*
missing (88)	26			62			
Violence Risk							
No	1448	*14.3%*	*68.5%*	6158	*65.2%*	*82.3%*	
Yes	619	*6.6%*	*31.5%*	1307	*13.9%*	*17.7%*	*< 0.0001*
missing (207)	73			134			
Injury Risk							
No	1563	*16.1%*	*78.2%*	5596	*60.0%*	*75.5%*	
Yes	416	*4.5%*	*21.8%*	1663	*19.4%*	*24.5%*	*0.0216*
missing (501)	161			340			
Diet Risk							
No	182	*1.8%*	*8.7%*	1194	*12.6%*	*16.0%*	
Yes	1937	*19.3%*	*91.3%*	6373	*66.2%*	*84.0%*	*< 0.0001*
missing (53)	21			32			

* = Rao-Scott Chi-square test

n = unweighted frequency

% = weighted percent

Characteristic	Low Academic Achievement: Mostly Cs, Ds, Fs			High Academic Achievement: Mostly As, Bs			
	n = 2140	% = 21.2	Column %	n = 7599	% = 78.8	Column %	*p-value**
Physical Inactivity Risk							
No	1269	*12.8%*	*60.4%*	5177	*53.5%*	*67.9%*	
Yes	849	*8.4%*	*39.6%*	2386	*25.3%*	*32.1%*	*0.0066*
missing (154)	22			36			
Screen Time Risk							
No	815	*8.6%*	*40.9%*	3540	*39.6%*	*50.2%*	
Yes	1216	*12.4%*	*59.1%*	3758	*39.4%*	*49.8%*	*< 0.0001*
missing (410)	109			301			

* = Rao-Scott Chi-square test

n = unweighted frequency

% = weighted percent

Table 3. **Characteristics of 9th-12 Graders in the United States by electronic nicotine delivery system (ENDS) use -**
2017 Youth Risk Behavior Survey

Characteristic	Never ENDS Use			Past ENDS Use			Current ENDS Use			
	n = 6492	% = 65.7	Column %	n = 2153	% = 21.6	Column %	n = 1094	% = 12.7	Column %	p-value*
Academic Achievement										
Low: Mostly Cs, Ds, Fs	1156	10.7%	16.2%	603	6.1%	28.1%	381	4.5%	35.2%	
High: Mostly As, Bs	5336	55.0%	83.8%	1550	15.5%	71.9%	713	8.2%	64.8%	< 0.0001
Year in School										
9th Grade	1910	20.5%	31.2%	388	4.1%	19.1%	193	2.4%	19.2%	
10th Grade	1673	17.0%	25.9%	503	5.4%	25.1%	232	2.6%	20.6%	
11th Grade	1493	14.3%	21.8%	640	6.3%	28.9%	284	3.3%	25.8%	
12th Grade	1374	13.9%	21.1%	610	5.8%	26.9%	368	4.4%	34.5%	< 0.0001
missing (71)	42			12			17			
Gender										
Female	3437	35.1%	53.5%	1125	11.0%	50.6%	471	5.4%	42.2%	
Male	3010	30.5%	46.5%	1017	10.7%	49.4%	609	7.3%	57.8%	< 0.0001
missing (70)	45			11			14			

* Rao-Scott Chi-square test

n = unweighted frequency

% = weighted percent

Characteristic	Never ENDS Use			Past ENDS Use			Current ENDS Use			
	n = 6492	% = 65.7	Column %	n = 2153	% = 21.6	Column %	n = 1094	% = 12.7	Column %	p-value*
Race/Ethnicity										
White	2794	37.2%	56.8%	868	11.0%	50.8%	637	8.4%	65.8%	
Black	1158	8.1%	12.4%	317	2.4%	11.1%	100	1.0%	7.6%	
Hispanic	1563	13.1%	19.9%	692	6.0%	27.7%	239	2.4%	18.7%	
Other	844	7.1%	10.9%	247	2.3%	10.4%	98	1.0%	7.9%	< 0.0001
missing (182)	133			29			20			
Cigarette Use										
Never	5773	60.2%	91.0%	1092	10.7%	50.4%	221	2.6%	20.6%	
Past	513	5.1%	7.7%	807	8.6%	40.6%	307	3.6%	28.8%	
Current	93	0.9%	1.3%	167	1.9%	9.0%	519	6.4%	50.7%	< 0.0001
missing (247)	113			87			47			
Alcohol Risk										
No	4633	53.9%	81.3%	891	9.8%	46.2%	129	1.6%	13.1%	
Yes	1108	12.4%	18.7%	966	11.4%	53.8%	811	10.8%	86.9%	< 0.0001
missing (1434)	751			296			154			

* Rao-Scott Chi-square test

n = unweighted frequency

% = weighted percent

Characteristic	Never ENDS Use			Past ENDS Use			Current ENDS Use			
	n = 6492	% = 65.7	Column %	n = 2153	% = 21.6	Column %	n = 1094	% = 12.7	Column %	*p-value**
Substance Use Risk										
No	5586	*58.3%*	*88.8%*	1249	*12.7%*	*58.7%*	284	*3.4%*	*26.7%*	
Yes	824	*7.4%*	*11.2%*	876	*8.9%*	*41.3%*	799	*9.4%*	*73.3%*	*< 0.0001*
missing (121)	82			28			11			
Sexual Activity Risk										
No	5222	*58.1%*	*89.8%*	1301	*14.7%*	*66.1%*	480	*6.1%*	*46.7%*	
Yes	669	*6.6%*	*10.2%*	685	*7.5%*	*33.9%*	535	*6.9%*	*53.3%*	*< 0.0001*
missing (847)	601			167			79			
Mental Health Risk										
No	4519	*46.8%*	*71.4%*	1267	*13.0%*	*60.0%*	556	*6.6%*	*51.4%*	
Yes	1909	*18.8%*	*28.6%*	871	*8.7%*	*40.0%*	529	*6.2%*	*48.6%*	*< 0.0001*
missing (88)	64			15			9			
Violence Risk										
No	5411	*56.3%*	*85.1%*	1620	*16.3%*	*75.4%*	575	*6.8%*	*55.9%*	
Yes	983	*9.8%*	*14.9%*	495	*5.3%*	*24.6%*	448	*5.4%*	*44.1%*	*< 0.0001*
missing (207)	98			38			71			

* Rao-Scott Chi-square test

n = unweighted frequency

% = weighted percent

Characteristic	Never ENDS Use			Past ENDS Use			Current ENDS Use			
	n = 6492	% = 65.7	Column %	n = 2153	% = 21.6	Column %	n = 1094	% = 12.7	Column %	*p-value**
Substance Use Risk										
No	5586	*58.3%*	*88.8%*	1249	*12.7%*	*58.7%*	284	*3.4%*	*26.7%*	
Yes	824	*7.4%*	*11.2%*	876	*8.9%*	*41.3%*	799	*9.4%*	*73.3%*	*< 0.0001*
missing (121)	82			28			11			
Sexual Activity Risk										
No	5222	*58.1%*	*89.8%*	1301	*14.7%*	*66.1%*	480	*6.1%*	*46.7%*	
Yes	669	*6.6%*	*10.2%*	685	*7.5%*	*33.9%*	535	*6.9%*	*53.3%*	*< 0.0001*
missing (847)	601			167			79			
Mental Health Risk										
No	4519	*46.8%*	*71.4%*	1267	*13.0%*	*60.0%*	556	*6.6%*	*51.4%*	
Yes	1909	*18.8%*	*28.6%*	871	*8.7%*	*40.0%*	529	*6.2%*	*48.6%*	*< 0.0001*
missing (88)	64			15			9			
Violence Risk										
No	5411	*56.3%*	*85.1%*	1620	*16.3%*	*75.4%*	575	*6.8%*	*55.9%*	
Yes	983	*9.8%*	*14.9%*	495	*5.3%*	*24.6%*	448	*5.4%*	*44.1%*	*< 0.0001*
missing (207)	98			38			71			

* Rao-Scott Chi-square test

n = unweighted frequency

% = weighted percent

Table 4. **Stratified multiple logistic regression models to assess the association between ENDS use and low academic achievement by gender among 9th - 12th grade students in the US - 2017 Youth Risk Behavior Survey**

| Characteristic | Multivariate Analysis: Model 1* | | | | Multivariate Analysis: Model 2^ | | | |
| | Females | | Males | | Females | | Males | |
	aPOR	95% CI	aPOR	95% CI	aPOR	95% CI	aPOR	95% CI
ENDS Use								
Never	1	---	1	---	1	---	1	---
Past	2.25	(1.77 - 2.85)	1.67	(1.40 - 1.99)	1.67	(1.25 - 2.24)	1.27	(1.05 - 1.53)
Current	3.88	(2.75 - 5.46)	2.61	(2.00 - 3.40)	2.28	(1.52 - 3.40)	1.32	(0.88 - 1.97)
Year in School								
9th Grade	1	---	1	---	1	---	1	---
10th Grade	1.23	(0.81 - 1.87)	1.08	(0.80 - 1.45)	1.3	(0.86 - 1.98)	1.01	(0.75 - 1.36)
11th Grade	1.47	(1.04 - 2.06)	1.18	(0.86 - 1.62)	1.49	(1.04 - 2.12)	1.14	(0.83 - 1.56)
12th Grade	0.93	(0.67 - 1.31)	0.8	(0.60 - 1.05)	0.9	(0.66 - 1.24)	0.73	(0.57 - 0.94)

* Model 1: Controlled for demographics (year in school and race/ethnicity)

^ Model 2: Controlled for demographics (year in school and race/ethnicity) and cigarette use

CI = Confidence interval

aPOR = Adjusted Prevalence Odds Ratio

Characteristic	Multivariate Analysis: Model 1*				Multivariate Analysis: Model 2^			
	Females		Males		Females		Males	
	aPOR	95% CI	aPOR	95% CI	aPOR	95% CI	aPOR	95% CI
Race/Ethnicity								
White	1	---	1	---	1	---	1	---
Black	2.59	(1.81 - 3.72)	2.52	(1.76 - 3.61)	2.8	(1.93 - 4.06)	2.69	(1.92 - 3.78)
Hispanic	2.68	(1.97 - 3.64)	2.73	(2.18 - 3.42)	2.92	(2.17 - 3.94)	2.97	(2.31 - 3.81)
Other	1.17	(0.78 - 1.74)	1.24	(0.95 - 1.62)	1.24	(0.84 - 1.83)	1.3	(1.00 - 1.70)
Cigarette Use								
Never	---	---	---	---	1	---	1	---
Past	---	---	---	---	2	(1.55 - 2.59)	1.83	(1.51 - 2.23)
Current	---	---	---	---	2.47	(1.63 - 3.72)	3.39	(2.23 - 5.16)

* Model 1: Controlled for demographics (year in school and race/ethnicity)

^ Model 2: Controlled for demographics (year in school and race/ethnicity) and cigarette use

CI = Confidence interval

aPOR = Adjusted Prevalence Odds Ratio

CHAPTER 3: Discussion

FINDINGS

The association between ENDS use and low academic achievement was statistically significant for both past and current ENDS use in females and past ENDS use in males; however, the strongest effect estimates were observed among current female ENDS use. While current ENDS use in males was higher in magnitude than past use, the observed association was not statistically significant as indicated by the confidence interval.

RECCOMENDATIONS

Future Analysis. The findings of this thesis represent an observed association between ENDS use and low academic achievement in the high school population in 2017, however that year represents a reduction in current ENDS use compared to previous and subsequent years. According to YRBS data, 24.1% of students were current ENDS users in 2015, while only 13.2% of students reported current ENDS use in 2017 [35, 37]. Past ENDS use however, did not adhere to this trend, and remained relatively stable during this time (around 44%) [35, 37]. The National Youth Tobacco Study (NYTS) also observed this trend in current ENDS use reduction in 2017. As the NYTS is conducted on an annual basis however, data from subsequent years shows that this reduction in current ENDS use quickly reversed from 2017-2019. By 2019, current ENDS use had increased to nearly 30% [16]. Therefore, future studies are needed to examine the association between ENDS use and low academic achievement, especially among current male users, who showed a marginal association in the current analysis, when there is a larger sample size.

In order to address potential information bias, future studies should examine biomarkers (such as cotinine, a metabolite of nicotine) in order to validate self-report

measures of ENDS use, in order to address under or overreporting of the behavior [29]. Further, the creators of the YRBS questionnaire should also consider the rise in adolescent THC vaping, when designing subsequent years survey questions [90]. While the questions pertaining to ENDS use in the 2017 survey are in the section of the survey addressing tobacco use, the questions do not differentiate between vaping nicotine and THC products [37]. Additionally, studies should be considered to validate student self-reported academic achievement measures with official academic records, in order to address a potential underreporting of low academic achievement.

As the results of this study are only representative of high school students in the US, future studies should examine ENDS use and its association using a sample of adolescents of the same age. While the YRBS is a nationally representative sample of 9th-12th grade high school students in the US, it does not represent all adolescent of the same age group, as students who have dropped out of school are excluded from participating [35]. In 2018, 2.2% of 16-year-olds, 3.2% of 17-year-olds, and 4.5% of 18-year-olds were not enrolled in high schools. Disparities also existed in dropout rates between males and females (6.2% and 4.4% respectively) and white (4.2%), Black (6.4%), and Hispanic (8.0%) students [4]. As dropouts (and ENDS users) are more commonly older, male, and Black or Hispanic, this could lead to conclusions that underreport the association between ENDS use and low academic achievement, as those who dropped out are not included in the sample of this analysis.

Further, the results of this analysis are based on a conservative approach regarding the association between ENDS and academic achievement. As the analysis of this thesis controls for cigarette usage as a separate confounder, despite the fact that both ENDS and

cigarettes are both comprised of nicotine, it is likely that the strength of the association described in the analysis underreports the size of the effect, particularly in males.

Finally, as the study design of the YRBS is cross-sectional, the results of this analysis do not lead to any conclusion on directionality or causality regarding the association between ENDS use and academic achievement among high school students. While previous studies suggest a strong reciprocal relationship between health risk behaviors and low academic performance, future longitudinal studies should examine the association between ENDS and academic performance to determine whether the association is directional or reciprocal. It is plausible adolescents may be coping with the stress associated with low academic achievement by using ENDS, but using ENDS may also lead to poor performance in the classroom as a result of a nicotine addiction and its significant effects on the adolescent brain.

ENDS Prevention Policy. As most tobacco use is initiated during adolescence, it is crucial that interventions focus on initiation prevention during these formative years [5, 7]. While there is no shortage of research on effective cigarette initiation prevention methods in adolescents at both the individual and policy level, whether or not these same measures will prove effective for ENDS use, is less clear [91].

In terms of prevention, many population initiatives at the policy level are being suggested in order to curb adolescent ENDS use. In order to limit access to ENDS products, price increases are being proposed as well as raising the legal age to purchase all tobacco products to age 21. Other suggested policies focus on the inclusion of ENDS into existing tobacco legislation such as indoor and outdoor smoke-free laws, flavor bans, and marketing/advertisement restrictions. While these measures are likely to be highly

effective, as they were for cigarette smoking prevention among adolescents over the past 20 years, education and prevention programs that target adolescents at higher risk are needed [17-19, 36].

While a fair amount of evidence-driven tobacco prevention programs for adolescents exists, most focus on the long-term health effects of cigarettes [91]. Due to the newness of ENDS, data on the long-term health effects is limited, but exposure to marketing and advertising for these products is not [17]. This creates a need for tobacco prevention programs for adolescents that account for the specific risks of ENDS. Using the Health Belief Model (HBM) as a guide for influencing an individual's behavior, programs should be designed that address an individual's perceived susceptibility to ENDS use, the risks associated with ENDS initiation, and the benefits of avoiding use [92].

An excellent example of the application of this theory in adolescent ENDS use prevention is the "CATCH My Breath" pilot program. This study took place in Texas from 2016-2017 and included 12 middle schools (6 intervention and 6 control schools). Data collection occurred at baseline, and 4- and 16-month follow-up. This program was designed to address a student's attitudes and knowledge regarding adolescent ENDS use, and perceived positive outcomes of avoiding ENDS in order to reduce adolescent nicotine dependence. The pilot showed promising results. In intervention schools, significant improvement in ENDS knowledge and perceived positive outcomes for not using ENDS were observed in the intervention schools at both the 4- and 16-month follow-ups. Further, at the 16-month follow-up, ever ENDS use increased significantly in control schools but did not increase significantly in the intervention schools. Further, current combustible

tobacco use increased significantly in control schools but did not increase significantly in the intervention schools [91].

Taking the findings of the "CATCH My Breath" study into consideration with the findings of this thesis, future prevention programs should be developed that target high school females and highlight the harmful effects of ENDS use on academic achievement. While the conclusions of this analysis need to be confirmed by future studies, the results provide evidence for the importance of gender in creating targeted ENDS prevention programs.

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APPENDIX

TABLES

Table 5. **Univariate and bivariate analysis of ENDS use and subject characteristics with low academic achievement of 9th-12 grade students in the US - 2017 Youth Risk Behavior Survey**

Characteristic	Crude Analysis^		Bivariate Analysis*	
	POR	95% CI	aPOR	95% CI
ENDS Use				
Never	1	---	---	---
Past	2.02	(1.77 - 2.31)	---	---
Current	2.80	(2.30 - 3.40)	---	---
Year in School				
9th Grade	1	---	1	---
10th Grade	1.15	(0.92 - 1.43)	1.08	(0.86 - 1.36)
11th Grade	1.38	(1.12 - 1.71)	1.22	(0.98 - 1.50)
12th Grade	0.97	(0.78 - 1.20)	0.81	(0.65 - 1.01)
Gender				
Female	1	---	1	---
Male	1.69	(1.43 - 2.00)	1.62	(1.38 - 1.90)

^ = Assesses the association of subject characteristic with low academic achievement

* = Assesses the association of ENDS use + subject characteristic with low academic achievement

POR = Prevalence Odds Ratio

aPOR = Adjusted Prevalence Odds Ratio

CI = Confidence interval

Characteristic	Crude Analysis^		Bivariate Analysis*	
	POR	95% CI	aPOR	95% CI
Race/Ethnicity				
White	1	---	1	---
Black	2.28	(1.69 - 3.09)	2.53	(1.88 - 3.41)
Hispanic	2.62	(2.15 - 3.20)	2.70	(2.21 - 3.29)
Other	1.15	(0.92 - 1.42)	1.21	(0.99 - 1.49)
Cigarette Use				
Never	1	---	1	---
Past	3.29	(2.62 - 4.14)	1.76	(1.45 - 2.13)
Current	2.25	(1.86 - 2.73)	2.28	(1.70 - 3.06)
Cigarette Risk				
No	1	---	1	---
Yes	2.63	(2.19 - 3.15)	1.95	(1.60 - 2.37)
Alcohol Risk				
No	1	---	1	---
Yes	1.89	(1.60 - 2.25)	1.33	(1.13 - 1.56)

^ = Assesses the association of subject characteristic with low academic achievement

* = Assesses the association of ENDS use + subject characteristic with low academic achievement

POR = Prevalence Odds Ratio

aPOR = Adjusted Prevalence Odds Ratio

CI = Confidence interval

Characteristic	Crude Analysis^		Bivariate Analysis*	
	POR	95% CI	aPOR	95% CI
Substance Use Risk				
No	1	---	1	---
Yes	2.77	(2,34 - 3.27)	2.13	(1.79 - 2.53)
Sexual Activity Risk				
No	1	---	1	---
Yes	2.20	(1.81 - 2.67)	1.66	(1.33 - 2.07)
Mental Health Risk				
No	1	---	1	---
Yes	1.59	(1.37 - 1.84)	1.41	(1.24 - 1.60)
Violence Risk				
No	1	---	1	---
Yes	2.14	(1.78 - 2.57)	1.79	(1.51 - 2.14)

^ = Assesses the association of subject characteristic with low academic achievement

* = Assesses the association of ENDS use + subject characteristic with low academic achievement

POR = Prevalence Odds Ratio

aPOR = Adjusted Prevalence Odds Ratio

CI = Confidence interval

Characteristic	Crude Analysis^		Bivariate Analysis*	
	POR	95% CI	aPOR	95% CI
Injury Risk				
No	1	---	1	---
Yes	0.86	(0.75 - 0.98)	0.62	(0.53 - 0.73)
Diet Risk				
No	1	---	1	---
Yes	2.00	(1.53 - 2.59)	1.82	(1.40 - 2.36)
Physical Inactivity Risk				
No	1	---	1	---
Yes	1.39	(1.11 - 1.73)	1.45	(1.18 - 1.77)
Screen Time Risk				
No	1	---	1	---
Yes	1.46	(1.19 - 1.78)	1.48	(1.22 - 1.80)

^ = Assesses the association of subject characteristic with low academic achievement

* = Assesses the association of ENDS use + subject characteristic with low academic achievement

POR = Prevalence Odds Ratio

aPOR = Adjusted Prevalence Odds Ratio

CI = Confidence interval

Table 6. **Crude and adjusted odds ratios of ENDS usage and subject characteristics with low academic achievement among 9th - 12th grade students in the US- 2017 Youth Risk Behavior Survey**

Characteristic	Past vs. Never ENDS Users			Current vs. Never ENDS Users		
	POR	95% CI	> 10%*	POR	95% CI	> 10%*
ENDS Usage						
cPOR:	2.02	(1.77 - 2.31)	---	2.80	(2.30 - 3.40)	---
Year in School						
aPOR:	2.02	(1.77 - 2.31)	No	2.85	(2.33 - 3.50)	No
Gender						
aPOR:	2.01	(1.76 - 2.28)	No	2.69	(2.22 - 3.27)	No
Race/Ethnicity						
aPOR:	1.92	(1.69 - 2.18)	No	3.12	(2.58 - 3.78)	Yes
Cigarette Use						
aPOR:	1.56	(1.35 - 1.80)	Yes	1.69	(1.30 - 2.20)	Yes

POR = Prevalence Odds Ratio

cPOR = Crude Prevalence Odds Ratio

aPOR = Adjusted Prevalence Odds Ratio

CI = Confidence interval

> 10%* = cPOR and aPOR differ by > 10%

Characteristic	Past vs. Never ENDS Users			Current vs. Never ENDS Users		
	POR	95% CI	> 10%*	POR	95% CI	> 10%*
Cigarette Risk						
aPOR:	1.53	(1.34 - 1.75)	Yes	1.80	(1.45 - 2.22)	Yes
Alcohol Risk						
aPOR:	1.88	(1.64 - 2.15)	No	2.25	(1.87 - 2.72)	Yes
Substance Use Risk						
aPOR:	1.60	(1.40 - 1.82)	Yes	1.78	(1.44 - 2.19)	Yes
Sexual Activity Risk						
aPOR:	1.78	(1.59 - 1.99)	Yes	2.14	(1.72 - 2.67)	Yes
Mental Health Risk						
aPOR:	1.96	(1.73 - 2.22)	No	2.65	(2.21 - 3.17)	No

POR = Prevalence Odds Ratio

cPOR = Crude Prevalence Odds Ratio

aPOR = Adjusted Prevalence Odds Ratio

CI = Confidence interval

> 10%* = cPOR and aPOR differ by > 10%

Characteristic	Past vs. Never ENDS Users			Current vs. Never ENDS Users		
	POR	95% CI	> 10%*	POR	95% CI	> 10%*
Violence Risk						
aPOR:	1.91	(1.66 - 2.19)	No	2.37	(1.97 - 2.86)	Yes
Injury Risk						
aPOR:	2.18	(1.88 - 2.52)	No	3.35	(2.73 - 4.10)	Yes
Diet Risk						
aPOR:	1.96	(1.72 - 2.23)	No	2.70	(2.21 - 3.30)	No
Physical Inactivity Risk						
aPOR:	2.04	(1.78 - 2.34)	No	2.89	(2.38 - 3.50)	No
Screen Time Risk						
aPOR:	2.02	(1.78 - 2.29)	No	2.84	(2.35 - 3.45)	No

POR = Prevalence Odds Ratio

cPOR = Crude Prevalence Odds Ratio

aPOR = Adjusted Prevalence Odds Ratio

CI = Confidence interval

> 10%* = cPOR and aPOR differ by > 10%

Table 7. **Confounding Summary Table**

Characteristic	Table 2. p-value*	Table 2. p-value^	Associated with outcome and exposure?	Table 6 †
ENDS Use	< 0.0001	-	-	-
Academic Achievement	-	< 0.0001	-	-
Grades	-	< 0.0001	-	-
Year	0.0021	< 0.0001	Potential Confounder	No
Gender	< 0.0001	< 0.0001	Potential Confounder	No
Race/Ethnicity	< 0.0001	< 0.0001	Potential Confounder	Yes
Cigarette Use	< 0.0001	< 0.0001	Potential Confounder	Yes
Alcohol Use Risk	< 0.0001	< 0.0001	Potential Confounder	Yes

* = Rao-Scott Chi-square test for association with academic achievement
^ = Rao-Scott Chi-square test for association with ENDS Use
† = cPOR and aPOR differ by > 10%
cPOR = Crude Prevalence Odds Ratio
aPOR = Adjusted Prevalence Odds Ratio

Characteristic	Table 2. p-value*	Table 2. p-value^	Associated with outcome and exposure?	Table 6 †
Substance Use Risk	< 0.0001	< 0.0001	Potential Confounder	Yes
Sexual Risk	< 0.0001	< 0.0001	Potential Confounder	Yes
Mental Health Risk	< 0.0001	< 0.0001	Potential Confounder	No
Violence Risk	< 0.0001	< 0.0001	Potential Confounder	Yes
Injury Risk	0.0216	< 0.0001	Potential Confounder	Yes
Diet Risk	< 0.0001	< 0.0001	Potential Confounder	No
Inactivity Risk	0.0066	0.1097	No	No
Screen Time Risk	< 0.0001	0.0191	Potential Confounder	No

* = Rao-Scott Chi-square test for association with academic achievement
^ = Rao-Scott Chi-square test for association with ENDS Use
† = cPOR and aPOR differ by > 10%
cPOR = Crude Prevalence Odds Ratio
aPOR = Adjusted Prevalence Odds Ratio

Table 8. **Correlation Matrix of Confounders***

Variable	Cigarette Use	Alcohol Risk	Substance Use Risk	Sexual Risk	Violence Risk	Injury Risk
Cigarette Use	-	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Alcohol Use Risk	< 0.0001	-	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Substance Use Risk	< 0.0001	< 0.0001	-	< 0.0001	< 0.0001	< 0.0001
Sexual Risk	< 0.0001	< 0.0001	< 0.0001	-	< 0.0001	< 0.0001
Violence Risk	< 0.0001	< 0.0001	< 0.0001	< 0.0001	-	< 0.0001
Injury Risk	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	-

* Rao-Scott Chi-square test

Table 9. **Assessing interaction between ENDS use and subject characteristics -**
2017 Youth Risk Behavior Survey

Characteristic	Past vs. Never ENDS Use	Current vs. Never ENDS Use	Joint Test p-value
	MLE p-value	MLE p-value	
Year in School			
9th Grade	---	---	0.2137
10th Grade	0.8250	0.2977	---
11th Grade	0.2178	0.0401	---
12th Grade	0.1691	0.0316	---
Gender			
Female	---	---	0.0414
Male	0.0637	0.0216	---
Race/Ethnicity			
White	---	---	0.0024
Black	0.0820	0.0055	---
Hispanic	0.0149	0.1394	---
Other	0.6203	0.5460	---

MLE = Maximum Likelihood Estimate

Characteristic	Past vs. Never ENDS Use	Current vs. Never ENDS Use	
	MLE p-value	MLE p-value	Joint Test p-value
Cigarette Use			
Never	---	---	0.0042
Past	0.0811	0.0014	---
Current	0.0073	0.0062	---
Alcohol Risk			
No	---	---	0.0459
Yes	0.0590	0.0241	---
Substance Use Risk			
No	---	---	0.0029
Yes	0.0498	0.0007	---
Sexual Activity Risk			
No	---	---	0.0619
Yes	0.0239	0.1010	---
Mental Health Risk			
No	---	---	0.0306
Yes	0.3265	0.0078	---

MLE = Maximum Likelihood Estimate

Characteristic	Past vs. Never ENDS Use	Current vs. Never ENDS Use	Joint Test
	MLE p-value	MLE p-value	p-value
Violence Risk			
No	---	---	0.1889
Yes	0.2044	0.1124	---
Injury Risk			
No	---	---	0.4003
Yes	0.2609	0.2139	---
Diet Risk			
No	---	---	0.2147
Yes	0.0842	0.7116	---
Physical Inactivity Risk			
No	---	---	0.1883
Yes	0.9182	0.0856	---
Screen Time Risk			
No	---	---	0.7248
Yes	0.4262	0.6672	---

MLE = Maximum Likelihood Estimate

Table 10. **Stratified multiple logistic regression models to assess the association between ENDS use and low academic achievement by gender among 9th - 12th grade students in the US - 2017 Youth Risk Behavior Survey**

| Characteristic | Multivariate Analysis: Model 3* | | | | Multivariate Analysis: Model 4^ | | | |
| | Females | | Males | | Females | | Males | |
	aPOR	95% CI	aPOR	95% CI	aPOR	95% CI	aPOR	95% CI
ENDS Use								
Never	1	---	1	---	1	---	1	---
Past	1.26	(0.91 - 1.74)	1.19	(0.90 - 1.59)	1.35	(1.01 - 1.79)	1.21	(0.96 - 1.52)
Current	1.09	(0.76 - 1.58)	1.16	(0.67 - 2.02)	1.23	(0.82 - 1.84)	1.21	(0.78 - 1.86)
Year in School								
9th Grade	1	---	1	---	1	---	1	---
10th Grade	1.32	(0.74 - 2.35)	1.03	(0.74 - 1.43)	1.39	(0.84 - 2.29)	1.00	(0.74 - 1.36)
11th Grade	1.59	(0.99 - 2.56)	1.42	(0.93 - 2.16)	1.43	(0.93 - 2.19)	1.20	(0.86 - 1.69)
12th Grade	1.02	(0.65 - 1.60)	0.76	(0.49 - 1.18)	0.83	(0.58 - 1.19)	0.66	(0.47 - 0.93)

* Model 3: Full model, controlled for demographics (year in school and race/ethnicity) and individual risk behaviors (cigarette use, alcohol risk, substance use risk, sexual activity risk, mental health risk, violence risk, injury risk, diet risk, physical inactivity risk, screen time risk)

^ Model 4: Original proposal model, controlled for demographics (year in school and race/ethnicity) and individual risk behaviors (cigarette use, alcohol risk, substance use risk, mental health risk)

CI = Confidence interval

aPOR = Adjusted Prevalence Odds Ratio

Characteristic	Multivariate Analysis: Model 3*				Multivariate Analysis: Model 4^			
	Females		Males		Females		Males	
	aPOR	95% CI	aPOR	95% CI	aPOR	95% CI	aPOR	95% CI
Race/Ethnicity								
White	1	---	1	---	1	---	1	---
Black	1.61	(1.00 - 2.58)	2.54	(1.81 - 3.55)	2.39	(1.57 - 3.65)	2.89	(2.03 - 4.12)
Hispanic	2.22	(1.49 - 3.28)	2.74	(2.08 - 3.60)	2.60	(1.86 - 3.62)	2.79	(2.16 - 3.60)
Other	0.89	(0.60 - 1.32)	1.06	(0.74 - 1.52)	0.99	(0.69 - 1.41)	1.28	(0.97 - 1.70)
Cigarette Use								
Never	1	---	1	---	1	---	1	---
Past	1.66	(1.20 - 2.29)	1.44	(1.10 - 1.87)	1.82	(1.36 - 2.43)	1.68	(1.29 - 2.19)
Current	2.22	(1.23 - 4.03)	2.17	(1.39 - 3.38)	2.20	(1.32 - 3.66)	2.36	(1.55 - 3.59)
Alcohol Risk								
No	1	---	1	---	1	---	1	---
Yes	1.07	(0.76 - 1.51)	1.03	(0.77 - 1.39)	1.05	(0.77 - 1.43)	0.95	(0.72 - 1.27)
Substance Use Risk								
No	1	---	1	---	1	---	1	---
Yes	1.51	(1.09 - 2.08)	1.68	(1.18 - 2.40)	1.85	(1.43 - 2.41)	1.68	(1.25 - 2.27)

* Model 3: Full model, controlled for demographics (year in school and race/ethnicity) and individual risk behaviors (cigarette use, alcohol risk, substance use risk, sexual activity risk, mental health risk, violence risk, injury risk, diet risk, physical inactivity risk, screen time risk)

^ Model 4: Original proposal model, controlled for demographics (year in school and race/ethnicity) and individual risk behaviors (cigarette use, alcohol risk, substance use risk, mental health risk)

CI = Confidence interval

aPOR = Adjusted Prevalence Odds Ratio

Characteristic	Multivariate Analysis: Model 3*				Multivariate Analysis: Model 4^			
	Females		Males		Females		Males	
	aPOR	95% CI	aPOR	95% CI	aPOR	95% CI	aPOR	95% CI
Sexual Activity Risk								
No	1	---	1	---	---	---	---	---
Yes	1.39	(1.06 - 1.82)	1.16	(0.85 - 1.59)	---	---	---	---
Mental Health Risk								
No	1	---	1	---	1	---	1	---
Yes	1.31	(1.08 - 1.60)	1.33	(1.00 - 1.77)	1.58	(1.31 - 1.92)	1.48	(1.15 - 1.90)
Violence Risk								
No	1	---	1	---	---	---	---	---
Yes	1.45	(1.13 - 1.86)	1.27	(1.02 - 1.59)	---	---	---	---
Injury Risk								
No	1	---	1	---	---	---	---	---
Yes	0.61	(0.44 - 0.84)	0.72	(0.53 - 0.97)	---	---	---	---

* Model 3: Full model, controlled for demographics (year in school and race/ethnicity) and individual risk behaviors (cigarette use, alcohol risk, substance use risk, sexual activity risk, mental health risk, violence risk, injury risk, diet risk, physical inactivity risk, screen time risk)

^ Model 4: Original proposal model, controlled for demographics (year in school and race/ethnicity) and individual risk behaviors (cigarette use, alcohol risk, substance use risk, mental health risk)

CI = Confidence interval

aPOR = Adjusted Prevalence Odds Ratio

Characteristic	Multivariate Analysis: Model 3*				Multivariate Analysis: Model 4^			
	Females		Males		Females		Males	
	aPOR	95% CI	aPOR	95% CI	aPOR	95% CI	aPOR	95% CI
Diet Risk								
No	1	---	1	---	---	---	---	---
Yes	1.35	(0.82 - 2.23)	1.62	(1.10 - 2.40)	---	---	---	---
Physical Inactivity Risk								
No	1	---	1	---	---	---	---	---
Yes	1.71	(1.27 - 2.29)	1.65	(1.29 - 2.09)	---	---	---	---
Screen Time Risk								
No	1	---	1	---	---	---	---	---
Yes	1.41	(1.09 - 1.82)	1.14	(0.88 - 1.46)	---	---	---	---

* Model 3: Full model, controlled for demographics (year in school and race/ethnicity) and individual risk behaviors (cigarette use, alcohol risk, substance use risk, sexual activity risk, mental health risk, violence risk, injury risk, diet risk, physical inactivity risk, screen time risk)

^ Model 4: Original proposal model, controlled for demographics (year in school and race/ethnicity) and individual risk behaviors (cigarette use, alcohol risk, substance use risk, mental health risk)

CI = Confidence interval

aPOR = Adjusted Prevalence Odds Ratio

YRBS SURVEY QUESTIONS

ENDS Use.

The next 3 questions ask about electronic vapor products, such as blu, NJOY, Vuse, MarkTen, Logic, Vapin Plus, eGo, and Halo. Electronic vapor products include e-cigarettes, e-cigars, e-pipes, vape pipes, vaping pens, e-hookahs, and hookah pens.

34. Have you ever used an electronic vapor product?
    A. Yes
    B. No

35. During the past 30 days, on how many days did you use an electronic vapor product?
    A. 0 days
    B. 1 or 2 days
    C. 3 to 5 days
    D. 6 to 9 days
    E. 10 to 19 days
    F. 20 to 29 days
    G. All 30 days

Academic Achievement.

89. During the past 12 months, how would you describe your grades in school?
    A. Mostly A's
    B. Mostly B's
    C. Mostly C's
    D. Mostly D's
    E. Mostly F's
    F. None of these grades
    G. Not sure

Year in School.

3.   In what grade are you?
      A.   9th grade
      B.   10th grade
      C.   11th grade
      D.   12th grade
      E.   Ungraded or other grade

Gender.

2.   What is your sex?
      A.   Female
      B.   Male

Race/Ethnicity.

4.   Are you Hispanic or Latino?
      A.   Yes
      B.   No

5.   What is your race? **(Select one or more responses.)**
      A.   American Indian or Alaska Native
      B.   Asian
      C.   Black or African American
      D.   Native Hawaiian or Other Pacific Islander
      E.   White

Cigarette Use.

30.   Have you ever tried cigarette smoking, even one or two puffs?
    A.   Yes
    B.   No

32.   During the past 30 days, on how many days did you smoke cigarettes?
    A.   0 days
    B.   1 or 2 days
    C.   3 to 5 days
    D.   6 to 9 days
    E.   10 to 19 days
    F.   20 to 29 days
    G.   All 30 days

Alcohol Risk.

41. How old were you when you had your first drink of alcohol other than a few sips?
  A. I have never had a drink of alcohol other than a few sips
  B. 8 years old or younger
  C. 9 or 10 years old
  D. 11 or 12 years old
  E. 13 or 14 years old
  F. 15 or 16 years old
  G. 17 years old or older

42. During the past 30 days, on how many days did you have at least one drink of alcohol?
  A. 0 days
  B. 1 or 2 days
  C. 3 to 5 days
  D. 6 to 9 days
  E. 10 to 19 days
  F. 20 to 29 days
  G. All 30 days

Substance Use Risk.

The next 3 questions ask about marijuana use. Marijuana also is called grass, pot, or weed.

46. During your life, how many times have you used marijuana?
  A. 0 times
  B. 1 or 2 times
  C. 3 to 9 times
  D. 10 to 19 times
  E. 20 to 39 times
  F. 40 to 99 times
  G. 100 or more times

47. How old were you when you tried marijuana for the first time?
    A. I have never tried marijuana
    B. 8 years old or younger
    C. 9 or 10 years old
    D. 11 or 12 years old
    E. 13 or 14 years old
    F. 15 or 16 years old
    G. 17 years old or older

48. During the past 30 days, how many times did you use marijuana?
    A. 0 times
    B. 1 or 2 times
    C. 3 to 9 times
    D. 10 to 19 times
    E. 20 to 39 times
    F. 40 or more times

49. During your life, how many times have you used **any** form of cocaine, including powder, crack, or freebase?
    A. 0 times
    B. 1 or 2 times
    C. 3 to 9 times
    D. 10 to 19 times
    E. 20 to 39 times
    F. 40 or more times

51. During your life, how many times have you used **heroin** (also called smack, junk, or China White)?
    A.   0 times
    B.   1 or 2 times
    C.   3 to 9 times
    D.   10 to 19 times
    E.   20 to 39 times
    F.   40 or more times

52. During your life, how many times have you used **methamphetamines** (also called speed, crystal, crank, or ice)?
    A.   0 times
    B.   1 or 2 times
    C.   3 to 9 times
    D.   10 to 19 times
    E.   20 to 39 times
    F.   40 or more times

53. During your life, how many times have you used **ecstasy** (also called MDMA)?
    A.   0 times
    B.   1 or 2 times
    C.   3 to 9 times
    D.   10 to 19 times
    E.   20 to 39 times
    F.   40 or more times

54. During your life, how many times have you used **synthetic marijuana** (also called K2, Spice, fake weed, King Kong, Yucatan Fire, Skunk, or Moon Rocks)?
    A.   0 times
    B.   1 or 2 times
    C.   3 to 9 times
    D.   10 to 19 times
    E.   20 to 39 times
    F.   40 or more times

55. During your life, how many times have you taken **steroid pills or shots** without a doctor's prescription?
   A.   0 times
   B.   1 or 2 times
   C.   3 to 9 times
   D.   10 to 19 times
   E.   20 to 39 times
   F.   40 or more times

56. During your life, how many times have you taken **prescription pain medicine** without a doctor's prescription or differently than how a doctor told you to use it? (Count drugs such as codeine, Vicodin, OxyContin, Hydrocodone, and Percocet.)
   A.   0 times
   B.   1 or 2 times
   C.   3 to 9 times
   D.   10 to 19 times
   E.   20 to 39 times
   F.   40 or more times

57. During your life, how many times have you used a needle to inject any **illegal** drug into your body?
   A.   0 times
   B.   1 time
   C.   2 or more times

Sexual Activity Risk.

61. During your life, with how many people have you had sexual intercourse?
   A.   I have never had sexual intercourse
   B.   1 person
   C.   2 people
   D.   3 people
   E.   4 people
   F.   5 people
   G.   6 or more people

63. Did you drink alcohol or use drugs before you had sexual intercourse the **last time**?
   A. I have never had sexual intercourse
   B. Yes
   C. No

64. The **last time** you had sexual intercourse, did you or your partner use a condom?
   A. I have never had sexual intercourse
   B. Yes
   C. No

65. The **last time** you had sexual intercourse, what **one** method did you or your partner use to **prevent pregnancy**? (Select only **one** response.)
   A. I have never had sexual intercourse
   B. No method was used to prevent pregnancy
   C. Birth control pills
   D. Condoms
   E. An IUD (such as Mirena or ParaGard) or implant (such as Implanon or Nexplanon)
   F. A shot (such as Depo-Provera), patch (such as Ortho Evra), or birth control ring (such as NuvaRing)
   G. Withdrawal or some other method
   H. Not sure

Mental Health Risk.

25. During the past 12 months, did you ever feel so sad or hopeless almost every day for **two weeks or more in a row** that you stopped doing some usual activities?
   A. Yes
   B. No

26.   During the past 12 months, did you ever **seriously** consider attempting suicide?
    A.   Yes
    B.   No

Violence Risk.

17.   During the past 12 months, how many times were you in a **physical fight**?
    A.   0 times
    B.   1 time
    C.   2 or 3 times
    D.   4 or 5 times
    E.   6 or 7 times
    F.   8 or 9 times
    G.   10 or 11 times
    H.   12 or more times

Injury Risk.

11.   During the past 30 days, on how many days did you **text or e-mail** while **driving** a car or other vehicle?
    A.   I did not drive a car or other vehicle during the past 30 days
    B.   0 days
    C.   1 or 2 days
    D.   3 to 5 days
    E.   6 to 9 days
    F.   10 to 19 days
    G.   20 to 29 days
    H.   All 30 days

Diet Risk.

71. During the past 7 days, how many times did you eat **fruit**? (Do **not** count fruit juice.)
    A. I did not eat fruit during the past 7 days
    B. 1 to 3 times during the past 7 days
    C. 4 to 6 times during the past 7 days
    D. 1 time per day
    E. 2 times per day
    F. 3 times per day
    G. 4 or more times per day

76. During the past 7 days, how many times did you drink a **can, bottle, or glass of soda or pop**, such as Coke, Pepsi, or Sprite? (Do **not** count diet soda or diet pop.)
    A. I did not drink soda or pop during the past 7 days
    B. 1 to 3 times during the past 7 days
    C. 4 to 6 times during the past 7 days
    D. 1 time per day
    E. 2 times per day
    F. 3 times per day
    G. 4 or more times per day

78. During the past 7 days, on how many days did you eat **breakfast**?
    A. 0 days
    B. 1 day
    C. 2 days
    D. 3 days
    E. 4 days
    F. 5 days
    G. 6 days
    H. 7 days

Physical Inactivity Risk.

79.   During the past 7 days, on how many days were you physically active for a total of **at least 60 minutes per day**? (Add up all the time you spent in any kind of physical activity that increased your heart rate and made you breathe hard some of the time.)
A.   0 days
B.   1 day
C.   2 days
D.   3 days
E.   4 days
F.   5 days
G.   6 days
H.   7 days

83.   During the past 12 months, on how many sports teams did you play? (Count any teams run by your school or community groups.)
A.   0 teams
B.   1 team
C.   2 teams
D.   3 or more teams

Screen Time Risk.

80. On an average school day, how many hours do you watch TV?
    A. I do not watch TV on an average school day
    B. Less than 1 hour per day
    C. 1 hour per day
    D. 2 hours per day
    E. 3 hours per day
    F. 4 hours per day
    G. 5 or more hours per day

81. On an average school day, how many hours do you play video or computer games or use a computer for something that is not school work? (Count time spent on things such as Xbox, PlayStation, an iPad or other tablet, a smartphone, texting, YouTube, Instagram, Facebook, or other social media.)
    A. I do not play video or computer games or use a computer for something that is not school work
    B. Less than 1 hour per day
    C. 1 hour per day
    D. 2 hours per day
    E. 3 hours per day
    F. 4 hours per day
    G. 5 or more hours per day