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Relationship Between Sports Participation, Weight Intentions, and Insufficient Sleep on E-Cigarette Use Among U.S. High School Students

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This is to certify that the doctoral study by

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Walden University
2024

Abstract

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MPH, University of New England, 2016

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Doctoral Study Submitted in Partial Fulfillment

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August 2024

Abstract

Despite public health efforts, e-cigarette use among youths persists, posing risks due to high nicotine content and the potential for transitioning to traditional cigarette smoking. Although sports participation has shielded individuals from traditional cigarette use, recent studies revealed a higher susceptibility to e-cigarette use among young athletes, though influencing factors were unexplored. Using the socioecological model, this retrospective cross-sectional study examined the relationship between sports participation, weight intentions, insufficient sleep, and e-cigarette use among U.S. high school students by analyzing 2021 National Youth Risk Behavior Survey data. Binary logistic regression assessed associations between variables. An interaction term examined the moderating roles of weight intentions and insufficient sleep on the relationship between sports participation and e-cigarette use. The analysis found significant associations between weight intentions and insufficient sleep with e-cigarette use. Students with insufficient sleep ($OR = 1.67$, $p < .001$) and those managing their weight had higher odds of e-cigarette use ($OR = 1.52$, $p < .001$). No significant direct association was found between sports participation and e-cigarette use, and weight intentions or insufficient sleep did not moderate this relationship. Public health interventions could include a holistic health education approach to promote healthy weight management and adequate sleep. Implementing educational interventions to address these factors may drive positive social change at various levels of influence, promoting healthier futures for youths.

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Dedication

To my husband, whose support, love, inspiration, and sacrifices have been the cornerstone of my academic endeavor. I can not thank you enough for making this possible, and I could not have undertaken this journey without you.

To my children, whose love, support, sacrifices, and understanding have been my motivation and joy throughout this scholarly pursuit, their resilience and encouragement have inspired me to persevere; this endeavor would not have been possible without you all here.

To my sister, whose support, assistance, and invaluable venting sessions provided solace during moments of uncertainty, her presence has been a source of strength for me, and I would like to express my deepest gratitude.

I am extremely grateful to my friends, especially my best friend, neighbors, and classmates, whose collective support and encouragement have been integral to my achievements. You being by my side has made this journey richer, and I am immensely grateful.

A heartfelt thank you to my mom and dad, whose successes and accomplishments have inspired me; their belief in my potential has fueled my determination to complete this journey.

To my cherished husband, children, sister, friends, neighbors, classmates, and parents—a collective tapestry of support, encouragement, and inspiration. Your roles have made this academic pursuit possible and profoundly meaningful. Words cannot express my gratitude. I thank and love you all.

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I sincerely thank the professors and support staff at Walden for laying the foundation that enabled me to achieve this highest academic milestone. Dr. Shanna Barnett, Dr. Amy Tobler, and Dr. Claudia Kozinetz, your wealth of knowledge shared throughout my coursework, residencies, and seminars played a pivotal role in shaping the foundation of this study. Thanks should also go to Dr. Irana Hawkins, whose inspiration and support in the early stages of my doctoral journey were instrumental in cultivating my path as a dietitian in the public health field.

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Table of Contents

List of Tables

List of Figures

Section 1: Foundation of the Study and Literature Review

Electronic cigarettes (e-cigarettes) have dominated the landscape of tobacco product use among youths in the United States over the past decade, prompting significant public health concerns (Birdsey et al., 2023; Centers for Disease Control and Prevention [CDC], 2023a). The appeal of e-cigarettes to young people often stems from the perception that e-cigarettes are less harmful, less addictive, and healthy compared to traditional cigarettes (CDC, 2023a; S. Singh et al., 2020). Marketed as "healthy," "safe," and "natural," e-cigarettes are promoted to youths as a means to enhance energy, alleviate anxiety, and manage weight (Dubé et al., 2023; J. Lee et al., 2023). Some studies suggested that e-cigarettes are used as a remedy for conditions such as appetite control and weight loss (Morean et al., 2020). Additionally, Holtz et al. (2022b) discovered a significant association between sleep troubles over the past year and an increased risk of initiating e-cigarette use (vaping). The rising acceptance of vaping may not be based only on the perceived lower risk but also on the potential role of e-cigarettes as a form of self-medication.

However, the opposite may be true, and the increasing trend of youth acceptance of vaping raises critical questions regarding potential health risks and long-term consequences in this demographic. Early long-term data indicated that youths using e-cigarettes face higher odds of using traditional cigarettes and other tobacco products in the future, amplifying a lifetime of health risks associated with nicotine and cigarette use (Becker et al., 2021; CDC, 2022b; Dai et al., 2022; United States Department of Health and Human Services [HHS], 2012). Additionally, the CDC (2022b) report health

concerns related to vaping include respiratory impedance, vaping-associated morbidity, heating of flavorings, exposure to known carcinogenic additives, risks of secondhand and thirdhand exposure, and the possibility of presently unknown health consequences.

These products have also captured the attention of young individuals engaged in sports, a well-established protective factor against traditional smoking (CDC, 2023a; Veliz et al., 2017). Although multiple studies demonstrated a positive correlation between sports participation and e-cigarette use, this relationship needed to be explored in the U.S. context (Milicic et al., 2017; Veliz et al., 2017; Williams et al., 2020). There were limited available data on the relationship between e-cigarette use and high school students involved in sports in the United States and a lack of evidence evaluating potential interactions with weight intentions and insufficient sleep. The current study addressed the relationship between sports participation and e-cigarette use while considering other potential factors and moderating influences, such as weight intentions and sleep deprivation, given the prevalent marketing and acceptance of vaping products for these purposes (Dubé et al., 2023; J. Lee et al., 2023). The current study addressed questions about e-cigarette use and sports participation among high school students in the United States, which may contribute valuable insights to public health campaigns and education. Section 1 covers the background, problem statement, study purpose, research questions and hypotheses, theoretical framework, nature of the study, literature search strategies, literature review on key variables and research questions, definitions, assumptions, scope, delimitations, limitations, significance, and a summary and conclusions.

Background

Among middle and high school students in the United States, e-cigarettes (American Cancer Society, n.d.) have been identified as the most frequently used tobacco product since 2014 and have become a severe public health concern (CDC, 2022b; Cooper et al., 2022; T. Singh et al., 2016). The CDC and U.S. Food and Drug Administration (FDA)(2022) found that 2.55 million youths in the United States reported current electronic cigarette use (Cooper et al., 2022). This is a troubling increase of 3.3% or almost one-half million youths from the previous year's findings (Cooper et al., 2022; Park-Lee et al., 2021) despite public health efforts to reduce the use of e-cigarettes (FDA, 2021). The disturbing acceptance of e-cigarette use among U.S. youths deserves further research to understand the mechanisms at play for the development of effective public health campaigns. Student athletes are among those who have an attraction and increasing acceptance of e-cigarette products among youths, and in several studies have been shown to have higher rates of e-cigarette use and are considered an at-risk group among U.S. adolescents (Irvine et al., 2021; Y. Lee et al., 2021; Milicic et al., 2017). This is concerning because sports participation has been shown to be protective against traditional cigarette use (Williams et al., 2020). Current research has yet to examine factors that may be playing a role in the rates of e-cigarette use by student athletes in the United States.

Vaping has been popular with adolescents for weight loss or improving energy (Holtz et al., 2022a; Merianos et al., 2021; Sanchez et al., 2021). Students participating in certain sports are susceptible to suboptimal sleep behaviors (Rebello et al., 2022) and

higher rates of disordered eating (Mancine et al., 2020). Students participating in sports may be vulnerable to e-cigarette use for weight-loss intentions or to improve energy due to insufficient sleep (Holtz et al., 2022a; Merianos et al., 2021; Sanchez et al., 2021). However, there was a paucity of data on sports participation and e-cigarette use and no research evaluating factors that may interact with the relationship, such as weight intentions or insufficient sleep. With the increasing use of e-cigarettes among adolescents and sports participation showing signs of higher risk, it was critical to gain further insight into factors associated with use to inform public health campaign efforts.

The results of the current study could provide a better understanding of the rising public health threat of youth e-cigarette use and positively impact social change. Unlike with traditional cigarette use (Williams et al., 2020), sports participation has not been shown to be protective against e-cigarette use and, in some cases, has been positively associated (Veliz et al., 2017). However, little was known about the relationship between sports participation and e-cigarette use in adolescents in the United States. This study approached the problem of e-cigarette use through the lens of the socioecological model (SEM) by recognizing likely multilevel influences on vaping by adolescents. The Youth Risk Behavior Surveillance System (YRBSS) monitors health-related behaviors established in young adulthood that are likely to contribute to the leading causes of death and disability as adults in the United States (CDC, 2022c). The 2021 YRBSS data set provided an opportunity to use secondary data for a quantitative study to evaluate the relationship between adolescents in the United States, vaping, sports participation, and how inadequate sleep or weight intentions may play a role in those relationships. This

study may create positive social change by providing insight into the relationship between sports participation and student e-cigarette use. A better understanding of these relationships could discourage e-cigarette use in public health programs for adolescents.

Problem Statement

Despite recent public health efforts, evidence suggested that e-cigarette use remains a widespread problem among adolescents in the United States. According to Kann et al. (2018), e-cigarette use has rapidly increased, with 42.2% of U.S. students in Grades 6–12 having used electronic vapor products, providing evidence of an apparent public health problem. The latest data suggested that 2.44 million middle and high school students are using e-cigarettes, with 1 in 4 using them daily, and within this population, e-cigarettes have been the most used tobacco product since 2014 (Cooper et al., 2022). E-cigarettes are known to be highly addictive, and most contain nicotine, which can be harmful to the developing brain of adolescents. Additionally, like other health-related behaviors that develop in young adulthood (CDC, 2022b), using e-cigarettes has been shown to deepen the pathway to smoking and more frequent tobacco cigarettes later in adolescence (Kelly et al., 2023). Although the problem with e-cigarette use in adolescence has been well established, there was less known about factors that influence use.

Sports participation is one factor that has been shown to be protective against traditional cigarette use but does not share this same benefit for e-cigarette use in this population. Recent literature has begun to examine the relationship between sport participation, activity level, and the use of e-cigarettes (Y. Lee et al., 2021; Milicic et al.,

2017; Veliz et al., 2017). Y. Lee et al. (2021) and Veliz et al. (2017) found that traditional tobacco health protective behaviors such as sports participation or physical activity are not protective against e-cigarette use, with some sports participation having a greater risk for e-cigarettes; therefore, it was essential to examine factors associated with e-cigarette use in this population. Recent evidence revealed that factors such as weight loss intention and sleep deprivation may be related to general adolescent e-cigarette use (Holtz et al., 2022a; Obinwa et al., 2021; Sanchez et al., 2021). Therefore, these factors may play a role in the relationship between sports participation and e-cigarette use.

Additionally, there was little research using the YRBSS to examine the relationship between factors such as sports participation, hours of sleep, intent to lose weight, and e-cigarette use in U.S. adolescents. The current study filled a gap in the current literature to determine whether there was an association between sports participation, hours of sleep, intent to lose weight, and e-cigarette use in U.S. adolescents or whether these factors act as moderators for the relationship between sports participation and e-cigarette use. The findings from this study have the potential to enhance public health education and campaigns addressing e-cigarette use, particularly among the high-risk demographic of young athletes.

Purpose of the Study

The purpose of this quantitative study using secondary data from YRBSS was to examine the relationship between sports participation, weight intentions, and insufficient sleep (independent variables) on e-cigarette use (dependent variable) in students (Grades 9–12) in the United States. Moreover, I sought to determine whether weight intentions

and insufficient sleep (moderating variables) moderated the relationship between sports participation and e-cigarette use. The findings of this study could improve public health education efforts and campaigns aimed at mitigating e-cigarette use, particularly within the high-risk group of young athletes.

Research Questions and Hypothesis

RQ1: Is there an association between sports participation, weight intentions, insufficient sleep (defined by 7 hours or less), and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity?

H_o1: Sports participation, weight intentions, and insufficient sleep as defined by 7 hours or less are not associated with e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity.

H_a1: Sports participation, weight intentions, and insufficient sleep as defined by 7 hours or less are associated with e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity.

RQ2: Does weight intentions moderate the relationship between sports participation and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity?

H_o2: Weight intentions do not moderate the relationship between sports participation and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity.

H_a2: Weight intentions moderates the relationship between sports participation and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity.

RQ3: Does insufficient sleep, as defined by 7 hours or less, moderate the relationship between sports participation and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity?

H_o3: Insufficient sleep, as defined by 7 hours or less, does not moderate the relationship between sports participation and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity.

H_a3: Insufficient sleep, as defined by 7 hours or less, moderates the relationship between sports participation and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity.

Theoretical Framework for the Study

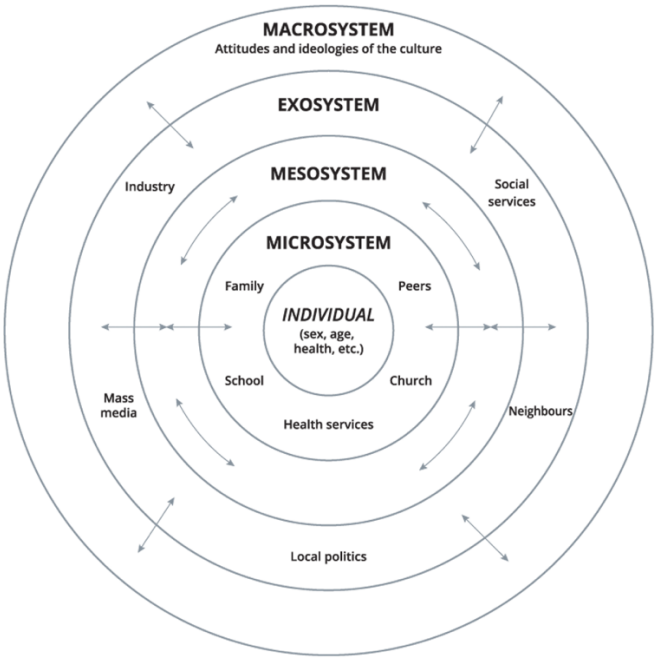
The theoretical base that grounded this study was the SEM, otherwise known as the ecological model (EM), first introduced by Bronfenbrenner (1977). Bronfenbrenner (1977) first introduced the conceptual model and then later formalized the SEM (Bronfenbrenner, 1994; McLeroy et al., 1988) to understand human development, where individuals are influenced by their interactions and relationships with the different levels of their environment. Bronfenbrenner (1977) conceived the individual's ecological environment as nested circles, similar to Russian nesting dolls in the original conceptual model. In these circles, the individual is at the center, followed by the microsystem, which encompasses the strongest influences from the interrelationships of the

individual's immediate surroundings (Bronfenbrenner, 1977). The mesosystem, which goes beyond the immediate interactions, is the next nested circle and includes interrelationships from things such as work, school, or neighborhood (Bronfenbrenner, 1977). The exosystem does not include the developing individual as an active participant but can wield both positive and negative interactive forces on their development, such as community, social networks, or policies (Bronfenbrenner, 1977).

A current rendering of the SEM core concepts has been adapted by the CDC (n.d.) and applied to various public health problems and solutions. This model includes the individual, relationship, community, and societal levels of interaction (CDC, n.d.). The SEM is a holistic and multifaceted approach to understanding an individual's behavior and provides a framework for appreciating the complex interplay between individuals and their multilevel environment. The uniqueness of the SEM, because it recognizes that multilevel interactions with the environment impact health and behavior, aligned with studying the vaping behavior of adolescents. Although the SEM provided a holistic framework for understanding the multilevel influences of the vaping behavior of adolescents, a significant challenge arises when attempting to implement multilevel interventions, particularly in the face of constrained public health budgets (CDC, n.d.). The current study aimed to provide valuable insights for public health and education campaigns, directing attention toward potential influences on adolescents' vaping choices within the context of sports participation. The goal was to enhance the effectiveness and focus of allocated resources in these campaigns; despite the notable limitation associated with the SEM, it was considered an appropriate framework for this study (see Figure 1).

Figure 1

Bronfenbrenner's Ecological Systems Theory



Note. Image adapted from PowerPoint images – public domain.

The SEM was a logical foundation for the current study examining e-cigarette use among adolescents. The SEM focuses on several layers of influences on health behaviors and posits that multiple factors within a variety of environments in an individual's life can influence the behavioral characteristics of an individual (McLeroy et al., 1988). This related to my research purpose and problem because I sought to examine possible relationships between vaping use and adolescents in various environments.

The layers of influence at an individual level, at home, and at school contribute to young people's behavior development, and the SEM allowed for focus on these environments, making an ideal framework to align with this study. According to the

SEM, the multilevel environments that could influence behavior include structures within the individual, such as perceptions and intentions, and physical, social, and organizational environments (McLeroy et al., 1988). Considering a framework that recognizes the importance of multiple environments' simultaneous ability to shape and influence behaviors to answer the research questions was essential. Alghzawi and Ghanem (2021) modeled how the SEM could be applied to underage drinking and argued that this framework provides a better understanding of the multilevel forces that influence children's behaviors when it comes to alcohol or drug use. The SEM provides a framework to explore associations from multiple influences in a grander context. For instance, the SEM allowed me to explore individual-level sociodemographic factors that have been linked to e-cigarette and tobacco use, such as race, age, gender, ethnicity, and their relationship to vaping in adolescent athletes (see Cheney et al., 2018; Obinwa et al., 2021). Additionally, at the individual level of the SEM, I examined whether sports participation, insufficient sleep, and weight intentions influence vaping while controlling for sociodemographic factors. Sports participation also fit into the social level, allowing me to examine peer influences through sports participation and the relationship to e-cigarette use.

Nature of the Study

The methodological approach for this study was quantitative, using binary logistic regression analysis with moderation to examine possible associations between the independent variables of sports participation, moderating variables of weight intentions and insufficient sleep, and the dependent variable of e-cigarette use in U.S. students

Grades 9–12 in the. The covariates in this study included age, sex, race, and ethnicity. The 2021 Youth Risk Behavior Survey (YRBS), conducted by the CDC (2022c) and found within the YRBSS,was used as the national secondary data source. The 2021 YRBS has publicly accessible data online and included the identified variables.

Literature Search Strategy

To establish the background for the study, I searched related literature using online databases from the Walden University Library in Thoreau, CINAHL Plus, ProQuest Central, Science Direct, PubMed, and Google Scholar. I expanded my search terms in each search by applying the recommended Boolean phrases. All searches were limited to peer-reviewed and scholarly sources, and focused most of my efforts on the last 5 years. However, older research and seminal works were included. The key search terms that I used to identify literature related to e-cigarette use included *e-cigarettes*, *electronic cigarettes*, *vapor cigarettes*, *vaping*, and *vape pens*. To identify literature related to the population of interest, I used the following critical search terms: *adolescents*, *teenagers*, *young adults*, *teens*, *students*, *youth*, *high-school students*, *secondary students* and *the United States, America, USA,* and *US*. I also included pertinent studies that were outside of the United States. The key search terms used in the literature search for the theoretical framework for this study included *ecological model*, *social-ecological model*, and *Bronfenbrenner*, and I applied additional phrases of *conceptual framework* and *theoretical framework*. To search the literature for the critical variables in this study, I added key search terms of *athlete*, *athletics*, *student-athletes*,

sports participation, *sleep deprivation*, *sleep quality*, *sports*, *inadequate sleep*, *sleep*, *disordered eating*, *intention to lose weight*, *weight loss*, and *weight intentions*.

Literature Review Related to Key Variables and/or Concepts

E-Cigarette Background

The e-cigarette, known by various names and evolving in popularity and form, constitutes a noteworthy phenomenon in the market. The e-cigarette is referred to as "e-cigs," "personal vaporizers," "mods," "vape pens," "vapes," "tank systems," or "electronic nicotine delivery system (ENDS)" (CDC, 2023a). An e-cigarette is characterized as a battery-operated device that heats a solution, semisolution, or solid into vapor, which the user subsequently inhales through the mouth and lungs, facilitating absorption into the bloodstream (CDC, 2022b; Jenssen & Walley, 2019; Peace et al., 2019). Additionally, bystanders are susceptible to inhaling the aerosol following the user's exhalation (CDC, 2023a). E-cigarette solutions contain flavorings for enhanced appeal, other chemicals for aerosol formation, and typically nicotine (CDC, 2022b). However, Peace et al. (2019), in a study supported by the National Institute of Justice, uncovered the prevalence of marijuana in e-cigarettes, encompassing cannabidiol and tetrahydrocannabinol, the psychoactive compound. Furthermore, e-cigarette devices are employed to administer drugs such as methamphetamine, fentanyl, and synthetic cannabinoids, enhancing the potency and flavor of these products (Peace et al., 2019).

E-cigarettes made their debut in 2003 in China, introduced by pharmacist Hon Lik in collaboration with Dragon Holding as a potentially less harmful alternative to smoking and a potential aid for smoking cessation (Sapru et al., 2020). E-cigarettes received

international patent recognition in 2007, and were introduced to the United States and other markets (Sapru et al., 2020). Presently, e-cigarettes exhibit diverse shapes, functionalities, and designs in disposable or rechargeable forms (CDC, 2022b; Sapru et al., 2020). These products come from many manufacturers offering thousands of unique flavorings, and are often cheaper than traditional cigarettes (CDC, 2022b; National Institute of Justice, 2020; Sapru et al., 2020). Since their introduction to the U.S. market, e-cigarettes have experienced a surge in popularity, attracting both traditional smokers seeking alternatives and nonsmokers with the most pronounced surge occurring over the past decade (Sapru et al., 2020).

The rapid adoption of e-cigarettes and their widespread acceptance among adolescents raise significant concerns because e-cigarettes have maintained their status as the most frequently used tobacco product among youths for nearly a decade (CDC, 2022b; Cullen et al., 2019). Much of this popularity can be attributed to the minimal regulation of e-cigarettes in the United States, rendering them easily accessible and heavily marketed to young individuals (Prochnow, 2017; Sapru et al., 2020). E-cigarettes are available in vending machines, offered as free samples, accessible via online purchases, and found in shopping mall kiosks, among other locations where traditional cigarette sales are prohibited (Sapru et al., 2020). Furthermore, the lack of a lingering cigarette or marijuana odor allows e-cigarettes to be used inconspicuously in public spaces (Peace et al., 2019; Sapru et al., 2020). The high use rates, particularly among the youth demographic, prompted public health concerns and calls for legislative action (Jenssen & Walley, 2019; Prochnow, 2017).

However, the regulation and legislation governing e-cigarettes have lagged behind the pace of their surging popularity. It was not until 2016 that the FDA initiated the classification of e-cigarettes as other tobacco products, mandating labeling requirements, market standards for new products, age restrictions limiting sales to individuals age 18 and above, and the prohibition of vending machine sales and the distribution of free samples (FDA, 2019). As of December 31, 2022, 33 states had enacted legislation mandating retail licenses for over-the-counter e-cigarette sales, 30 states had imposed an e-cigarette tax, and 17 states had incorporated e-cigarettes into smoke-free indoor air policies (CDC, 2023b). Nonetheless, the accessibility, persistent marketing directed at youths, and the challenges associated with regulation in the United States continue to preserve e-cigarettes' allure among this demographic.

E-Cigarette Current Use Among Youths

E-cigarettes have grown in popularity among youths in the United States since their introduction. The prevalence of e-cigarette use has escalated significantly, with data from the 2019 YRBSS revealing that 50.1% of high school students reported any use of e-cigarettes (Creamer et al., 2020). Recent statistics from 2022 indicated that approximately 2.55 million adolescents were using e-cigarettes (Cooper et al., 2022). For nearly a decade, e-cigarettes have maintained their status as the most frequently used tobacco product among American youths (Ali et al., 2020). Park-Lee et al. (2021) found that 1 out of 7 high school students and 1 out of 30 middle school students reported using e-cigarettes within the past 30 days. In stark contrast, the use of almost all other tobacco products, including cigarettes, cigars, hookah, heated tobacco products, or nicotine

pouches, was reported by only 1 out of 100 middle and high school students (Park-Lee et al., 2021).

The frequency of e-cigarette use among adolescents is particularly concerning, with 46% of high school students and 20.8% of middle school students reporting frequent use (Cooper et al., 2022). In comparison, 30.1% of high school students and 11.7% of middle school students reported daily use (Cooper et al., 2022). This burgeoning prevalence of e-cigarette use among adolescents constitutes a significant public health concern, prompting research endeavors to understand the factors contributing to this alarming trend.

Curiosity has emerged as a potentially contributing factor to adolescent e-cigarette use. Wang et al. (2019) identified that 55.3% of middle and high school students who experimented with e-cigarettes cited curiosity as a motivating factor. Similarly, Lindpere et al. (2022) found curiosity to be one of the primary reasons for e-cigarette initiation among adolescents. However, Lindpere et al. also reported that curiosity was associated with lower odds (adjusted odds ratio [AOR] = .05, $p < .0001$) of frequent e-cigarette use and higher odds ($AOR = 1.2$, $p = .26$) of intention to quit, suggesting that curiosity may not be a pivotal driver of sustained and frequent e-cigarette use, which poses the most significant risk to adolescent health.

Social factors, including the normalization of vaping within familial and peer circles, have been identified as influential in adolescent e-cigarette use. Dubé et al. (2023) found that friends or family members introduced vaping to most participants during social gatherings in homes, parties, parks, or school bathrooms. This qualitative insight

aligns with a quantitative study by Wang et al. (2019) in which 30.8% of students who experimented with vaping reported that friends and family member use motivated their initial e-cigarette trial. Lindpere et al. (2022) corroborated these findings, identifying family or friends' use as a primary driver of e-cigarette initiation among adolescents. Additionally, Dubé et al. uncovered instances in which participants felt coerced into vaping by older siblings or friends or experienced a sense of exclusion due to their nonvaping status. These observations are consistent with the findings of Chaffee et al. (2019) and Kinnunen et al. (2018) who reported that having friends who used tobacco products significantly influenced e-cigarette experimentation among youths. The literature review did not yield alternative findings regarding the impact of family and friends on adolescent e-cigarette use. Evidence suggested a robust connection between family and friends' e-cigarette use and adolescents' proclivity to sample these products.

E-cigarettes may exert a heightened appeal to youths due to the availability of an extensive array of flavors. Miyashita and Foley (2020) reported the existence of over 15,000 e-cigarette flavors, signifying a nearly twofold increase from the 7,700 flavors available in 2014 (American Academy of Pediatrics et al., 2017). The diverse flavor offerings have played a pivotal role in popularizing these products among youths. Wang et al. (2019) identified that 22.4% of middle and high school students who had experimented with e-cigarettes cited the availability of flavors as their motivation. Moreover, Ali et al. (2020) analyzed product sales trends, revealing a rapid surge in prefilled cartridges and flavored products compared to tobacco and menthol-flavored

counterparts. This body of evidence substantiated the significant role of e-cigarette flavoring in attracting a new generation to tobacco products.

Many studies have corroborated these findings, reinforcing the notion that flavored varieties are appealing to adolescents. Cullen et al. (2019) conducted a cross-sectional analysis, revealing that 72.2% of adolescent e-cigarette-exclusive users preferred flavored options such as fruit, mint, candy, desserts, and other confectioneries. Gentzke et al. (2022) reported that flavored e-cigarette use had surged to 80.2% among high school students and 74.6% among middle school students. Similarly, Cooper et al. (2022) identified an even higher prevalence of flavored e-cigarette use among youths, with 85% of high school students and 81.5% of middle school students partaking, with fruit (69.1%) and candy, desserts, or other sweets (38.3%) ranking as the most commonly favored flavor types.

Moreover, Lindpere et al. (2022) discerned that product characteristics, notably flavors, featured prominently as reported reasons for e-cigarette use among U.S. youths. Of greater concern, Lindpere et al. revealed that these product characteristics are associated with elevated odds of frequent vaping use ($AOR = 1.7$, $p < .0001$) and diminished odds of intention to quit ($AOR = 0.3$, $p < .000$). Flavorings in vape products display a robust correlation with both the initiation of e-cigarette use and its persistence among youths. An intriguing perspective arises, suggesting that adolescents may opt for vaping products over calorie-dense foods.

In addition to flavoring, the marketing of e-cigarettes to young individuals constitutes another influential factor contributing to product acceptance among this

demographic. Wang et al. (2019) noted that 9 out of 10 middle and high school students reported exposure to advertisements promoting tobacco products, often misperceiving the associated harm due to the marketing's youth-oriented nature. Social media has emerged as a prominent promotional channel for the tobacco industry, largely resistant to regulation (J. Lee et al., 2023). Smith et al. (2023) uncovered that a substantial portion of social media marketing promotes e-cigarette use while disregarding negative aspects and warnings. Promotional themes associated with e-cigarettes frequently convey positive concepts, including "healthy," "safe," "natural," "cool," "young," and "independent" (J. Lee et al., 2023). These marketing messages have been proven effective, with 21.2% of students who experimented with vaping reporting that they were motivated by the ability to perform tricks with e-cigarettes (Wang et al., 2019). Other marketing messages suggest benefits related to energy improvement, weight loss, anxiety alleviation, or symptom management for depression (Dubé et al., 2023; J. Lee et al., 2023; H. Singh et al., 2018).

Furthermore, most adolescents perceive e-cigarettes as less harmful than traditional cigarettes (Dubé et al., 2023; Sharma et al., 2021). This perception of minimal risk heightens adolescents' willingness to experiment with these products. In addition, Van et al. (2022) established a correlation between youth exposure to e-cigarette marketing and subsequent increased use. E-cigarette marketing targets platforms that are challenging to regulate, leveraging an appealing image, misleadingly promoting health benefits, and portraying e-cigarettes as trendy to youths. These multifaceted factors contribute to youth e-cigarette use.

Youth Health Risk

The literature established several known risks associated with e-cigarettes, even though research has not assessed their impact on youths. E-cigarettes present significant risks to children, necessitating careful consideration. Developers initially designed vapor products as a smoking cessation aid for adults (CDC, 2023a). E-cigarettes emit fewer harmful substances than traditional cigarettes, suggesting that vaping is a less harmful alternative to smoking and may offer harm reduction potential for adult smokers attempting to quit (CDC, 2023a; S. Singh et al., 2020). However, data were scarce on using e-cigarettes as a smoking cessation tool among young individuals (CDC, 2023a; S. Singh et al., 2020). This gap in research was mainly due to studies indicating that adolescents often initiate vapor product use before trying traditional cigarettes (CDC, 2023a). Consensus dictates that youths or nonsmokers should avoid initiating e-cigarette use because of the potential severe hazards associated with vaping (American Cancer Society, n.d; CDC, 2022b). Despite the potential role of e-cigarettes as harm-reduction tools for adult smokers seeking cessation, e-cigarettes pose risks to children and adolescents.

Nicotine

Nicotine, a highly addictive substance, is prominently present in most e-cigarettes and poses substantial health risks to adolescents. Research consistently highlights the detrimental effects of nicotine exposure during the critical developmental phase of adolescence. Numerous studies have established that nicotine can interfere with cognitive development, adversely affecting attention, memory, and learning processes (Becker et

al., 2021; CDC, 2022b; Dai et al., 2022; McGrath-Morrow et al., 2020; United States Department of Health and Human Services [HHS], 2012). Furthermore, nicotine exposure has been associated with alterations in brain structure and function, particularly in mental health, impulse control, and decision-making (Becker et al., 2021; CDC, 2022b; Dai et al., 2022; HHS, 2012). Physiologically, nicotine use among adolescents has been linked to adverse effects, including elevated heart rate, blood pressure, and diminished lung function (HHS, 2012; McGrath-Morrow et al., 2020).

The potential for lifelong addiction among adolescents who regularly use nicotine products is of significant concern. Extensive evidence underscores that nicotine use during adolescence increases the risk of transitioning to cigarette smoking and continued tobacco use into adulthood (HHS, 2012; McGrath-Morrow et al., 2020; Murthy, 2017). The substantial presence of nicotine in e-cigarettes, coupled with its well-documented adverse health effects on adolescents, emphasizes the imperative need for ongoing research into adolecents' acceptance of vaping products. Developing a deeper understanding of the underlying mechanisms holds the potential to mitigate the cognitive, physiological, and behavioral consequences of nicotine exposure during this critical developmental phase.

Future Tobacco Use

To fully appreciate the potential consequences of adolescent e-cigarette use, it is crucial to grasp the substantial impact of nicotine and its addictive nature. E-cigarettes, a category in which most products contain nicotine, are widely recognized as carriers of this highly addictive substance (CDC, 2022b). Given that most tobacco use commences

during adolescence, a significant public health concern arises: adolescents who engage in e-cigarette use may face an elevated likelihood of transitioning to cigarette smoking or other tobacco products. Preventing tobacco use in youths has long been established as paramount for lifelong prevention, as several studies indicate that the initiation of tobacco product use typically occurs during adolescence (HHS, 2012). The HHS (2012) reports that 90% of adults who become daily cigarette smokers first experimented with smoking by the age of 18, and 99% initiated smoking by the age of 26. The future trajectory of tobacco product use remains uncertain for youths currently addicted to e-cigarettes.

Emerging evidence suggests that the patterns observed with traditional cigarettes may similarly apply to e-cigarettes, raising concerns about the potential normalization of tobacco product consumption. A systematic review and meta-analysis encompassing 17 studies by Khouja et al. (2020) revealed that self-reported non-smoking e-cigarette users were approximately four and a half times more likely to self-report future cigarette use. Notably, adolescents tend to hold favorable perceptions of e-cigarettes compared to traditional cigarettes, often underestimating the addictive nature of e-cigarettes due to a lack of awareness regarding their nicotine content (Gorukanti et al., 2017). Two extensive longitudinal cohort studies found that adolescents initiating e-cigarette use exhibited an increased propensity to initiate traditional cigarette use during subsequent follow-up periods (Berry et al., 2019; Watkins et al., 2018). These findings align with a systematic review and meta-analysis indicating that European and North American teenagers who used e-cigarettes were 4.06 times more likely to subsequently adopt conventional cigarette use compared to their non-e-cigarette-using counterparts at baseline (D. O’Brien

et al., 2021). Consequently, the existing body of literature on adolescent e-cigarette usage underscores prevalent concerns regarding the renormalization of tobacco product consumption and the potential for e-cigarettes to serve as a gateway to traditional cigarette use.

Cigarette smoking among youths, which has steadily declined over the past two decades, with only 1% of middle school students and 2% of high school students reporting cigarette use in the past 30 days, amplifies this concern (Park-Lee et al., 2021). Consequently, there are valid public health apprehensions that e-cigarettes may function as a gateway to future cigarette use among youths due to early nicotine addiction. Alarming trends in e-cigarette use among youths have the potential to stall or even reverse the decline in smoking rates, contributing to the emergence of new generations of nicotine addicts.

Flavorings and Chemical Additives

In addition to nicotine, the flavorings and chemical additives incorporated into e-cigarettes present supplementary health concerns. While many flavorings are deemed safe for consumption, their safety when subjected to heating and inhalation warrants further investigation (S. Singh et al., 2020). The heating process can lead to noxious compounds and respiratory irritants, including volatile organic compounds and toxicants like formaldehyde and acetaldehyde (Goniewicz et al., 2018). Goniewicz et al. (2018) observed that individuals using e-cigarettes exhibited comparable levels of metals and volatile organic compounds in their urine, specifically toluene, benzene, and carbon disulfide, akin to those found in traditional cigarette smokers. Additionally, Park et al.

(2019) demonstrated that inhaling these flavoring substances may result in respiratory symptoms and impaired lung function, primarily by disrupting cilia function in the airway epithelium.

Furthermore, inhaling harmful substances via e-cigarettes can exacerbate preexisting health conditions, such as asthma (National Academy of Sciences, Engineering, and Medicine et al., 2018, p. 406). A tragic illustration of how the heating and inhalation of substances can alter their safety is the e-cigarette or vaping product use-associated lung injury (EVALI) outbreak, which led to over 2,800 hospitalizations and 68 fatalities in the United States between 2019 and 2020. Notably, a significant proportion of those affected were youths as young as 13 years old and young adults (Krishnasamy et al., 2020). EVALI was directly linked to inhaling Vitamin E acetate, an otherwise safe substance, when consumed as a supplement or applied topically (Krishnasamy et al., 2020).

In conclusion, beyond the realm of nicotine, including flavorings and chemical additives, introduces an array of additional health risks associated with e-cigarette use among adolescents. However, the potential hazards related to e-cigarette usage extend beyond nicotine, and ongoing research is only beginning to scratch the surface of this intricate landscape.

Secondhand and Thirdhand Exposures

Inhaling vapor from e-cigarettes carries potential health hazards for individual users and those exposed to secondhand and thirdhand emissions. While the health effects of secondhand e-cigarette exposure remain uncertain, some evidence calls for caution.

Studies have shown that repeated vaping instances increase concentrations of nicotine, fine and ultrafine particulates, and volatile inorganic compounds have been shown to increase indoors, and these substances persist on surfaces and clothing (Melstrom et al., 2017). This raises concerns regarding both respiratory and dermal absorption (Melstrom et al., 2017). Similarly, in settings with multiple e-cigarette users, airborne particulate and nicotine levels were found to be comparable to indoor environments where traditional smoking was allowed (Chen et al., 2018). However, in household settings with average use, baseline particulate matter ≤2.5 μm in diameter (PM2.5) was observed to be 58 times higher in traditional smoking households compared to e-cigarette use. However, significant PM2.5 peaks coincided with e-cigarette puffs (Fernández et al., 2015). Non-smokers have also been demonstrated to absorb nicotine through secondhand exposure (Ballbè et al., 2014; Logue et al., 2017). However, precise quantification of exposures is challenging due to substantial variability in the composition of harmful chemicals, depending on the specific device and voltage used (Logue et al., 2017). Continued research is necessary to fully understand the spectrum of risks associated with secondhand exposure to e-cigarette vapor. Nonetheless, the existing body of evidence underscores that the scope of e-cigarette vapor hazards extends to secondhand exposures, warranting caution despite uncertainties regarding specific health consequences.

Progression to Other Substances

Another risk associated with e-cigarettes and youths is the potential for an escalation into the use of various substances. Numerous studies have revealed associations between e-cigarette use and other forms of substance abuse, including

alcohol, marijuana, amphetamines, and non-prescribed medications such as Ritalin or Adderall (Boccio & Jackson, 2021; Demissie et al., 2017; Keyes et al., 2022; Silveira et al., 2018). Westling et al. (2022) conducted a longitudinal study to investigate this further, finding a higher transition rate from e-cigarette use to marijuana use compared to the transition to traditional cigarette use. Additionally, the versatility of e-cigarette devices has provided a new means of administering various illicit substances, including cannabis, synthetic cannabinoids, cocaine, heroin, fentanyl, and methamphetamines, among others (Breitbarth et al., 2018; Masson et al., 2022). As previously discussed, one appeal of e-cigarettes to youths is their inconspicuous use in public settings, free from the distinctive odors associated with cigarettes or marijuana (Peace et al., 2019; Sapru et al., 2020). While enhancing their allure, this characteristic may also serve as a gateway to experimenting with other illicit substances that individuals might not consider otherwise. However, it is essential to note that the exploration of e-cigarettes serving as a conduit for illicit drugs remains largely unexplored in the literature, rendering the progression from e-cigarette use to illicit drug engagement an area of uncertainty. Nevertheless, the complex interrelationships between e-cigarettes and the use of other substances persist as a noteworthy public health concern, posing a risk to the younger population engaged in vaping.

Sports Participation

Interestingly, sports participation does not offer a protective shield against vaping, as is often the case with traditional cigarette use. This is concerning because athletes may be more impacted by effects of vaping (Young et al., 2020). Multiple studies have

revealed that adolescent athletes are more inclined to use e-cigarettes than non-athlete peers (Irvine et al., 2021; Milicic et al., 2017, Rapoport et al., 2022). Similarly, a study examining self-reported physical activity and e-cigarette use in young adults (with a mean age of 21.2), conducted by Pokhrel et al. (2020), discovered a positive association between higher levels of physical activity at baseline and increased e-cigarette use. Y. Lee et al., (2021) also found a positive relationship between more physically active students and vaping, compared to less active peers. Thus, despite the common assumption that individuals involved in sports tend to make healthier choices, engagement in athletics and physical activity may heighten the likelihood of using vapor products. The literature has started to explore the factors influencing the relationship between sports participation and vaping.

Some studies propose that specific characteristics or subgroups within the athlete population may have a higher risk of vaping. Veliz et al. (2017) delved deeper into the connection between vaping and sports participation by examining different competitive sports. However, they found that no particular sport offered protection against e-cigarette use (Veliz et al., 2017). In an intriguing twist, a study investigating smokeless tobacco product use among rural high school baseball players by Chaffee et al. (2019) discovered that e-cigarettes (36%) were equally as prevalent as smokeless tobacco (36%). On the other hand, Kinnunen et al. (2018) noted that the relationship between sports participation and vaping was only significant for boys, not girls. Further exploration of these factors is essential to gain a comprehensive understanding of the complex relationship between sport participation and e-cigarette use among adolescents.

Furthermore, when considering the impact of sports participation on e-cigarette use among adolescents, it is crucial to delve into the specific aspects that may influence this relationship. For instance, Kinnunen et al. (2018) found that only team sports predicted e-cigarette use, whereas individual sports, such as swimming or running, showed no such association. Kinnunen et al. hypothesized that this discrepancy was related to the risk-taking personalities often associated with contact sports like lacrosse, wrestling, and football compared to non-contact sports like cross country or swimming. Conversely, Veliz et al. (2017) found that baseball and softball (for girls), both non-contact sports, had a higher risk of e-cigarette use. Therefore, while certain studies have started to shed light on the potential factors and characteristics within the athlete population that might contribute to e-cigarette use, a more comprehensive understanding of these relationships and the possible moderators involved remains a critical area for further research in this field.

While some studies have provided valuable insights into factors influencing e-cigarette use among athletes, there still needs to be more consensus and a notable gap in our understanding of the various influencing factors involved in the relationship between sports participation and e-cigarette use. The existing literature has predominantly concentrated on factors such as the type of sport and gender, leaving room for other external variables to influence vaping behaviors in the context of sports participation. Additionally, limited research has explored potential moderators of these relationships. Consequently, it is crucial to embark on further investigations to gain a more

comprehensive understanding of the factors associated with sports participation and e-cigarette use and the potential moderators that may shape this complex relationship.

Inadequate Sleep

The American Academy of Sleep Medicine recommends that adolescents aim for eight to ten hours of sleep per night to ensure proper emotional, cognitive, and physical development (Paruthi et al., 2016). However, many adolescents do not meet this recommendation, leading to several detrimental consequences, including engagement in substance abuse, increased risk-taking behaviors, and mood and mental health issues (Short et al., 2018; Weaver et al., 2018). Furthermore, there is a well-established connection between sleep disturbances and nicotine use, although this relationship's directionality is unclear. Some studies suggest that nicotine's stimulant effects can lead to poor sleep (Mathews & Stitzel, 2018), while others propose that poor sleep may trigger the initiation of nicotine use (Wiener et al., 2020; Wong et al., 2010). Given the high rates of nicotine exposure associated with e-cigarettes, it is reasonable to assume that a relationship between vaping and inadequate sleep could also exist.

Recent research has explored the potential link between sleep patterns and e-cigarette use. Kianersi et al. (2021) investigated the relationship between sleep deprivation and e-cigarette use in young adults aged 18 to 24. They discovered that e-cigarette users were more likely to experience sleep deprivation, and this association grew stronger with increased e-cigarette use (Kianersi et al., 2021). Similarly, Baiden et al. (2023) and Holtz et al. (2022a) identified a similar connection among adolescents. Baiden et al. observed that adolescents who used e-cigarettes had higher odds of

reporting insufficient sleep (less than seven hours). Moreover, Holtz et al. delved into the direction of this relationship and found that sleep deprivation (six hours or less) correlated with self-reported susceptibility to initiating e-cigarette use within the following month (Holtz et al., 2022a). To better understand this relationship's direction, Holtz et al. (2022b) conducted a longitudinal cohort study assessing the transition from never using e-cigarettes to ever using them over one year. After controlling for several variables, the researchers found that past-year sleep troubles significantly increased the risk of initiating e-cigarette use compared to respondents with no reported sleep troubles. Consequently, accumulating research emphasizes a robust association between sleep patterns and e-cigarette use, indicating that sleep deprivation correlates with a higher likelihood of e-cigarette use and suggests a potential bidirectional relationship where inadequate sleep could contribute to increased susceptibility to vaping initiation among youths.

Over the past decade, researchers and healthcare groups have focused more attention on the potential risks of inadequate or disrupted sleep among teenage athletes and its subsequent adverse cognitive, physical, and psychological effects. Researchers have proposed that the increasing competitiveness and training intensity in youth sports have compromised adolescents' ability to rest and recover properly (Bergeron et al., 2015). Athletes face additional challenges in obtaining adequate and high-quality sleep, including sleep disturbances due to performance anxiety, fragmented sleep, and limited sleep time due to academic commitments and training schedules (Bolin, 2019; Coel et al., 2022). Studies further support this issue by revealing alarmingly high rates of self-

reported sleep inadequacy among athletes (Mah et al., 2018; Rebello et al., 2022; Walsh et al., 2020). Objective sleep monitoring data corroborated these findings (Potter et al., 2019; Suppiah et al., 2015; Suppiah et al., 2016). Therefore, mounting evidence underscores significant sleep challenges faced by adolescent athletes. The convergence of research highlighting the potentially elevated risk of compromised sleep duration and quality among young athletes, coupled with the intricate relationship between sleep patterns and e-cigarette use, underscores the need for ongoing research to determine whether these factors play a role in vaping behavior among students who participate in sports.

Weight Intentions

There is evidence suggesting that weight intentions may contribute to vaping risk among adolescents. As discussed earlier, e-cigarettes are often marketed to young individuals as "safe," "natural," "healthy," and even promoted as a means to aid weight control by delivering nicotine without calories, resembling various sweet treats (Dubé et al., 2023; J. Lee et al., 2023; Smith et al., 2023). Furthermore, e-cigarette companies are developing patented technologies related to weight loss (H. Singh et al., 2018). It is, therefore, not surprising that many studies have found a relationship between adolescents attempting to lose weight and vaping. Morean et al. (2020) discovered that appetite control (13.8%) and weight loss (9.3%) were both reported reasons for vaping e-cigarettes among users, and these reasons were associated with more frequent use. Similarly, using a nationally representative sample, Mantey et al. (2020) found associations between e-cigarette use and weight loss intentions. There appears to be a

consensus among studies that a connection may exist between e-cigarette use and weight intentions among young people. However, additional variables influencing this relationship require further investigation.

Preliminary research has explored gender as a variable in the relationship between e-cigarette use and weight intentions, but consensus on its role is lacking. Hochgraf et al. (2023) examined intentions to lose weight and their association with vaping in adolescent boys and girls. They found an association between weight loss intentions and current vaping among girls, with the strongest association among girls aged 14.2-15.9 years. Similarly, Mantey et al. (2020) found associations between e-cigarette use and weight loss intentions among 9-12 graders, with females showing stronger associations. In contrast, in a middle school population, Sanchez et al. (2021) discovered that male respondents with obesity were more likely to use e-cigarettes if they had weight loss intentions than obese females with the same intentions. Conversely, Mantey et al. found that e-cigarette use was associated with greater odds of intentions to gain weight among boys. However, Morean et al. found no gender differences in their study. Thus, emerging evidence suggests that variables such as age or gender may influence the relationship between vaping and weight intentions, but several gaps in this data remain.

One area that has yet to be explored and may play a role in the relationship between e-cigarette use and weight intentions is sports participation. Weight-related pressures specific to certain sports have been extensively documented among athletes (Mancine et al., 2020; Roberts et al., 2022). Several studies have identified a high risk of disordered eating among both female and male athletes (Karrer et al., 2020; Mancine et

al., 2020; Pallotto et al., 2022) with adolescence being a critical period influenced by peers and social settings (Keel & Forney, 2013). Athletes may be at a higher risk of disordered eating due to the pressures within specific sports environments, especially those focusing on weight class, leanness, endurance, or aesthetics (Mancine et al., 2020; Pallotto et al., 2022; Roberts et al., 2022), as well as certain personality traits among athletes (Keel & Forney, 2013; Mancine et al., 2020; Roberts et al., 2022). Consequently, the pressure on adolescent athletes to achieve a sport-specific body type for improved performance could influence their decisions to engage in vaping for weight-related intentions. Therefore, the identified relationships between adolescents aiming to change their weight status through vaping may also be relevant for athletes involved in e-cigarette use.

Mediators and Moderators of Adolescent Vaping

Limited research has delved into the empirical basis of associations involving vaping and adolescents and the variables that might influence these connections. Notably, Kim (2021) found interesting gender-based moderation effects in adolescents where the female gender significantly moderated the relationship between mental health problems and e-cigarette use, while the male gender significantly moderated the relationship between current cigarette and marijuana use and vaping. Another pertinent study by Trucco et al. (2021) explored the potential mediating effects within the realm of parental attitudes, peer norms, and adolescent e-cigarette utilization. In their investigation, Trucco and colleagues discovered that adolescent intentions mediated the association between parental attitudes and e-cigarette use but not between peer norms and e-cigarette use

(Trucco et al., 2021). Furthermore, they reported that positive expectancies regarding vaping failed to mediate any of the assessed associations (Trucco et al., 2021). Rocheleau et al. (2020) also investigated the mediation dynamics in the context of how personal perceptions mediated the relationship between peer e-cigarette use and personal usage. Their findings align with Trucco et al.'s results, indicating that personal risk perceptions of e-cigarette use had a minimal mediating role. All three studies adopted a multifaceted approach to assess influencing factors, revealing complex interactions. Nonetheless, despite these contributions, there remains a need for further exploration into potential influences on the relationships between adolescents and e-cigarette use. Considering the literature alongside the prevalence of e-cigarette usage among adolescents engaged in sports, a compelling rationale exists to investigate potential moderating mechanisms of this relationship. Such an inquiry could shed light on the factors contributing to the rise in e-cigarette usage within a population once deemed low-risk with traditional smoking.

Definitions

Adolescence/youth/high school students: For the purposes of this study, the population will be defined as students in Grades 9–12 .

E-cigarette use: E-cigarette use will be defined as answering yes to question 34 of the 2021 YRBS, which asks, "Have you ever used an electronic vapor product?"

Electronic cigarette: E-cigarette – also known as, "e-cigs", electronic cigars, "e-cigars", electronic hookah, "e-hookah", hookah sticks, cig-a-like, personal vaporizers, mechanical mods, mod, vape, vape pens, vaping devices, tank system, or electronic nicotine delivery system (ENDS) are handheld devices that produce an aerosol from a

solution (e-liquid), semi-solid or solid materials that typically contain nicotine or other drug formulation, flavoring chemicals and other additives for the inhalation through a mouthpiece by the user (CDC, 2022b, Jenssen & Walley, 2019, Peace et al., 2019).

Insufficient sleep: For the sake of this study, insufficient sleep will be defined as reporting 7 hours of sleep at night or less, which is in accordance with the consensus statement for pediatric populations by the Academy of Sleep Medicine (Paruthi et al., 2016). Question 86 of the 2021 YRBS, asks, "On an average school night, how many hours of sleep do you get?" Respondents can answer 4 or less hours, 5 hours, 6 hours, 7 hours, 8 hours, 9 hours, 10 or more hours.

Sports participation: For the sake of this study, sports participation will be defined by answering any number other than "0" to question 80 of the 2021 YRBS, "During the past 12 months, how many sports teams did you play?"

Weight intentions: If the respondents are trying to do anything about their weight. For the purposes of the study, this will be categorized by using question 67 of the 2021 YRBS, "Which of the following are you trying to do about your weight?" Respondents can answer, Lose weight, Gain weight, Stay the same weight, I am not trying to do anything about my weight.

Assumptions

Numerous underlying assumptions warrant consideration in this study. Primarily, the study examines secondary data from the National YRBSS, which involves various assumptions. The foundational assumption rests upon the reliability, representativeness, and validity of the YRBSS conducted by the CDC, grounded in the established

questionnaire and the documented methodology (Underwood et al., 2020). Furthermore, the study also assumes the validation and efficacy of the YRBSS in adequately gathering pertinent data on sports participation, e-cigarette use, sleep duration, and weight-related intentions. The YRBSS includes survey questions on e-cigarette use, nightly sleep duration, involvement in sports teams within the past 12 months, and individual intentions regarding weight. The precision of these variables forms the bedrock of the secondary data analysis. Additionally, the study rests upon the assumption that the students voluntarily answered the questions accurately and honestly, without concerns for confidentiality or repercussions, particularly concerning sensitive or illicit behaviors. Notably, existent literature underscored the response reliability of the YRBSS (Charles et al., 2022; Underwood et al., 2020).

Additionally, the study assumes the accuracy of the demographic data, which is crucial for accurately delineating the target population of high school students in Grades 9–12 . This demographic data also serves a pivotal role in effectively controlling for variables such as age, gender, race, and ethnicity during the analytical phases of the research. These underlying assumptions collectively underpin the methodology and scope of this study, and acknowledging their presence is vital for interpreting the findings and implications that ensue.

Scope and Delimitations

This study aimed to investigate the relationship between sports participation, weight intentions, insufficient sleep, and e-cigarette use among US adolescents in Grades 9–12. The high school student population was selected based on the existing literature

gap and the high prevalence of e-cigarette use (46%) among this demographic (Cooper et al., 2022). Middle school students reported lower rates of use (20.8%), and the reliability of YRBSS data is lower in younger students (Brener et al., 2002, 2003, 2013; Cooper et al., 2022). While college-age students reported high e-cigarette use (40%), their varied schedules and demands led to their exclusion from this study, making the results specific to high school students in the United States (Jones et al., 2020; Omoike & Johnson, 2020). However, the knowledge gained from this study could be valuable for future research.

The specific variables, including sports participation, weight intentions, and insufficient sleep, were chosen due to inconsistent evidence or evidence in other populations. While sports participation is widely accepted as a protective factor against cigarette use, numerous studies have found that it increases the odds of e-cigarette use (Milicic et al., 2017; Rapoport et al., 2022; Veliz et al., 2017; Williams et al., 2020). However, data is lacking in the US, and interactions influencing the relationship between sports participation and e-cigarette use are not well understood. Studies have shown that e-cigarettes are used for weight loss and marketed accordingly (Mantey et al., 2020; Morean et al., 2020; H. Singh et al., 2018), and athletes may face weight-related pressures specific to certain sports (Mancine et al., 2020; Roberts et al., 2022). Similarly, sleep disturbances may have a positive relationship with e-cigarette use. Holtz et al. (2022a) found that sleep deprivation (six hours or less) correlated with e-cigarette use initiation within the following month. Also of concern is the potential risk of inadequate or disrupted sleep among teenage athletes, where the demands and pressures that athletes

face impact sleep adequacy (Rebello et al., 2022; Walsh et al., 2020). Although these are not the only variables involved in adolescent vaping practices, this study aims to investigate the relationships between sports participation, weight intentions, insufficient sleep, and e-cigarette use to provide knowledge for future research, public health education, and campaigns.

When choosing a theoretical framework, selecting one that could recognize the simultaneous influence of multiple environments on behavior was essential to address the research questions adequately. Therefore, the SEM was chosen as it provides a framework for concurrently exploring associations from multiple influences. The Social Cognitive Theory (SCT) was considered, as it can be applied to internal and external forces influencing behavior (Bandura, 2001). However, a limitation of SCT for the research questions is its focus on the process of learning to change behavior and not on individual factors influencing behavior (Bandura, 2001; Glanz, n.d.; Glanz et al., 2008). A framework was needed to give equal importance to individual, relationship, and community levels for potential influencing factors on behavior to answer the research questions adequately.

Limitations

It is imperative to acknowledge and thoroughly assess several notable limitations that will shape the contours of this investigation. First, it is essential to recognize that this study relies on a secondary analysis of data derived from the YRBSS, which carries inherent constraints. This research is contingent upon the participants' willingness to provide accurate and candid responses, and the extent to which they do so may influence

the study's outcomes. While valuable, self-reported data introduces the potential for bias and subjectivity and lacks objective assessment. Moreover, the study's scope is limited by the predefined questions within the YRBSS instrument, which, while comprehensive, may not encompass certain nuances or specific aspects related to sports participation that could be of interest. In particular, the YRBSS does not collect data on the type of sports students are engaged in, limiting my ability to explore potential differences across different sporting disciplines. Another pivotal limitation arises from the cross-sectional design of the YRBSS, which limited the ability to establish causal relationships. This research can provide valuable insights into associations and correlations but cannot definitively infer causation. Longitudinal studies would be required for such purposes. Furthermore, it is essential to acknowledge that the YRBSS data collection does not encompass cyber students, who represent a growing demographic of students who receive their education online. The omission of this population may limit the inclusivity of certain participants in the analysis, potentially affecting the generalizability of the findings to all adolescent athletes.

Another limitation of this study is using the questionnaire to understand insufficient sleep. In addition to the pressures related to sports activities that can put athletes at higher risk for insufficient sleep, various other factors can contribute to insufficient sleep in high school students. For example, academic pressures, school hours, increasing use of electronic devices, poor sleep hygiene, insomnia, employment, socializing with peers, anxiety, and stress have all been shown to contribute to irregular sleep schedules and insufficient sleep duration in high school students (Fox et al., 2019;

Kansagra, S., 2020; Widome et al., 2020). Therefore, it is difficult to understand if inadequate sleep is directly related to sports participation, as details explaining insufficient sleep are not collected on the questionnaire.

One final limitation to consider is the decision to exclude smoking and other substances in the analysis while exploring the relationship between sports participation, weight intentions, insufficient sleep, and e-cigarette use among high school students. The decision was made to maintain clarity and specificity in examining the primary variables of interest. This decision was supported by research by Y. Lee et al. (2021), who used the 2017 cohort of the YRBS to broadly investigate potential correlates of EVP use and including dual users in the category of e-cigarette use. However, the exclusion of these confounding variables could be considered a limitation of the study as research indicates that smoking and substance use behaviors often co-occur with e-cigarette use among adolescents (Erhabor et al., 2023). Thus, omitting these confounding factors may limit the comprehensiveness of the analysis and ability to understand the interplay of variables contributing to e-cigarette use among high school students. By embracing these limitations as integral aspects of the research process, I can ensure that the study's findings are interpreted within the context of these constraints.

Significance

Numerous factors are known to contribute to adolescent e-cigarette use. However, a significant gap exists in understanding why non-smoking adolescents initiate vaping, as identified by Caie and Ran's (2023) scoping review. Despite extensive public health initiatives aimed at curbing e-cigarette usage among adolescents, the prevalence of

vaping in this age group remains a cause for concern. While a considerable body of research has focused on adolescent e-cigarette use, several knowledge gaps persist within the literature. Of particular significance is the increased susceptibility of student-athletes, who, despite being less prone to traditional cigarette use, now exhibit higher acceptance rates of vapor products, rendering them a vulnerable population in the United States. The existing scholarship has yet to comprehensively investigate the multifaceted factors influencing e-cigarette adoption among student-athletes. However, emerging research indicates potential connections between insufficient sleep, weight loss intentions, and the embrace of e-cigarettes. This study seeks to explore the intricate interplay among sports participation, weight intentions, and inadequate sleep concerning e-cigarette use while also considering whether weight intentions and insufficient sleep serve as moderators in the relationship between sports involvement and e-cigarette adoption. By doing so, this research aims to bridge a critical gap in the current literature by shedding light on the various factors influencing the acceptance of e-cigarettes among adolescents actively engaged in sports. Notably, while participation in sports has historically been a protective factor against traditional cigarette smoking, this effect does not extend to vaping. In fact, prior research has already demonstrated that physically active adolescents are more prone to e-cigarette use than their less active peers, underscoring the ineffectiveness of traditional protective behaviors, such as sports engagement, in the context of vaping products (Irvine et al., 2021; Y. Lee et al., 2021; Milicic et al., 2017). This highlights the critical need to unravel the motivations driving young individuals with no smoking history to engage in electronic cigarette use. The outcomes of this investigation hold

promise for enhancing our comprehension of the intricate relationship between sports participation and e-cigarette use.

Applying the SEM as a conceptual framework, this study aims to facilitate a more comprehensive and multilevel understanding of the issue. By adopting an SEM perspective, this research could drive social change by providing insights that can inform public health strategies. Recognizing the importance of supportive relationships across various levels of the SEM, as advocated by Cheney et al. (2018), this study can contribute to more effective public health education initiatives and campaigns, ultimately helping prevent e-cigarette use among vulnerable adolescent athletes.

Summary and Conclusions

Despite extensive public health initiatives aimed at curbing e-cigarette usage among adolescents, the prevalence of vaping in this age group remains a cause for concern. While a considerable body of research has focused on adolescent e-cigarette use, several knowledge gaps persist within the literature. Of particular significance is the increased susceptibility of student-athletes, who, despite being less prone to traditional cigarette use, now exhibit higher acceptance rates of vapor products, rendering them a vulnerable population in the United States. The existing scholarship has yet to investigate the multifaceted factors influencing e-cigarette adoption among student-athletes comprehensively. However, emerging research indicates potential connections between insufficient sleep, weight loss intentions, and the embrace of e-cigarettes. This study seeks to explore the intricate interplay among sports participation, weight intentions, and inadequate sleep concerning e-cigarette use while also considering whether weight

intentions and insufficient sleep serve as mediators in the relationship between sports involvement and e-cigarette adoption. By doing so, this research aims to bridge a critical gap in the current literature by shedding light on the various factors influencing the acceptance of e-cigarettes among adolescents actively engaged in sports.

In this section, I have laid the groundwork for this study by conducting an extensive literature review and establishing how the SEM framework will help examine the intricate relationships among self-reported e-cigarette use, sports participation, weight loss intentions, and insufficient sleep among adolescents in the United States. Furthermore, I will examine these relationships for potential mediation roles played by insufficient sleep and weight loss intentions in vaping use and sports participation. While previous research has hinted at possible associations among these variables, the full extent of these connections within the specific subset of adolescent student-athletes still needs to be discovered. Consequently, this study is poised to contribute significantly to the existing body of literature by addressing this gap, thereby enhancing the understanding of the escalating public health concern surrounding youth e-cigarette use. Insights gleaned from this research will inform targeted public health interventions tailored to mitigate this pressing issue among this vulnerable cohort of adolescents. The subsequent section will pivot to a detailed discussion of the rationale for the research design, methodologies, and plan for data collection. I will also explore the YRBSS's utility as a valuable secondary data analysis tool

Section 2: Research Design and Data Collection

The purpose of this quantitative study utilizing secondary data from the YRBSS was to explore the relationship between sports participation, weight intentions, and insufficient sleep and their impact on e-cigarette use among U.S. students in Grades 9–12. The independent variables were sports participation, weight intentions, and insufficient sleep, and the dependent variable was e-cigarette use. Additionally, the study aimed to determine whether weight intentions and insufficient sleep moderated the relationship between sports participation and e-cigarette use. Consequently, the moderator variables included weight intentions and insufficient sleep.

Section 2 provides a comprehensive overview of the research methods employed in the study. The sections address the research design, rationale, methodology, and potential threats to the validity of the findings. Furthermore, I explain the methodology, including details regarding the study population, sampling procedures, research instrument, operationalization process, and data analysis plan. Finally, ethical considerations relevant to the study are presented, and Section 2 concludes with a summary.

Research Design and Rationale

This study investigated the relationship between sports participation, weight intentions, and insufficient sleep on e-cigarette use in students Grades 9–12 in the United States using secondary data from the 2021 National YRBSS. Additionally, I sought to determine whether the independent variables of weight intentions and insufficient sleep moderated the relationship between sports participation and e-cigarette use. The

dependent variable was self-reported e-cigarette use. The independent variables included sports participation, weight intentions, and insufficient sleep, as as defined by 7 hours of sleep or less. Covariates that were included in this study were age, sex, race, and ethnicity. The target population for this study was adolescents in Grades 9–12 in the United States.

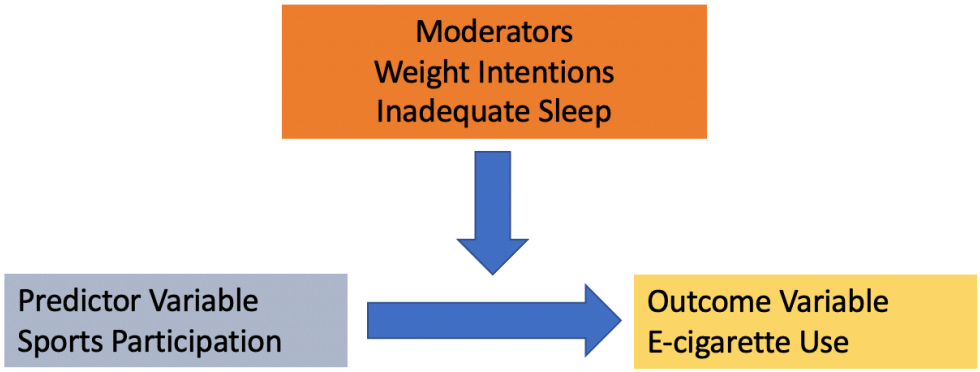
A retrospective quantitative cross-sectional design was chosen using secondary data analysis to answer the research questions. The quantitative approach was deemed appropriate to answer the research questions addressing the relationship and moderation effects between variables and to make predictions (see Burkholder et al., 2019). A quantitative approach was suitable to examine the relationships between variables such as sports participation, weight intentions, and insufficient sleep on e-cigarette use. Additionally, this approach was appropriate for examining the moderating effect of chosen variables on the relationship between sports participation and e-cigarette use. The retrospective quantitative cross-sectional design offers a method for investigators to examine the relationships between outcome and dependent variables after hypothesis formulation (see Burkholder et al., 2019). Despite its limitation in facilitating causal assertions, this design was expected to enhance the understanding of factors linked to youth e-cigarette use and sports participation.

The application of moderation was selected to address the second and third research questions, aiming to enhance the understanding of the relationship between sports participation and e-cigarette use. According to Baron and Kenny (1986), moderators are qualitative or quantitative variables that affect the direction or strength of

the relationship between independent and dependent variables (see Figure 2). Moderation analysis in this context was intended to elucidate whether athletes exhibit higher or lower odds of using e-cigarettes based on their weight intentions. Unlike mediation, which requires linear analysis, moderators can be used in logistic and linear analysis (Baron & Kenny, 1986). Moreover, moderation analysis is appropriate when confronted with an unexpected, weak, or inconsistent relationship between the predictor and outcome variable. This circumstance aligned with the dynamics of sports participation and e-cigarette use, making moderation a more suitable analytical approach than mediation, which mandates a robust relationship between the predictor, mediating variable, and outcome variable (Baron & Kenny, 1986). In navigating these complexities, moderation analysis proved more appropriate than mediation analysis because it did not demand a strong and direct link between the predictor and outcome variables and could be used in a nonlinear analysis.

Figure 2

Moderation Conceptualization



The data provided by the 2021 National YRBSS allowed me to answer the research questions using quantitative secondary data analysis. The YRBSS is a national school-based survey of cross-sectional design administered by the CDC to provide representative data on health risk behaviors of ninth- through 12th-grade public and private school students. This survey was chosen as a secondary data source because it collects self-reported data on the variables of interest for this study, including vaping use, sports participation, weight intentions, and sleep patterns in the population of interest (United States high school students in Grades 9–12). The 2021 National YRBSS was used because the results from the 2023 data were not yet available to the public. Moreover, an advantage of using the YRBSS data is that it allows for a quantitative research design necessary to answer research questions of association and moderation with large sample sizes. Finally, using secondary data analysis from a validated and

representative survey reduced the time needed to create and validate survey instruments and collect data and allowed for the scope of the study to include ninth through 12th graders across the United States.

Methodology

Population

This research focused on students in the United States in Grades 9–12, using data extracted from the 2021 YRBSS high school data set. This age group was identified as an at-risk population, as highlighted by the 2019 YRBSS, indicating that 50.1% of high school students reported any e-cigarette use (Creamer et al., 2020). The concern was beyond experimentation because the frequency of use within this demographic raised alarms. According to Cooper et al. (2022), 1 out of 7 high school students reported use in the past 30 days, with 46 % indicating frequent use and 30.1% reporting daily use.

Furthermore, e-cigarettes pose substantial risks to adolescents, contributing to nicotine addiction that hampers cognitive development and impacts mental and physiological health (Becker et al., 2021; CDC, 2022b; Dai et al., 2022; McGrath-Morrow et al., 2020). A comprehensive understanding of the factors influencing vaping among this population was essential for informing policies and programs aimed at reducing use in a vulnerable demographic facing heightened health risks. The 2021 YRBS data set comprised 17,232 usable questionnaires from students in Grades 9–12 across public and private schools in the United States, all of which were included in the analysis for the current study.

Sampling Procedures

The National YRBSS constitutes a comprehensive, nationwide, self-administered survey encompassing students in Grades 9–12 across public, Catholic, and private schools in the United States. The primary objective is to systematically monitor health risk behaviors and student experiences contributing to prevalent causes of mortality and morbidity within this demographic (CDC, 2023d). The YRBSS is conducted every 2 years during the spring term, with an exception made in 2021 when the survey was administered in the fall semester due to the COVID-19 pandemic (CDC, 2023d). Participation is selected by determining a nationally representative sample of schools, and a random selection of classes occurs within those schools (Mpofu et al., 2023). Since the inception of the YRBSS, the CDC (2023d) has highlighted its efficacy in surveilling the prevalence, co-occurrence, and health risk behaviors.

Furthermore, the system measures its alignment with public health initiatives such as Healthy People and other national objectives. YRBSS results have facilitated subpopulation analyses and provided invaluable data for comparisons at local, tribal, state, and national levels (CDC, 2023d). Additionally, temporal changes in risk behaviors can be assessed because of the biennial administration of the YRBSS. The YRBSS is an invaluable instrument and resource that systematically investigates health risk behaviors and facilitates in-depth analysis to monitor health trends and emerging issues and inform public health program development, evaluation, and implementation.

The YRBSS consists of two major components to provide valuable data on the health trends of students within the United States. The CDC conducts the National

Survey, called the YRBS, in both public and private schools in the United States. The 2021 YRBS, the focus of the current study, offered reliable publicly accessible data in two formats: Access and ASCII (CDC, 2023d). With 87 questions, most undergoing test-retest analysis, the survey included English and Spanish versions for the first time (Mpofu et al., 2023). Within the surveillance system, researchers can find data collected in several areas. Some examples include student demographic information such as gender, race, or ethnicity. Youth health behaviors and conditions are another topic area that includes data on things such as diet and physical activity, obesity, bullying or injury, and violence. Additional topic areas include substance use behaviors (e.g., electronic vapor products, tobacco products, alcohol, or other drugs). Additionally, students' experiences, such as housing, exposure to violence, school connectedness, and parental monitoring, are also included in the system. Data from the YRBSS is used in various ways by public health officials, community organizations, researchers, educators, lawmakers, and health care providers.

The YRBS employs a three-stage, cluster sample method to collect data on a nationally representative sample of high school students (Grades 9–12) in public, parochial, and private schools in the United States (Mpofu et al., 2023). Selection of the primary sampling units was the first stage of the design; the next was selecting schools (secondary sampling units), and the final stage was randomly selecting the classes that participated in the questionnaire in which all students assigned to that class who could independently complete the survey were eligible to participate (Mpofu et al., 2023). If a school, class, or individual refused to participate, they were not replaced (Mpofu et al.,

2023). Before public release of data, the CDC reviews the data for accuracy and completeness to identify out-of-range responses, logical inconsistencies, and missing data (Mpofu et al., 2023). Mpofu et al. (2023) reported that the 2021 sample size was increased due to a lower than anticipated response rate from the COVID-19 pandemic. Response rates for the 2021 YRBS were lower (57.5%) than previous years (60%–82%), which included student response rate (79.1%) times school response rate (72.7%) of 17,232 usable questionnaires out of 17,508 completed questionnaires (Mpofu et al., 2023). To adjust for school, student nonresponse, and oversampling of Black and Hispanic students, a weight based on student sex, race, ethnicity, and grade was applied to each record, which was scaled to provide weighted estimates that were nationally representative of all students in the U.S. public and private schools (Mpofu et al., 2023).

Validity and Reliability

For decades, the YRBSS has maintained a reputation for reliability and validity in collecting data on the health behaviors of U.S. middle and high school students. Studies by the CDC demonstrated high test-retest reliability for questions targeted at students in Grades 8–12 (Brener et al., 2002, 2003, 2013). In these studies, a total of 10 questions were identified as needing revision or deletion for future studies due to low kappas (< 61%; Brener et al., 2002, 2013). Many of the survey questions used in the 2021 questionnaire also underwent test-retest analysis with external research because the data were publicly available. Findings were consistent with CDC's findings with reported good, moderate, or substantial reliability, including when asked in the online format (Charles et al., 2022; Raghupathy & Hahn-Smith, 2012).

Although validity testing on all self-reported behaviors is limited, studies comparing objective and self-reported data, such as weight and height, revealed some discrepancies. Brener et al. (2003) conducted a study to test validity using questions in which objective data could be compared to self-reported data such as weight and height. Brener et al. found that in these categories, students overreported height by 2.7 inches and underreported weight by 3.5 pounds, although these questions were still reliable from test-retest. However, the CDC's literature review asserted that although these factors exist, these discrepancies do not threaten the survey's behavioral components' validity, emphasizing the importance of understanding factors influencing self-reporting (Brener et al., 2013). The CDC pointed out that understanding the differences in cognitive and situational factors influencing self-reporting validity can help researchers interpret data (Brener et al., 2013). Psychomotor tests conducted by both the CDC and outside researchers throughout questionnaire development supported the overall validity of YRBS data (Mpofu et al., 2023). The YRBSS provided reliable and valid data to investigate the relationship of self-reported behaviors about targeted topics of e-cigarette use, sports participation, sleep deprivation, and weight intentions among United States high school students.

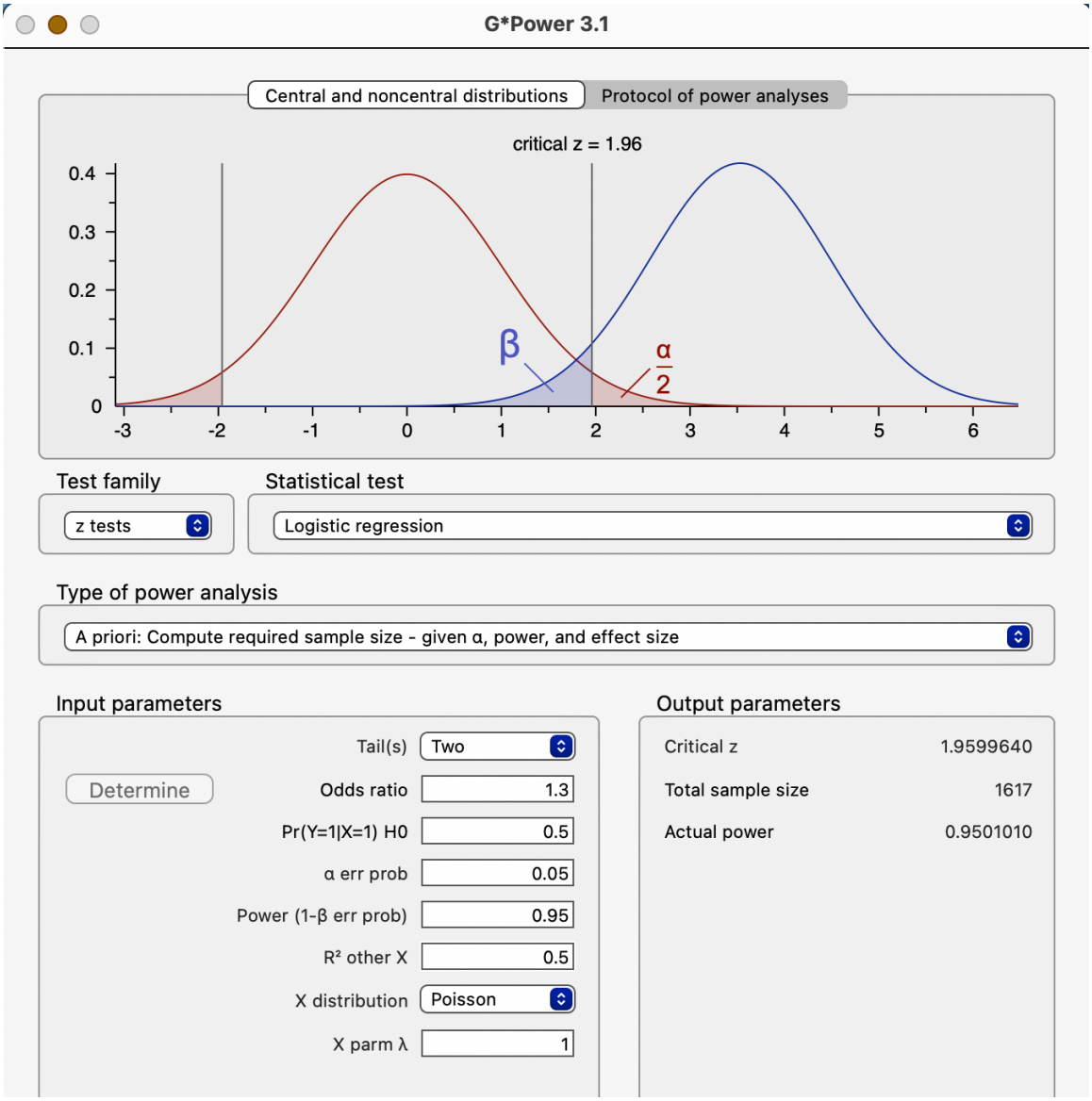
Power Analysis

A power analysis was completed using G*Power Software Version 3.1.9.6 to determine the minimum required sample size, effect size, alpha level, and power level appropriate for the current study. The first step was choosing *z* tests for the test family, then logistic regression for the statistical test, and a priori for the type of power analysis

(see Kang, 2021). The input parameters for the power analysis included Tails: two, Pr (Y = 1½ X = 1) H_0: .05, α err prob: .05, R^2 other X: 0.5 and X parm l: 1, which were all conventionally set (see Kang, 2021). I chose Power 1-b: .95 instead of the conventionally set Power 1-b: .80 (see Kang, 2021) due to my analysis's secondary data availability and more robust power. I used an odds ratio of 1.3 for logistic regression, which was determined from extant literature (see Kang, 2021; Rapoport et al., 2022). For the power analysis, sports participation was identified as the primary predictor variable, an ordinal variable; therefore, Poisson was chosen for X distribution (see Kang, 2021). The calculated sample size required for the study was 1,617 (see Figure 3). According to Mpofu et al. (2023), the 2021 YRBS had 17,232 usable questionnaires. Therefore, the available number for sample size well exceeded the minimum sample size requirement.

Figure 3

*Sample Size Calculation for Main Predictor Variable in G*Power*



Operationalization

The study examined several variables, including the dependent variable (DV), e-cigarette use, and independent variables (IVs), insufficient sleep, sports participation, weight intentions, and covariates age, sex, race, and ethnicity. In the 2021 National YRBS survey, e-cigarette use, classified as dichotomous nominal, was queried in Question 34: Have you ever used a vapor product? Respondents chose A. Yes or B. No. E-cigarette use is the DV used in all the research questions.

Insufficient sleep, an independent variable for the first research question and moderating variable for the third research question was assessed in Question 86, which inquired: On an average school night, how many hours of sleep do you get? Respondents can answer four or less, five hours, six hours, seven hours, eight hours, nine hours, ten or more hours. *Insufficient sleep* is defined as 7 hours or less (Baiden et al., 2023; Paruthi et al., 2016). To align with research objectives, responses of 7 hours or less were recorded as "yes" and 8 hours or more as "no," resulting in a dichotomous nominal variable.

Sports participation, an independent variable gauged in Question 80, sought: During the past 12 months, how many sports teams did you play? (Count any teams run by your school or community groups). Responses of zero teams, one team, two teams, or three or more teams could be chosen, constituting an ordinal variable utilized in all three research questions.

Weight intentions, an independent variable for the first research question and moderating variable for the second research question, was a nominal variable found in Question 67: Which of the following are you trying to do about your weight?

Respondents indicated their weight-related goals as “lose weight,” “gain weight,” “stay the same weight,” or “I am not trying to do anything about my weight.”

Covariates, identified as age, sex, race, and ethnicity, were chosen based on their potential to indirectly influence the relationship between e-cigarette use, sports participation, insufficient sleep, and weight loss intentions (Cooper et al., 2022; Creamer et al., 2020; Irvine et al., 2021; Kinnunen et al., 2018). Age, determined by Question 1: How old are you? Respondents can select 12 years old or younger, 13, 14, 15, 16, 17, 18 years or older, and therefore was treated as a continuous, ordinal variable. Sex, obtained from Question 2: What is your sex? was considered a dichotomous nominal variable with options limited to females/males.

Race, established as categorical and nominal, was addressed in Question 5: What race are you? Respondents can select the subsequent options: American Indian or Alaskan Native, Asian, Black or African American, Native Hawaiian or Other Pacific Islander, and White. Lastly, ethnicity was deemed a dichotomous nominal variable, derived from Question 4: Are you Hispanic or Latino?

Table 1

Operationalization of Variables

Variable name	Type of measure	Use	Definition	Variable code
E-cigarette use	Dichotomous nominal	Dependent	Reported e-cigarette use	Have you ever used a vapor product? Yes No
Insufficient sleep	Dichotomous nominal	Independent Moderating	Reported hours of sleep are defined as 7 hours of sleep or less	On an average school night, how many hours of sleep do you get?" Respondents can answer: 4 or less hours, 5 hours, 6 hours, 7 hours, 8 hours, 9 hours, 10 or more hours; answers will be recoded to yes/no
Sports participation	Ordinal (treated as continuous for logistic regression)	Independent	Reported number of sports teams respondent participated in over past 12 months	During the past 12 months, on how many sports teams did you play? (Count any teams run by your school or community groups.)" Respondents can answer: 0 teams, 1 team, 2 teams, 3 or more teams
Weight intentions	Nominal	Independent moderating	Reported weight intentions, i.e., if the respondent is trying to lose,	Which of the following are you trying to do about your weight?" Respondents can

Variable name	Type of measure	Use	Definition	Variable code
			gain, stay the same, or do nothing about weight.	answer: Lose weight, Gain weight, Stay the same weight, I am not trying to do anything about my weight
Age	Ordinal (treated as continuous for logistic regression)	Covariate	Reported age at time of survey	How old are you? 12 years old or younger 13 years old 14 years old 15 years old 16 years old 17 years old 18 years old or older
Sex	Dichotomous nominal	Covariate	Reported sex	What is your sex? Female Male
Race	Nominal	Covariate	Reported race	What is your race? American Indian Asian Black or African American Native Hawaiian or Pacific Islander White
Ethnicity	Dichotomous nominal	Covariate	Reported ethnicity	Are you Hispanic or Latino? Yes No

Data Analysis Plan

During the data analysis, I addressed the complex sampling design of the YRBS. I utilized IBM SPSS Statistics Version 29.0.2.0 Complex Samples, recommended by the CDC (2023c), for handling YRBS data, incorporating sample selection and analysis for complex sample survey data. For the second and third research questions, I employed PROCESS for SPSS, a plug-in developed by Dr. Andrew Hayes, available as a free download. I formatted data from the CDC (2022c) YRBS website in SPSS. I included all participants with completed responses to questions on e-cigarette use (Question 34), sports team participation (Question 80), hours of sleep (Question 86), and weight intentions (Question 67), and missing data is detailed below. Responses underwent a thorough review and screening for accuracy and missing data, aligning with the research questions.

The data cleaning and screening process is crucial for ensuring robust data analysis. Utilizing secondary data from the YRBSS provides an advantage, as it undergoes prescreening for inconsistencies and out-of-range responses. The CDC reviews raw data for missing data, logical inconsistencies, and out-of-range responses before public release. Questionnaires with fewer than 20 valid responses after cleaning (0.5%) are deleted and sent for weighting (Mpofu et al., 2023). After reviewing survey responses and running frequency tables for all variables, I considered imputation and deletion for missing data, guided by the percentage of missing data.

Listwise deletion, the SPSS default method for handling missing data, might be suitable if very few missing values do not significantly impact statistical power. Warner

(2020) suggests a threshold of less than 5% of observations, although this may be considered bad practice in general. Rapoport et al. (2022) used listwise deletion when evaluating associations of e-cigarette use, cigarette use, and sports participation using YRBS data due to the very low rate of incomplete responses. However, it is essential to note that listwise deletion may introduce bias if missing data exceeds 5% (Warner, 2020). Other potential remedies for missing data include imputation, where the missing value is replaced with the mean of that variable, or multiple imputation, where missing data is replaced with a predicted value (Warner, 2020). While most researchers recommend multiple imputation, the final decision on handling missing data depends on the number and type of missing values.

Research Questions

RQ1: Is there an association between sports participation, weight intentions, insufficient sleep (defined by 7 hours or less), and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity?

H_o1: Sports participation, weight intentions, and insufficient sleep as defined by 7 hours or less are not associated with e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity.

H_a1: Sports participation, weight intentions, and insufficient sleep as defined by 7 hours or less are associated with e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity.

RQ2: Does weight intentions moderate the relationship between sports participation and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity?

H_o2: Weight intentions do not moderate the relationship between sports participation and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity.

H_a2: Weight intentions moderates the relationship between sports participation and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity.

RQ3: Does insufficient sleep, as defined by 7 hours or less, moderate the relationship between sports participation and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity?

H_o3: Insufficient sleep, as defined by 7 hours or less, does not moderate the relationship between sports participation and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity.

H_a3: Insufficient sleep, as defined by 7 hours or less, moderates the relationship between sports participation and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity.

Statistical Test

For the first research question, I utilized binary logistic regression in SPSS to predict the dependent variable of e-cigarette use. The choice of the logistic regression model was driven by the dichotomous measurement of the dependent variable (Yes or

No) in the YBRSS. The predictive variables, identified as ordinal or nominal, included sports participation (ordinal), sleep deprivation (dichotomous nominal), and weight intentions (nominal). I incorporated covariate variables of age (ordinal), sex (dichotomous nominal), race (nominal), and ethnicity (dichotomous nominal) in the logistic regression analysis. Logistic regression is suitable for this case due to its independence from a linear relationship, acceptance of ordinal or nominal independent variables, lack of reliance on homoscedasticity, and freedom from the need for a multivariate scale (Laerd Statistics, n.d.). After cleaning the data and ensuring initial assumptions were met, I employed SPSS for analysis. The procedure involved selecting 'Analyze,' followed by 'Regression,' and then choosing 'Binary Logistic Regression' due to the dichotomous nature of the dependent variable. I added covariates for age, sex, race, and ethnicity to block one, while block two included sports participation and weight intentions as the IVs. I utilized the 'Enter' method within logistic regression, assigning categorical variables first to establish the reference group. Options selected included classification plots, Hosmer-Lameshow goodness-of-fit, casewise listing of residuals, and a 95% confidence interval for exp (B).

For the last two research questions, I employed binary logistic regression with an interaction variable to predict the categorical dependent variable of e-cigarette use. To address the second research question, the initial step in SPSS for binary logistic regression with moderation involved creating a product term for sports participation and weight intentions through the 'Transform' and 'Compute Variable' options. After adding the moderator variable, the analysis proceeded by selecting 'Analyze,' then 'Regression,'

and choosing ‘Binary Logistic Regression.’ Similar to the first research question, covariates of age, sex, race, and ethnicity were included in block one, while block two introduced sports participation, weight intentions, and the product term for sports participation and weight intentions. I selected the same options for classification plots, Hosmer-Lameshow goodness-of-fit, casewise listing of residuals, and a 95% confidence interval for exp (B). This process was repeated for the second research question using the created product term for sleep deprivation and sports participation.

The inclusion of age, gender, race, and ethnicity as covariates in this study stems from existing literature highlighting their potential impact on e-cigarette and smoking behaviors. Demographic factors such as gender, race, age, and ethnicity have been associated with e-cigarette and tobacco use (Cheney et al., 2018; Obinwa et al., 2021; Pérez et al., 2021). Racial and ethnic disparities in e-cigarette initiation and continued use have been documented (Stokes et al., 2020). Veliz et al. (2017) identified gender as a potential moderator in the relationship between sports participation and e-cigarette use. Additionally, Kim (2021) explored gender’s moderation effect between mental health problems and e-cigarette use. Hence, while age, gender, race, and ethnicity could influence the outcome variable, they were treated as covariates in investigating the relationship between sports participation, weight intentions, insufficient sleep, and e-cigarette use.

Seven assumptions related to logistic regression were considered, with the first four conducted before using SPSS. The first assumption confirmed the dichotomous nature of the dependent variable, as indicated by the YRBS question on e-cigarette use

(yes/no). The second assumption addressed having one or more continuous or nominal independent variables met in the study design with IVs, including sports participation, sleep deprivation, weight intentions, and covariates. The third assumption, independence of observations, was affirmed as each person in the 2021 YBRSS dataset answered only once, and the CDC cleaned logical errors from the data. The fourth assumption, minimum sample size, was addressed through an A priori analysis using G*Power Software during the study planning stage. These initial assumptions guided the selection of binomial logistic regression as the appropriate statistical test.

The last three assumptions, related to the nature of the data, were tested using SPSS Statistics software. The fifth assumption, linearity between continuous variables such as age and the logit transformation of the dependent variable, was checked using a Box-Tidwell test in SPSS. If the transform variables were not significant, it indicated meeting the assumption, with the possibility of incorporating higher-order polynomial terms to achieve linearity. The sixth assumption focused on showing no multicollinearity, determined by correlation coefficients and VIF values in SPSS. The multicollinearity assumption was deemed unmet if collinearity tolerance was less than 0.1 or VIF exceeded 10, with significance guiding the decision to use or address multicollinearity. The last assumption involved no significant outliers, tested in SPSS using casewise diagnostics. Cases with standardized residuals (ZResid) greater than 2.5 were considered potential outliers, each dealt with individually, with further explanation in the results section.

A customary p-value of 0.05 was considered significant for inferential statistics, with the null hypothesis considered valid if the p-value exceeded 0.05 and the alternative

hypothesis considered true if the p-value was below 0.05. Confidence intervals were set at 95% to ensure generalizability to high school students in Grades 9–12 in the US. Logistic regression used an odds ratio to predict the probability of being in a particular category of the dependent variable (e-cigarette use yes/no) given the independent variables after controlling for covariates (age, sex, race, and ethnicity). SPSS statistics classified e-cigarette use as 'yes' if the estimated probability of the event was greater than or equal to 0.5. Odds ratios with their confidence intervals were reported for each independent variable. For moderation analysis in research questions two and three, I focused on the interaction between the predictor and the moderator variables and looked for a significance of 0.05.

Threats to Validity

Threats to validity are critical to research design and interpretation as they are concerned with factors that can compromise the accuracy and reliability of research findings and results. These threats must be considered for internal, external, and construct validity. I will briefly review each type of validity and its threats in this section as they relate to this study.

External Validity

External validity refers to the degree to which research findings remain applicable and generalizable across different contexts (Burkholder et al., 2019). Threats to external validity manifest when inaccurate inferences are made from the data and applied to other settings (Creswell & Creswell, 2018). Interaction threats were one type of external validity threat considered for this study.

Burkholder et al. (2019) explain that an interaction threat could occur when what is observed with one sample, setting, or context may not occur in another sample, setting, or context. YRBS data should be representative and weighted appropriately to reduce external validity threats related to interaction (CDC, 2023d). For example, YRBS attempts to reduce the threat of sample interactions by including multiple sites, urban, suburban, and rural (CDC, 2023d). In addition, YRBS addresses the threat of context-dependent mediation interaction by having trained contractors administer the questionnaire in each school using the same protocol (CDC, 2023d). However, there could always be an influence of a mediating factor in one classroom or school versus another, despite the contractors using the same protocol.

Additionally, the threat of setting interaction could be a concern as the students take the questionnaires in school. Students may answer questionnaires differently if they could take them in their homes' privacy, or students in affluent areas may answer differently than students in impoverished settings. Although the multisite, representative nature of the YRBS attempts to address these threats to external validity and has been designed to be representative and enable researchers to apply findings across contexts in high school-aged populations within the US (Brener et al., 2013). Despite this, it is still important to reflect on these threats when interpreting the results and considering the future implications

Internal Validity

Internal validity refers to the extent to which a research study accurately measures or tests what it intends due to its accuracy and reliability (Creswell & Creswell, 2018). In

this research, challenges to internal validity may arise if the procedures or experiences undergone by study participants disrupt the accurate interpretation of the data (Creswell & Creswell, 2018). Threats to internal validity related to history, regression, maturation, repeated testing, changes in instrumentation, researcher bias, attrition, and differential mortality are not a concern using data from the National YRBS because it is a cross-sectional study questionnaire conducted at a singular point in time (Brener et al., 2013; Burkholder et al., 2019). Several internal validity issues related to instrumentation are also addressed in this research by the single point-in-time instrumentation.

However, there may be unknown contextual elements that may influence the way students report their behavior. I also discussed this concept of students honestly answering the questions in the assumptions for this study. To reduce this threat to validity, the CDC administers the survey in such a way that encourages the students to answer honestly and knowing that their identities are protected. However, the literature revealed that the questionnaire and procedural components are highly reliable in students Grades 8–12 (Brener et al., 2002; 2003, 2013). Selection is another threat to internal validity that should be considered (Burkholder et al., 2019). The National YRBS randomly selects areas, schools, and classrooms within the US, so the concern for selection bias using this dataset is low. However, students are only allowed to participate with parental consent, and this could be a consideration for "self-selection" bias because, theoretically, there could be different characteristics of students who are allowed to participate in a CDC study compared to those who are not. This type of self-selection bias may be of particular concern in the 2021 or post-COVID questionnaire, given the

political division and waning public support for the CDC (CDC, 2023c). However, selection bias was reduced in this study as it included all students in Grades 9–12 in the US or the entire sample population

Statistical Conclusion Validity

Statistical conclusion validity pertains to how researchers discern the relationship between two variables and whether conclusions drawn from the statistical analysis are accurate and appropriate (Burkholder et al., 2019). Threats to statistical conclusion validity include measurement error, Type I and Type II errors that impact the validity of statistical conclusions, confounding variables, small sample size, measurement error, low statistical power, violation of assumptions, and sampling bias (Burkholder et al., 2019). I have previously addressed threats related to sampling bias and measurement error when discussing the validity, reliability, and sampling procedures of the National YRBS. An a priori power analysis was completed using G*Power to ensure statistically appropriate power and sample size. Moreover, in the planning stages of this research study, I examined and recognized variables as suitable measures and employed appropriate statistical tests for the types of variables. Additionally, I addressed the underlying assumptions for the chosen statistical tests before and while running the data. Finally, I took steps to enhance overall external and internal validity and tried to address limitations in that section of the research paper. I aimed to enhance statistical conclusion validity by selecting appropriate variables and statistical methods to answer the research question and match the variables, ensuring adequate sample size, and verifying statistical assumptions related to binary logistic regression.

Ethical Procedures

The CDC designed the procedures for surveys to protect the student's privacy. According to local requirements, parental permission was required before the student volunteered for the survey (Mpofu et al., 2023). Official data collectors read a standardized script before administering the survey to the students and collected school and classroom data. Data collected about schools and classrooms helped to weigh data and verify sample selections in the YRBSS process. The data collectors encouraged students to spread out in the classrooms and cover questionnaires with paper to prevent other students from seeing responses (Mpofu et al., 2023). Students completed the self-administered questionnaire and recorded responses directly on a computer scannable booklet or during one class period or approximately 45 minutes (Mpofu et al., 2023). Moreover, to ensure confidentiality and privacy, the CDC maintained the anonymity of the students. The CDC and the technical contractors responsible for transmitting raw data to the CDC implemented a system of checks and balances for data processing (Mpofu et al., 2023). The YRBS procedures were specifically designed to safeguard the identity and anonymity of the participants. These procedures not only comply with federal data collection laws and CDC policies but also received approval from the CDC and the institutional review boards of the survey contractor.

Summary

This section comprehensively outlines the methodology employed for the current study. Key aspects discussed include the research design, the target population, the dataset utilized, and the selected variables, each accompanied by a detailed explanation. I

reviewed the data analysis plan, covering the chosen statistical procedures and potential threats to validity and ethical considerations.

The secondary data analysis study utilized the 2021 YRBS to address research inquiries related to sports participation, weight intentions, inadequate sleep, and e-cigarette use among high school students. The target population for this study consisted of adolescents in Grades 9–12 within the United States who responded to the data points of interest in the 2021 YRBS. Noteworthy variables in the study included the IVs of sports participation, weight intentions, and sleep deprivation, the DV of e-cigarette use, and the MVs of weight intentions and sleep deprivation. Additionally, I included covariates of age, gender, race, and ethnicity.

In addition, I included an explanation and operationalization of the variables, emphasizing their role in guiding the selection of appropriate statistical tests to address the research questions. The data analysis plan involved employing binary logistic regression and binary logistic regression with moderation due to the dichotomous measurement of the dependent variable (e-cigarette use) in the YRBS (categorized as Yes or No). Assumptions associated with this statistical test were delineated, and I outlined strategies for addressing potential unmet assumptions. Moreover, I provided a comprehensive explanation of the statistical procedures, accompanied by an a priori power analysis, to ensure the adequacy of the sample size and power level.

The section concludes with a discussion of potential threats to the study's validity, encompassing internal, external, and construct validity considerations. I also elucidated

the ethical procedures integral to the research process. The subsequent section will present the outcomes of the statistical analysis and research findings.

Section 3: Presentation of the Results and Findings

In this quantitative study of secondary data using the 2021 YRBS, I investigated the association between sports participation, weight intentions, inadequate sleep, and e-cigarette use among high school students using binary logistic regression in SPSS. Additionally, I evaluated the moderating effect of weight intentions and sleep deprivation on the relationship between sports participation and e-cigarette use by adding a moderation analysis to the binary logistic regression. The target population for this study consisted of U.S. adolescents in Grades 9–12 who responded to the data points of interest. Three research questions and their associated hypotheses guided this study:

RQ1: Is there an association between sports participation, weight intentions, insufficient sleep (defined by 7 hours or less), and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity?

H_o1: Sports participation, weight intentions, and insufficient sleep as defined by 7 hours or less are not associated with e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity.

H_a1: Sports participation, weight intentions, and insufficient sleep as defined by 7 hours or less are associated with e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity.

RQ2: Does weight intentions moderate the relationship between sports participation and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity?

H_o2: Weight intentions does not moderate the relationship between sports participation and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity.

H_a2: Weight intentions moderates the relationship between sports participation and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity.

RQ3: Does insufficient sleep, as defined by 7 hours or less, moderate the relationship between sports participation and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity?

H_o3: Insufficient sleep, as defined by 7 hours or less, does not moderate the relationship between sports participation and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity.

H_a3: Insufficient sleep, as defined by 7 hours or less, moderates the relationship between sports participation and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity.

Section 3 outlines this study's data collection, analysis, and results. I review accessing the data for secondary analysis, baseline descriptive statistics, evaluation of assumptions, statistical findings, and any discrepancies from the initial plan. Section 3 concludes with a summary and transition to Section 4.

Accessing the Data for Secondary Analysis

The data for this study were obtained from the 2021 National YRBS, which were considered the most current data available at the time of analysis. The data were publicly

available from the CDC website. The data from the 2021 YRBS were electronically available under the Data and Documentation tab of the YRBSS CDC website and could be accessed using ASCII and ACCESS formats (CDC, 2022c). There were 17,508 total and 17,232 usable questionnaires completed after data were cleaned and edited in 152 schools for the 2021 YRBS (Mpofu et al., 2023). Questionnaires failed quality control when they had fewer than 20 responses remaining after editing or if they contained more than or equal to 15 of the same answer (Mpofu et al., 2023). The reported response rate was 72.7% for schools and 79.1% for students, with an overall response (student rate times school rate) of 57.5% (Mpofu et al., 2023).

The reliability and validity of the National YRBS had been addressed. Brener et al. (2002, 2003, 2013) assessed the reliability and validity of the YRBS and revealed that the questionnaire and procedural components are highly reliable in students Grades 9–12. The National YRBS is a cross-sectional design with a single point-in-time instrumentation in which students complete the survey during one class period (approximately 45 minutes; Mpofu et al., 2023). This design addresses several threats to internal validity, such as history, regression, maturation, repeated testing, changes in instrumentation, research bias, attrition, and differential mortality. YRBS uses a three-stage cluster sampling design to produce a nationally representative sample and randomly selects areas, schools, and classrooms across the United States but does not include online students (Mpofu et al., 2023). Therefore, the generalizability for this study was for U.S. classroom students in Grades 9–12.

There were a few discrepancies between the proposed and actual data collection methods used to reach study conclusions after the initial review of the descriptive statistics and related frequencies was completed. The first discrepancy was regarding race and ethnicity covariates, which were combined into one variable, and the second was how the missing data were handled. The initial plan was to evaluate race and ethnicity separately. However, based on the 2021 user's guide recommendations to avoid redundancy and ensure clarity, the variables regarding race and ethnicity were combined into a 7-level answer (*raceeth* variable) and not set as a dichotomous variable, and this was used for analysis from the 2021 combined YRBS data set (see CDC, 2023d). Next, the proposed methods included several possibilities to consider while handling the missing data, such as imputation, multiple imputation, and listwise deletion based on the characteristics of missing data. Due to the high number of missing values in this data set, multiple imputation, where missing data are replaced with predicted values, was the chosen method to handle the missing values. A further explanation of this process is provided in the upcoming sections.

Statistical Analysis

In this study, the initial step involved managing missing data, which was crucial for ensuring the robustness of subsequent analyses. A thorough investigation of missing data patterns was conducted to ascertain the mechanism of missingness, determining whether data were missing completely at random or missing at random. Based on this assessment, multiple imputation was chosen as the most suitable approach to handle missing data, employing regression imputation to estimate missing values. This method

created multiple complete data sets by imputing missing values based on the relationships observed in the data, thereby preserving the underlying data structure. Following the imputation process, binary logistic regression was used to test the hypotheses and assess the main effects of the variables of interest. Additionally, interaction terms were included in the models to explore potential moderating effects, providing insights into how different variables might influence each other in relation to e-cigarette use among high school students. To account for the variability introduced by the imputation process, the results from the multiple imputed data sets were pooled. This approach ensured that the final statistical inferences reflected both the uncertainty associated with missing data and the true relationships present in the complete data. All statistical tests were conducted using IBM SPSS Statistics Version 29, with a significance level set at 0.05, to determine the presence of statistically meaningful relationships.

Data Cleaning and Editing

Prior to commencing the data analysis, I conducted an initial step of data cleaning and editing to ensure the accuracy and relevance of the data in relation to the study's inclusion criteria. The data set was first reviewed for accuracy in the grade and age of the participants. An examination of the grade variable revealed that 23 students were either ungraded or belonged to other grades, with an additional 136 records missing this information. These cases were excluded from the analysis to minimize bias and enhance the accuracy of the results pertinent to the research questions. The analysis was confined to 17,073 students who were accurately categorized within Grades 9–12. Further data editing involved recoding the responses to the question regarding sleep duration: "On an

average school night, how many hours of sleep do you get?" The original responses ranged across several categories: 4 hours or less, 5 hours, 6 hours, 7 hours, 8 hours, 9 hours, and 10 hours or more. These were consolidated into two groups to create a new variable: insufficient sleep. Students reporting 7 hours of sleep or less were classified as having insufficient sleep, and those reporting 8 hours or more were classified as not having insufficient sleep. This recoding was integral to aligning the data set with the study's operational definition of insufficient sleep and facilitating subsequent analyses that addressed the research questions. Following the establishment of exclusion criteria and completion of the data editing process, the data set underwent a thorough examination for missing values to prepare for the ensuing statistical analysis.

Missing Value Management

Missing data analysis was conducted to enhance the accuracy and reliability of study results. Initial assessments revealed substantial missing data across several variables (see Table 2). The variables weight intentions, sports participation, and insufficient sleep exhibited the highest percentages of missing values at 46.2%, 39.6%, and 20.8%, respectively.

Table 2

Summary of Missing and Valid Data for Key Study Variables

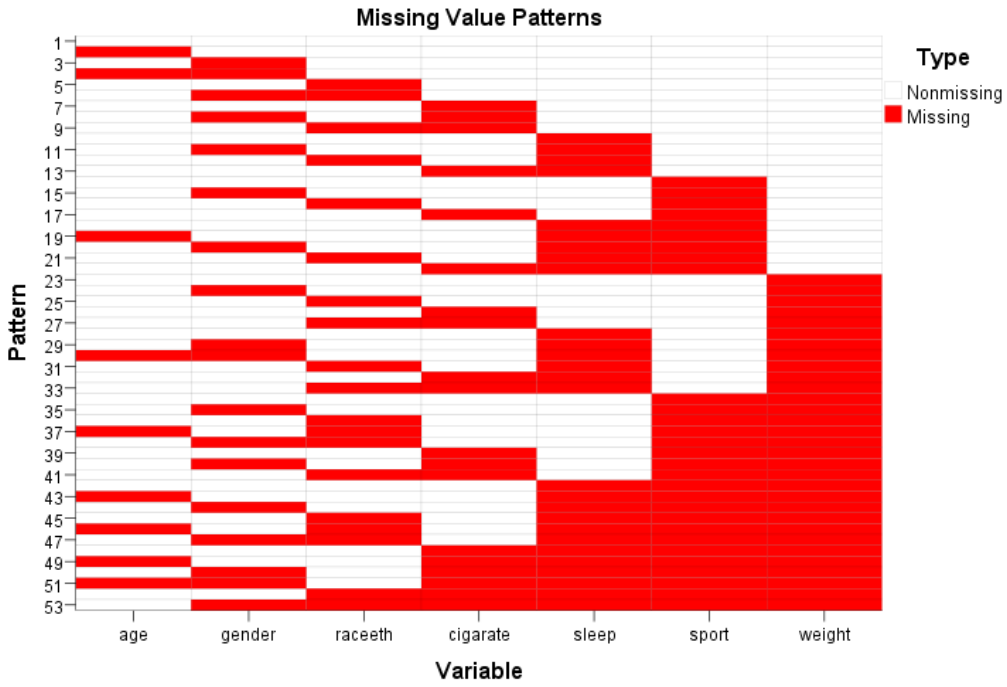
	Missing		
	Number	Percentage	Valid Number
Weight intentions	7,882	46.2%	9,191
Sports participation	6,760	39.6%	10,313
Insufficient sleep	3,558	20.8%	13,515
E-cigarette use	406	2.4%	16,667
Race/ethnicity	334	2.0%	16,739
Gender	180	1.1%	16,893
Age	20	0.1%	17,053

Note. The table summarizes the number and percentage of missing values alongside the valid number of responses for each study variable. Missing percentages were calculated based on the total initial sample size ($N = 17,073$).

Initially, listwise deletion was considered, which reduced the data set to 8,546 participants, representing a loss of 50.1% of the original data. However, given the significant data reduction and potential biases, multiple imputation was adopted to handle missing values more robustly. Multiple imputation, a process that iteratively fills in missing values using a stochastic imputation technique based on the observed data distribution, was implemented to create several plausible data sets (see Schafer & Graham, 2002; White et al., 2010). This technique reflected the uncertainty surrounding the true values, thereby providing a more reliable basis for subsequent analyses (see Rubin, 1987), as shown in Figure 4.

Figure 4

Pattern of Missing Data Across Study Variables



Note. This figure illustrates the distribution of missing data across the key variables in the study: sports participation (sport), weight intentions (weight), insufficient sleep (sleep), and others. Sports participation, weight intentions, and insufficient sleep exhibited the highest rates of missing data, which may indicate challenges in data collection or respondent engagement related to these areas.

Allison (2002) notes that multiple imputation can perform effectively even with up to 50% of missing data under certain conditions. As the volume of missing data increases, the probability of encountering estimation challenges during the imputation process also rises, and achieving the missing at random assumption becomes less likely unless the missing data are part of a planned missingness design (Johnson & Young, 2011). To assess the nature of the missingness, I conducted Little and Rubin (2002) missing completely at random test . A significant result was found, $\chi 2$ (329) 2204.45 $p <$ .001, indicating that the missing data were not missing completely at random. Subsequent analyses using *t* tests and chi-square tests evaluated the association between missingness and other observed variables. The significant results suggested that the missing data could be considered missing at random, thereby validating the use of multiple imputation under missing at random assumptions (see Enders, 2010).

Multiple imputation was performed using the multivariate normal distribution method in SPSS, with regression imputation chosen as the most suitable option. Consistent with recommendations by Rubin (1987), 10 iterations were conducted to optimize the reliability of the imputed data sets. After imputation, the fraction of missing information (FMI) and relative efficiency (RE) were calculated to assess the impact of missing data on the study's estimates. A lower FMI and an RE higher than 95% indicate minimal loss of information and high efficiency of the estimators, respectively (Rubin, 1987). Each imputed data set was analyzed separately, and the results were pooled to provide comprehensive estimates that accounted for the variability introduced by the imputation process (see Little & Rubin, 2002). The final pooled results were integrated

into the subsequent analysis sections, ensuring that both observed and imputed data were reflected in the study's conclusions.

Descriptive and Demographic Characteristics

The statistical analysis presented in Table 3 provides a comprehensive overview of the demographic and behavioral characteristics of high school students participating in the study based on original and pooled data after multiple imputation. The gender distribution in the pooled data showed a slight male majority (51.9% male compared to 48.1% female), mirroring the original data set. Age distribution was consistent, with most participants age 15 (25.9%) and 16 (25.0%), reflecting typical high school demographics. Racial and ethnic composition indicated Whites as the majority (54.5%), followed by Black or African American (13.8%) and multiple-Hispanic (12.0%) participants. Sports participation data revealed a notable increase in reported activity in the pooled data, particularly for students reporting no team involvement, which rose to 49.8%. Weight intentions indicated a predominant desire to lose weight (45.5%), an increase likely reflecting underreporting in the original data. Insufficient sleep (≤ 7 hours) indicated a significant majority (76.6%), underscoring a common issue among adolescents. Finally, e-cigarette use was reported by 35.9% of the sample in the pooled data, suggesting a slight underreporting in the initial responses. These characteristics establish a foundation for understanding the factors influencing adolescent health behaviors, with imputation ensuring data completeness and reliability.

Table 3

Demographic and Behavioral Characteristics of High School Students

Characteristic	Original data (*n*)	Pooled data (*n*)	%
Gender			
Male	8,765	8,853	51.9
Female	8,128	8,218	48.1
Age			
12	29	29	0.2
13	61	61	0.4
14	3,391	3,391	19.9
15	4,410	4,410	25.9
16	4,257	4,257	25.0
17	3,894	3,894	22.8
18	1,011	1,011	5.9
Race/ethnicity			
Indian/Alaska Native	145	148	0.9
Asian	848	867	5.1
Black or African American	2,313	2,359	13.8
Native Hawaiian/Other PI	88	91	0.5
White	9,131	9,309	54.5
Hispanic/Latino	1,207	1,232	7.2
Multiple-Hispanic	2,009	2,051	12.0
Multiple- non-Hispanic	998	1,015	6.0
Sports participation			
No team	5,221	8,501	49.8
1 team	2,500	4,161	24.4
2 teams	1,478	2,497	14.6
3 teams and more	1,114	1,912	11.2
Weight intentions			
Lose weight	4,227	7,761	45.5
Gain weight	1,916	3,524	20.6
Stay the same weight	1,349	2,512	14.7
Not trying to do anything	1,699	3,274	19.2
Insufficient sleep			
≥ 8 hours sleep	3,188	3,999	23.4

Characteristic	Original data (*n*)	Pooled data (*n*)	%
≤ 7 hours sleep	1,0327	1,3072	76.6
E-cigarette use			
No	10,676	10,930	64.1
Yes	5,991	6,141	35.9

Note: This table presents the demographic and behavioral characteristics of participants both before and after multiple imputation. The 'Original Data' column reflects the observed data prior to imputation, while the 'Pooled Data' column shows results after multiple imputation to address missing values. Percentages indicate the proportion of participants in each category relative to the total sample in the pooled dataset.

Bivariate Data Analysis

In investigating the associations between demographic characteristics and e-cigarette use among students, a chi-square test of independence was employed to analyze data across multiple categories: gender, age, race/ethnicity, sports participation, weight intentions, and sleep patterns. The results as seen in Table 4 revealed significant differences in e-cigarette use based on gender (χ^2 (1) = 117.79, $p < .001$), with females showing higher usage (54%) compared to males (46%). Age also showed a significant variation in usage (χ^2 (6) = 488.87, $p < .001$), with increasing usage peaking at age 17 (29%) before a slight decrease at age 18 (8%). Racial and ethnic differences were evident (χ^2 (7) = 157.56, $p < .001$), particularly higher usage among White students (14%) and lower among Asians (3%). No significant association was found between sports participation and e-cigarette use (χ^2 (3) = 4.61, $p = .222$), though sports participation is one of the key IVs and was the basis of the original research query. Weight intentions correlated significantly with usage, as those intending to lose weight reported higher use

(51%) compared to those not trying to change their weight (13%) (χ^2 (3) = 233.08, p < .001). Additionally, insufficient sleep was linked to higher e-cigarette use (χ^2 (1) = 167.26, p < .001), with 82% of users sleeping less than 8 hours. These preliminary findings suggest possible relationships exist to the DV of e-cigarette use among students including influential demographic factors, particularly focusing on females, older students, those from certain racial and ethnic backgrounds, and those with specific weight intentions or sleep patterns. Therefore, the bivariate analysis justified the inclusion of these variables for the purposes of this study. However, there may not be an observed possible relationship between sports participation and e-cigarette use within this dataset. Though, further analysis may reveal weight intentions and sleep patterns may influence the strength of the relationship between sports participation and e-cigarette use, and therefore, sports participation was still included in the analysis.

Table 4

Associations Between Demographic Characteristics and E-Cigarette Use Among Students

Characteristic	E-cigarette use		Chi-square	
	No *n* (%)	Yes *n* (%)	X	*p*
Gender			117.79	<.001
Male	6,026 (55)	2,827 (46)		
Female	490 (45)	3,314 (54)		
Age			488.87	<.001
12	13 (0.1)	15 (0.1)		
13	48 (0.1)	13 (0.1)		
14	2,565 (23)	826 (13)		
15	2,992 (27)	1,416 (23)		
16	2,665 (24)	1,592 (26)		
17	2,093 (19)	1,801 (29)		
18	540 (5)	470 (8)		
Race/ethnicity			157.56	<.001
Indian/Alaska Native	88 (1)	60 (1)		
Asian	698 (6)	169 (3)		
Black or African American	1,541 (14)	818 (13)		
Native Hawaiian/Other PI	55 (1)	35 (1)		
White	5,982 (55)	3,327 (54)		
Hispanic/Latino	782 (7)	449 (7)		
Multiple-Hispanic	1,170 (11)	881 (14)		
Multiple- non-Hispanic	614 (6)	402 (7)		
Sports participation			4.61	.222
No team	5,391 (49)	3,109 (51)		
1 team	2,705 (25)	1,455 (24)		
2 teams	1,597 (15)	899 (15)		
3 teams and more	1,236 (11)	676 (11)		
Weight intentions			233.08	<.001
Lose weight	4,630 (42)	3,131 (51)		
Gain weight	2,182 (20)	1,343 (22)		
Stay the same weight	1,679 (15)	883 (14)		

Characteristic	E-cigarette use		Chi-square	
	No *n* (%)	Yes *n* (%)	X	*p*
Not trying to do anything	2,440 (22)	834 (13)		
Insufficient sleep			167.26	<.001
≥ 8 hours sleep	2,909 (27)	1,090 (18)		
≤ 7 hours sleep	8,022 (73)	5,050 (82)		

Note. Chi-square tests were used to examine the association between demographic characteristics and e-cigarette use. E-cigarette use percentages are shown within parentheses.

Results

Binary logistic regression was used to examine whether sports participation, weight intentions, and inadequate sleep were associated with the likelihood of e-cigarette use in high school students Grades 9–12 when controlling for age, sex, race, and ethnicity.

Statistical Assumptions

In statistical analysis, it is essential to ensure statistical assumptions are met to ensure you do not draw false conclusions from the analysis. Binary logistic regression differs from linear regression analysis in that it uses predictive variables to try to predict an outcome within a binary categorical variable (Laerd Statistics, n.d.). Thus, graphical representations such as those used in linear regression are unnecessary with binary logistic regression analysis with only one continuous variable. The explanation of checking assumptions for binary logistic regression includes the following for this analysis. The first assumption in binary logistic regression is that the dependent variable should be dichotomous (Laerd Statistics, n.d.). In the case of this research study, this

assumption was met with the categorical outcome variable of the YRBS question on e-cigarette use (yes/no). The second assumption is that independent variables should be measured on a continuous or nominal scale, which was also met with the IVs, including sports participation, sleep deprivation, weight intentions, and covariates (Laerd Statistics, n.d.). The third assumption is independence in observations and the categories of dichotomous dependent variables, and all nominal independent variables must be mutually exclusive, which was met given the independence of observations of the YRBS (Laerd Statistics, n.d.). The fourth assumption, which requires a minimum of 15 cases per independent variable, is met because of the large dataset provided by the secondary analysis of the YRBS (Laerd Statistics, n.d.). The fifth assumption is that a linear relationship is required between continuous independent variables and the logit transformation of the dependent variable, which is met for this analysis because age was the only continuous variable analyzed (Laerd Statistics, n.d.). Similarly, the sixth assumption is that the data should not exhibit multicollinearity; age is the only continuous variable, so this assumption is not applicable (Laerd Statistics, n.d.). The last assumption for binary logistic regression is that there should be no significant outliers; this assumption was met as most variables in this research study were categorical (Laerd Statistics, n.d.).

Research Question Analysis

RQ1: Is there an association between sports participation, weight intentions, insufficient sleep (defined by 7 hours or less), and e-cigarette use in students Grades 9-12 in the United States when controlling for age, sex, race, and ethnicity?

Binary logistic regression was used to explore the association between sports participation, weight intentions, insufficient sleep, and e-cigarette use among U.S. high school students in Grades 9-12, controlling for age, gender, and race/ethnicity. Variables were treated as follows in the logistic regression model: Gender, Race, Weight Intentions, and Insufficient Sleep were entered as dummy variables, whereas Age and Sports Participation were treated as interval variables to facilitate interpretation and reflect their logical increase. Multiple Imputation (MI) was employed to address missing data, enhancing the robustness of the analyses. The Fraction of Missing Information (FMI) and Relative Increase in Variance (RIV) were assessed to ensure that the imputation process adequately compensated for the missing data. While FMI values varied, with a maximum of 0.44 for 'Stay the same weight' in Weight Intentions, this level indicates a moderate amount of information loss due to missing data (refer to Table 5). However, the Relative Efficiency (RE) across all variables remained high, indicating that the efficiency of the estimates was minimally affected by the missing data. Specifically, the RE values were satisfactory, suggesting that despite the higher FMI for certain variables, the overall integrity and reliability of the statistical analysis were maintained.

The logistic regression analysis revealed no significant association between sports participation and e-cigarette use among students, with an odds ratio of 1.02 (95% *CI* [0.98, 1.06], $p = .393$). In contrast, Weight intentions were significantly associated with e-cigarette use. Compared to students not attempting to alter their weight, those aiming to lose weight had a notably higher likelihood of e-cigarette use ($b = 0.59$, $SE = 0.06$, $p < .001$, $Exp(b) = 1.81$, 95% *CI* [1.63, 2.03]). Similarly, students intending to gain weight

exhibited increased odds of using e-cigarettes (b = 0.63, SE = 0.06, p < .001, $Exp(b)$ = 1.87, 95% CI [1.65, 2.13]). Additionally, those who were trying to maintain their weight also showed a greater likelihood of e-cigarette use compared to those with no weight change intentions (b = 0.36, SE = 0.08, p < .001\), $Exp(b)$ = 1.43, 95% CI [1.22, 1.67]), indicating that any active engagement in weight management, whether it be to lose, gain, or maintain weight, is associated with higher e-cigarette use. Finally, students getting sufficient sleep (≥ 8 hours) were significantly less likely to use e-cigarettes compared to those who slept 7 hours or less (b = 0.43, SE = 0.05, p < .001, $Exp(b)$ = 0.65, 95% CI [0.58, 0.72]), as shown in Table 5.

Overall, these results suggest that weight intentions and sleep patterns significantly influence e-cigarette use among high school students, while sports participation does not. Specifically, students who are actively managing their weight—whether trying to lose, gain, or maintain it—show increased odds of using e-cigarettes compared to those who are not engaging in weight management activities. This indicates a clear link between weight-related behaviors and the likelihood of e-cigarette use. Additionally, the analysis showed that getting sufficient sleep, defined as 8 hours or more, significantly reduces the odds of e-cigarette use among students. These findings highlight the importance of considering both weight management and sleep quality in understanding the behaviors associated with e-cigarette use among adolescents.

Table 5

Binary Logistic Regression Analysis of Factors Influencing E-Cigarette Use Among High School Students

	b	*SE*	*p*	Exp (*b*)	95% CI for Exp (*b*) LB	UB	FMI	RIV	RE
Gender									
Ref: Male									
Female	.39	.04	<.001	1.48	1.37	1.59	.18	.22	.98
Age	.27	.01	<.001	1.31	1.27	1.35	.03	.03	1.00
Race									
Ref: White									
Am Indian/Alaska Native	.23	.18	.211	1.26	.88	1.80	.09	.10	.99
Asian	-.82	.09	<.001	.44	.37	.53	.04	.04	1.00
Black or African American	-.10	.05	.069	.91	.82	1.01	.13	.14	.99
Native Hawaiian/Other PI	.12	.23	.589	1.13	.73	1.77	.03	.03	1.00
Hispanic / Latino	.02	.07	.760	1.02	.89	1.16	.08	.08	.99
Multiple - Hispanic	.24	.05	<.001	1.27	1.14	1.41	.09	.10	.99
Multiple - non-Hispanic	.15	.07	.039	1.16	1.01	1.33	.04	.04	1.00
Sport participants	.02	.02	.393	1.02	.98	1.06	.40	.61	.96
Weight intentions									
Ref: Not trying anything									
Lose weight	.59	.06	<.001	1.81	1.63	2.03	.28	.36	.97
Gain weight	.63	.06	<.001	1.87	1.65	2.13	.26	.34	.97
Stay the same weight	.36	.08	<.001	1.43	1.22	1.67	.44	.71	.96
Insufficient sleep									
Ref: ≤ 7 hours sleep									
≥ 8 hours sleep	-.43	.05	<.001	.65	.58	.72	.41	.63	.96
(Constant)	-2.4	.10	<.001	.09	.07	.11	.16	.18	.98

Note: This table presents the pooled results from a logistic regression analysis examining the association between sports participation, weight intentions, insufficient sleep, and e-cigarette use, controlling for age, gender, and race/ethnicity. Age and sports participation were treated as interval variables to facilitate interpretation. Gender, Race, Weight Intentions, and Insufficient Sleep were included as dummy variables, with specific categories designated as reference groups (*Ref*). *b* represents regression coefficient. *Exp(b)* represents the odds ratios, with corresponding 95% confidence intervals (*CI*) listed. *SE* denotes the standard error for each coefficient. *FMI* (Fraction of Missing Information), *RIV* (Relative Increase in Variance), and *RE* (Relative Efficiency) indicate the robustness of the imputation used for handling missing data.

RQ2: Does weight intentions moderate the relationship between sports participation and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity?

To investigate whether weight intentions moderate the relationship between sports participation and e-cigarette use among U.S. high school students in Grades 9–12, a logistic regression model with interaction terms was employed. This analysis controlled for demographic factors such as age, sex, and race/ethnicity. The inclusion of interaction terms between Sports Participants (SP) and Weight Intentions (WI) aimed to assess the potential moderating effects of these variables on e-cigarette use.

The logistic regression analysis revealed that main effect of sports participation on e-cigarette use was not significant ($b = 0.01$, $SE = 0.04$, $p = .813$, *Exp(b)* = 1.01, 95% *CI* [0.93, 1.10]), indicating that sports participation alone does not influence e-cigarette usage among students. Regarding the main effects of weight intentions, significant differences were noted. Students with an intention to lose weight exhibited higher odds of using e-cigarettes compared to those not trying to change their weight ($b = 0.63$, $SE = 0.11$, $p < .001$, *Exp(b)* = 1.87, 95% CI [1.51, 2.32]). Similarly, the intention to gain weight also significantly increased the likelihood of e-cigarette use ($b = 0.62$, $SE = 0.13$, $p < .001$, *Exp(b)* = 1.87, 95% *CI* [1.45, 2.39]), as did the intention to maintain weight ($b = 0.42$, $SE = 0.16$, $p = .010$, *Exp(b)* = 1.52, 95% CI [1.11, 2.07]). However, when examining the interaction effects, there was no significant moderation by sports participation across different weight intention categories. The interaction between sports participation and the intention to lose weight yielded an odds ratio of 1.00 ($b = 0.01$, $SE =$

0.05, p = .956, *Exp(b)* = 1.00, 95% *CI* [0.90, 1.10]), and similar non-significant results were observed for gaining weight (b = 0.01, *SE* = 0.06, p = .923, *Exp(b)* = 1.01, 95% *CI* [0.90, 1.13]) and maintaining weight (b = -0.03, *SE* = 0.07, p = .649, *Exp(b)* = 0.97, 95% CI [0.85, 1.11]). These findings, as shown in Table 6, suggest that the relationship between sports participation and e-cigarette use is consistent across different weight intention categories, demonstrating no significant moderating effects from weight intentions on this relationship.

The analysis conducted to assess the moderating effects of weight intentions on the relationship between sports participation and e-cigarette use in high school students did not reveal any significant moderating impacts. Despite the clear influence of weight intentions on e-cigarette use, as indicated by their main effects, sports participation did not interact significantly with these intentions to alter the likelihood of e-cigarette use. This lack of moderation suggests that the effects of sports participation on e-cigarette use are stable across students with varying weight management goals. Therefore, interventions aimed at reducing e-cigarette use may benefit from directly addressing weight management and behavioral intentions rather than focusing on the interaction of these factors with sports participation.

Table 6

Moderating Effects of Weight Intentions on the Relationship Between Sports Participation and E-Cigarette Use

	b	*SE*	*p*	Exp (*b*)	95% CI for Exp (*b*) LB	UB	FMI	RIV	RE
Gender									
Ref: Male									
Female	.40	.04	<.001	1.49	1.38	1.60	.18	.22	.98
Age	.28	.01	<.001	1.32	1.29		.03	.04	.99
Race									
Ref: White									
Am Indian/Alaska Native	.21	.18	.248	1.23	.86	1.76	.08	.09	.99
Asian	-.81	.09	<.001	.45	.37	.53	.04	.04	.99
Black or African American	-.08	.05	.142	.93	.83	1.03	.12	.14	.99
Native Hawaiian/Other PI	.14	.23	.523	1.16	.74	1.80	.03	.03	.99
Hispanic / Latino	.02	.07	.810	1.02	.89	1.16	.05	.06	.99
Multiple - Hispanic	.24	.05	<.001	1.27	1.14	1.41	.09	.10	.99
Multiple - non-Hispanic	.17	.07	.014	1.19	1.04	1.37	.03	.03	.99
Sport participants (SP)	.01	.04	.813	1.01	.93	1.10	.20	.24	.98
Weight intentions (WI)									
Ref: Not trying anything									
Lose weight	.63	.11	<.001	1.87	1.51	2.32	.24	.29	.98
weight	.62	.13	<.001	1.87	1.45	2.39	.24	.25	.98
Stay the same weight	.42	.16	.010	1.52	1.11	2.07	.39	.60	.98
Interaction (SP x WI)									
Ref: SP x Not trying									
SP x Lose weight	.01	.05	.956	1.00	.90	1.10	.21	.25	.98
SP x Gain weight	.01	.06	.923	1.01	.90	1.13	.23	.28	.98
SP x Stay the same weight	-.03	.07	.649	.97	.85	1.11	.27	.35	.98
(Constant)	-2.6	.12	<.001	.08	.06	.10	.19	.23	.98

Note: This table presents the results of a logistic regression analysis examining the moderating effects of weight intentions on the relationship between sports participation and e-cigarette use among high school students in Grades 9–12, while controlling for demographic factors such as age, sex, and race/ethnicity. Interaction terms (SP x WI) assess whether the relationship between sports participation and e-cigarette use varies by weight intentions. Age and sports participation were treated as interval variables to facilitate interpretation. Gender, Race, and Weight Intentions were included as dummy variables, with specific categories designated as reference groups (*Ref*). *b* represents regression coefficient. *Exp(b)* represents the odds ratios, with corresponding 95% confidence intervals (*CI*) listed. *SE* denotes the standard error for each coefficient. *FMI* (Fraction of Missing Information), *RIV* (Relative Increase in Variance), and *RE* (Relative Efficiency) indicate the robustness of the imputation used for handling missing data.

RQ3: Does insufficient sleep, as defined by 7 hours or less, moderate the relationship between sports participation and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity

This study investigated whether insufficient sleep, defined as 7 hours or less, moderates the relationship between sports participation and e-cigarette use among U.S. high school students in Grades 9–12, while controlling for demographic variables such as age, sex, and race/ethnicity. Logistic regression was employed with interaction terms between sports participation (SP) and insufficient sleep (IS) to explore potential moderation effects.

The logistic regression model indicated no significant direct effect of sports participation on e-cigarette use (b = 0.01, SE = 0.04, p = .952, *Exp(b)* = 1.00, 95% *CI* [0.92, 1.09]). However, insufficient sleep showed a significant association with e-cigarette use, where students getting less than 7 hours of sleep demonstrated an increased likelihood of e-cigarette use (b = -0.40, SE = 0.11, p < .001, *Exp(b)* = 1.49, 95% CI [1.20, 1.83]) compared to those with 8 hours and more sleep. Regarding the interaction effects, the analysis did not find significant moderating impacts of insufficient sleep on the relationship between sports participation and e-cigarette use. The interaction term between sports participation and having sufficient sleep (b = 0.03, SE = 0.05, p = .486, *Exp(b)* = 1.03, 95% *CI* [0.94, 1.13]) did not show a significant effect, suggesting that the relationship between sports participation and e-cigarette use does not vary by sleep duration, as shown in Table 7.

The findings indicate that insufficient sleep does not moderate the relationship between sports participation and e-cigarette use among high school students. While insufficient sleep is associated with a higher likelihood of e-cigarette use, sports participation does not interact with sleep duration to influence this outcome. This suggests that interventions targeting e-cigarette use may need to address sleep patterns independently of sports participation, focusing on improving sleep hygiene as a potential strategy to reduce vaping among adolescents.

Table 7

Moderating Effects of Insufficient Sleep on the Relationship Between Sports Participation and E-Cigarette Use

	b	*SE*	*p*	Exp (*b*)	95% CI for Exp (*b*) LB	UB	FMI	RIV	RE
Gender									
Ref: Male									
Female	.39	.04	<.001	1.47	1.38	1.58	.13	.14	.99
Age	.27	.01	<.001	1.31	1.28	1.35	.02	.02	.99
Race									
Ref: White									
Am Indian/Alaska Native	.27	.18	.139	1.31	.92	1.87	.09	.09	.99
Asian	-.83	.09	<.001	.44	.37	.52	.03	.03	.99
Black or African American	-.06	.05	.285	.95	.85	1.05	.10	.11	.99
Native Hawaiian/Other PI	.19	.23	.394	1.21	.78	1.89	.04	.04	.99
Hispanic / Latino	.07	.07	.292	1.07	.94	1.23	.08	.08	.99
Multiple - Hispanic	.28	.05	<.001	1.33	1.20	1.47	.09	.10	.99
Multiple - non-Hispanic	.16	.07	.026	1.17	1.02	1.34	.03	.03	.99
Sport participants (SP)	.01	.04	.952	1.00	.92	1.09	.42	.67	.96
Insufficient sleep (IS)									
Ref: ≤ 7 hours sleep									
≥ 8 hours sleep	-.40	.11	<.001	1.49	1.20	1.83	.39	.58	.96
Interaction (SP *x IS*)									
Ref: SP *x* ≤ 7 hours sleep									
SP *x* ≥ 8 hours sleep	.03	.05	.486	1.03	.94	1.13	.35	.51	.97
(Constant)	-2.4	.12	<.001	.09	.07	.11	.30	.40	.97

Note: This table presents the results of a logistic regression analysis examining the moderating effects of Insufficient Sleep on the relationship between sports participation and e-cigarette use among high school students in Grades 9–12, while controlling for demographic factors such as age, sex, and race/ethnicity. Interaction terms (SP x WI) assess whether the relationship between sports participation and e-cigarette use varies by Insufficient Sleep. Age and sports participation were treated as interval variables to facilitate interpretation. Gender, Race, and Insufficient Sleep were included as dummy variables, with specific categories designated as reference groups (*Ref*). *b* represents regression coefficient. *Exp(b)* represents the odds ratios, with corresponding 95% confidence intervals (*CI*) listed. *SE* denotes the standard error for each coefficient. *FMI* (Fraction of Missing Information), *RIV* (Relative Increase in Variance), and *RE* (Relative Efficiency) indicate the robustness of the imputation used for handling missing data.

Summary

Binary logistic regression was used to complete Research Question 1. Results revealed no significant association between sports participation and e-cigarette use. However, weight intentions showed a significant impact, with students aiming to lose, gain, or maintain weight exhibiting a higher likelihood of e-cigarette use compared to those not attempting weight alteration. Additionally, insufficient sleep was associated with increased odds of e-cigarette use, while sufficient sleep significantly reduced these odds. To answer research questions 2 and 3, which aimed to investigate the interaction effect of sleep disturbances and weight intentions on the relationship between sports participation and e-cigarette use, I employed binary logistic regression with an interaction term. Again, the results of the logistic regression analysis revealed no significant direct effect of sports participation and sleep disturbances on e-cigarette use, despite testing for interaction effects. These findings suggest that although significant relationships were identified between sleep disturbances and weight intentions and e-cigarette use, these variables do not moderate the relationship between sports participation and e-cigarette use among high school students.

Considering the findings uncovered in this study, there is a clear call for further exploration to contextualize these results within the existing body of research. The following section aims to present and interpret these findings in a meaningful manner and integrate them into the existing literature. Section 4 will end with shedding light on the implications for social change and guiding potential avenues for future research in public health practice.

Section 4: Application to Professional Practice and Implications for Social Change

Sparking public health concern, e-cigarettes have surged in popularity among youths in the United States over the past decade, likely fueled by perceptions of reduced harm compared to traditional cigarettes. Marketed as healthier alternatives, e-cigarettes are often perceived as remedies for energy enhancement, anxiety relief, sleep troubles, and weight management (Dubé et al., 2023; Holtz et al., 2022b; Morean et al., 2020). Moreover, despite the well-known protective factor of sports participation against traditional smoking, there is a growing interest among young athletes in e-cigarettes. Although prior studies suggested a positive correlation between sports involvement and e-cigarette use, this relationship was underexplored (Milicic et al., 2017; Veliz et al., 2017; Williams et al., 2020). Additionally, limited data existed on the association between e-cigarette use and high school athletes in the United States, particularly regarding potential interactions with weight intentions and insufficient sleep.

The purpose of this study was to examine the relationship between sports participation, weight intentions, and insufficient sleep on e-cigarette use among high school students in the United States. Furthermore, I examined the potential moderating role of weight intentions and insufficient sleep on the relationship between sports participation and e-cigarette use. This quantitative study used the CDC's 2021 National YRBS to investigate how sports participation, weight intentions, and insufficient sleep affect e-cigarette use among U.S. high school students. The findings from this study could inform public health efforts targeting e-cigarette use, particularly among young

athletes, and contribute to the existing literature on factors influencing e-cigarette use among youths in the United States.

Summary of Key Findings

Bivariate data analysis of covariates and baseline demographic and behavioral characteristics revealed several noteworthy relationships. Descriptive characteristics revealed that 35.9% of students reported e-cigarette use, almost 50% reported no team participation, 45.5% desired weight loss, and 76.6% experienced sleep deprivation. Further examination through bivariate analysis exposed associations between demographic characteristics and e-cigarette use: Females exhibited higher e-cigarette usage than males (54% vs. 46%), peak reported e-cigarette use occurred at age 17 (29%), and e-cigarette use was highest among White students (14%) and lowest among Asian students (3%). Moreover, weight intentions exhibited a strong correlation with e-cigarette use, with individuals intending to lose weight reporting higher use (51%) compared to those not seeking weight change (13%). Additionally, insufficient sleep was highly correlated with e-cigarette use, with 82% of e-cigarette users reporting less than 8 hours of sleep.

Binary logistic regression addressed the first research question examining associations between sports participation, weight intentions, insufficient sleep (7 hours or less), and e-cigarette use among U.S. high school students (Grades 9–12) while controlling for age, sex, race, and ethnicity. Although I found no significant association between sports participation and e-cigarette use, weight intentions exhibited a significant association; any active engagement in weight management (gain, loss, or maintain

weight) was linked to higher e-cigarette use compared to students with no weight intentions. Moreover, students reporting sufficient sleep were significantly less likely to use e-cigarettes than those with insufficient sleep.

Logistic regression analysis with an interaction term addressed the second research question, revealing no statistical significance in the moderation effects of weight intentions on the relationship between sports participation and e-cigarette use among U.S. high school students. Despite weight intentions showing an association with e-cigarette use as a main effect, no significant moderating effects were observed on the relationship between sports participation and e-cigarette use. Likewise, logistic regression analysis with an interaction term addressed the third research question and found that sleep deprivation (7 hours or less) did not moderate the relationship between sports participation and e-cigarette use among U.S. high school students. Despite the clear association between insufficient sleep and increased likelihood of e-cigarette use, no moderating effects of sleep deprivation were observed on the relationship between sports participation and e-cigarette use.

Interpretation of the Findings

The baseline covariates, demographic characteristics, and behavioral characteristics examined in this study corroborate and offer new insights into previous study findings. The current results revealed that nearly 50% of students reported no team participation based on the 2021 YRBS data, which contrasts with previously reported YRBS data averaging 43.7% across 2015, 2017, and 2019 (Rapoport et al., 2022). Additionally, 35.9% of students reported any e-cigarette use in the 2021 YRBS data set,

compared to 50.1% in the 2019 YRBS data set (Creamer et al., 2020), indicating a notable difference. However, the current finding aligns with a 2020 study using the National Youth Tobacco Survey, which identified significant declines in e-cigarette use between 2019 and 2020 (Wang et al., 2019), suggesting a potential continuation of downward trends in e-cigarette use. Demographic factors observed in this analysis, such as higher reported use among females and non-Hispanic Whites, are consistent with findings from some national surveys (see Birdsey et al., 2023). Nevertheless, the literature lacks consistency regarding race/ethnicity or gender (Trucco et al., 2020). Other data suggested that males were more likely than females to use e-cigarettes (Gaiha et al., 2021). In summary, the current study's findings align with and enhance the understanding of existing literature and underscore the nuanced complexities within demographic and behavioral characteristics influencing e-cigarette use among high school students.

The findings from the bivariate analysis of the independent variables align with the recent literature. Prevalence rates of sleep deprivation among high school students typically range from 71% to 84% (CDC, 2022a). The finding that 76.6% of students reported sleep deprivation in the current study is consistent with existing evidence. Lastly, 45.5% of students reported a desire to lose weight in the current study, similar to findings from national surveys of U.S. high school students (43%; Dey et al., 2019). These demographic and baseline comparisons were crucial considerations as I contextualized my findings within the existing literature.

Research Question 1

Is there an association between sports participation, weight intentions, insufficient sleep (defined by 7 hours or less), and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity? Binary logistic regression was employed to examine the relationships in RQ1, with multiple imputations addressing the high numbers of missing data to enhance analysis robustness. The logistic regression analysis revealed no significant association between sports participation and e-cigarette use among students, with an odds ratio of 1.02 (95% CI [0.98, 1.06], $p = .393$). I accepted the null hypothesis for this aspect of the study: Sports participation is not associated with e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity. This finding contrasts with a significant body of recent literature, which often showed that individuals participating in sports are more likely to use e-cigarettes than their nonathlete counterparts (Irvine et al., 2021; Milicic et al., 2017; Rapoport et al., 2022). However, inconsistencies exist; for instance, Kinnunen et al. (2018) found a significant relationship between sports participation and vaping only among boys. Similarly, using the 2017 YRBS data set, Y. Lee et al. (2021) found no direct relationship between sports team participation and e-cigarette use but observed that physically active adolescents were more prone to e-cigarette use than physically inactive peers.

Despite the lack of consistent findings, the current study contributes to the literature. Not observing the relationship between sports participation and e-cigarette use in this data set could be attributed to the smaller sample size compared to studies that

identified a relationship and the inclusion of dual users (both e-cigarette and cigarette users) in the e-cigarette use category. The absence of this relationship adds nuance to the recent literature, suggesting avenues for improving the approach to studying the association between sports participation and e-cigarette use.

In contrast, weight intentions were significantly associated with e-cigarette use. Students aiming to lose weight had a higher likelihood of e-cigarette use compared to those not attempting change weight ($p < .001$). Similarly, students intending to gain weight or maintain weight also exhibited increased odds of using e-cigarettes compared to those with no weight change intentions ($p < .001$), indicating that any level of active engagement in weight management is associated with higher e-cigarette use. This finding rejects the null hypothesis for this aspect of RQ1 and supports the alternative hypothesis that weight intentions are associated with e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity, highlighting a clear link between weight-related behaviors and e-cigarette use among high school students.

The current results align with previous findings to some extent. Although most literature focused on weight loss intentions, the current study found an increased likelihood of e-cigarette use among those intending to maintain or gain weight. This study is the first to demonstrate a higher likelihood of e-cigarette use among individuals aiming to maintain their weight, broadening the understanding of the relationship between weight intentions and e-cigarette use.

Lastly, I found a significant association between inadequate sleep (≤ 7 hours) and e-cigarette use among high school students. Students obtaining sufficient sleep (≥ 8

hours) were significantly less likely to use e-cigarettes compared to those with insufficient sleep ($p < .001$). Rejecting the null hypothesis for this aspect of RQ1, this finding corroborates previous literature, affirming a notable relationship between insufficient sleep and e-cigarette use in youths. Several studies established this connection, with some exploring the directionality of the relationship, suggesting that sleep deprivation or sleep troubles significantly increase the risk of initiating e-cigarette use. These findings illuminate the complex interplay between factors such as insufficient sleep influencing e-cigarette use among high school students, underscoring the importance of further exploration of this relationship to mitigate the growing public health concern surrounding youth vaping.

In summary, the findings of RQ1 suggest that weight intentions and sleep patterns significantly influence e-cigarette use among high school students. At the same time, the anticipated relationship between sports participation and vaping was not observed. The confirmation of insufficient sleep and vaping use among high school students supports existing literature. Although the findings regarding weight intentions align with previous research on weight loss and gain intentions, this study adds to the literature by revealing a relationship between intent to maintain weight and e-cigarette use. Additionally, although the relationship between sports participation and e-cigarette use was not detected in this analysis, this finding contributes to the literature by emphasizing the importance of considering data set size and the exclusion of dual users when examining the possible relationship between sports participation and e-cigarette use. Current findings provide

valuable insights into the multifaceted factors influencing e-cigarette use among high school students, offering potential avenues for targeted interventions and future research.

Research Question 2

Does weight intentions moderate the relationship between sports participation and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity? To address Research Question 2, I conducted binary logistic regression with an interaction term between sports participation and weight intentions. Multiple imputation was used to handle missing values, and demographic factors such as age, sex, and race/ethnicity were controlled for in the analysis. The analysis revealed no significant moderation by sports participation across different weight intention categories. The interaction between sports participation and the intention to lose weight (b = 0.01, SE = 0.05, p = .956) as well as intentions to gain weight (b = 0.01, SE = 0.06, p = .923) or maintain weight (b = -0.03, SE = 0.07, p = .649) did not yield significant effects. These findings suggest that the relationship between sports participation and e-cigarette use remains consistent regardless of weight intentions, indicating no significant moderating effects. The null hypothesis was accepted that weight intentions do not moderate the relationship between sports participation and e-cigarette use in students Grades 9–12 in the United States when controlling for demographic variables.

This study contributes to the current literature by being the first to investigate the moderation effects of weight intentions on the relationship between sports participation and e-cigarette use among youths. The main effect finding was weight intentions (weight loss, weight gain, or maintaining weight) were significantly associated with e-cigarette

use. Although previous research and main effect findings demonstrated a significant association between weight intentions and e-cigarette use, I did not find evidence of moderation. Despite expectations based on existing literature on weight-related pressures among student athletes and main effect findings (Mancine et al., 2020; Roberts et al., 2022), the lack of moderation from the current study suggests the need for further research on the topic and to identify additional risk factors influencing the relationship between sports participation and e-cigarette use.

Research Question 3

Does insufficient sleep, as defined by 7 hours or less, moderate the relationship between sports participation and e-cigarette use in students Grades 9–12 in the United States when controlling for age, sex, race, and ethnicity? In addressing Research Question 3, I conducted binary logistic regression with interaction terms between sports participation and insufficient sleep to explore moderation effects. Again, multiple imputation was employed to handle missing values, and demographic factors such as age, sex, and race/ethnicity were controlled for in the analysis. The results revealed no significant moderating effects of insufficient sleep on the relationship between sports participation and e-cigarette use among U.S. high school students ($b = 0.03$, $SE = 0.05$, $p = .486$). These findings indicate that the relationship between sports participation and e-cigarette use does not vary by sleep duration, with no significant moderating effects observed. The null hypothesis was accepted, suggesting insufficient sleep does not moderate the relationship between sports participation and e-cigarette use in U.S. high school students when controlling for demographic variables.

This was the first study examining the moderation effects of insufficient sleep on the relationship between sports participation and e-cigarette use, which adds to the recent literature on youth e-cigarette use. The main effect finding was that insufficient sleep was significantly associated with e-cigarette use. The main effect findings and recent research on the high incidence of insufficient sleep and students who participate in sports support the possibility of insufficient sleep playing a role in the relationship between sports participation and e-cigarette use (see Bolin, 2019; Coel et al., 2022; Mah et al., 2018; Rebello et al., 2022; Walsh et al., 2020). However, the current study did not observe the moderation effect, indicating a need for future research to identify other risk factors that may improve the understanding of the relationship between sports participation and e-cigarette use.

Findings Related to the SEM

The findings of this study can be interpreted through the lens of the SEM, which was the theoretical base for this study and provided the framework for understanding health behaviors within the context of various interacting factors across multiple levels of influence (Bronfenbrenner, 1994; McLeroy et al., 1988). This research study explored the relationships between vaping use and adolescents in various environments, including layers of influence on the individual, such as socio-demographic characteristics, weight intentions, sports participation, and insufficient sleep. For example, at the individual level, weight intentions were found to be significantly associated with e-cigarette use among high school students (RQ1 and RQ2). This finding aligns with the individual or interpersonal level of the SEM, which emphasizes individual characteristics such as

weight-related concerns and how they would influence health behaviors (Alghzawi & Ghanem, 2021; McLeroy et al., 1988). Additionally, I found insufficient sleep (RQ1 and RQ3) to be significantly associated with e-cigarette use, which would also be an individual characteristic that influences health behaviors (Alghzawi & Ghanem, 2021; McLeroy et al., 1988).

Furthermore, the lack of moderation effects of weight intentions (RQ2) and insufficient sleep (RQ3) on the relationship between sports participation and e-cigarette use suggest that these factors operate independently at the interpersonal level, which encompasses relationships with peers such as sports participation (Alghzawi & Ghanem, 2021). This finding suggests that other factors influence the relationship between sports participation and e-cigarette use.

At the organizational level, the findings suggest it is important to consider broader factors, such as sports participation, in understanding e-cigarette use among high school students in the US. Although sports participation did not show a direct association with e-cigarette use in this study, its role as a potential influencing factor underscores the significance of environmental contexts in shaping health-related behaviors (Alghzawi & Ghanem, 2021) Likewise, the lack of significant moderation effects of weight intentions and insufficient sleep on the relationship between sports participation and e-cigarette use highlights the need to consider the interplay between individual factors and broader environmental influences in the community or societal levels of the SEM in future research such as community norms, policies or attitudes towards health-related behaviors (Alghzawi & Ghanem, 2021)

In summary, considering the study findings as they relate to the study's theoretical base, the SEM, is essential. The findings underscore the importance of considering multiple levels of influence and understanding the complex interplay of factors that could influence e-cigarette use among high school students in the US.

Limitations of the Study

Several notable limitations shape the contours of this investigation. It relies on a secondary analysis of data from the YRBS, which carries inherent constraints. This study hinges upon participants' willingness to provide accurate responses, introducing potential bias and subjectivity into the data. Additionally, while comprehensive, the predefined questions within the YRBS instrument may not encompass specific nuances related to sports participation and insufficient sleep, such as the hours of sports participation each week, intentisty or competitiveness of the sport or the specific types of sports engaged in by students. For instance, Veliz et al. (2017) found no associations using broad sports team participation measures. Yet, they did find associations for wrestling, baseball, and softball when analyzing types of sports (Veliz et al., 2017). Moreover, insufficient sleep was assessed only using one question related to hours of sleep obtained per night in the questionnaire, which may not capture all factors contributing to irregular sleep schedules and inadequate sleep duration among high school students; therefore, it is challenging to attribute insufficient sleep to sports participation directly.

Another limitation of the study is the use of 2021 data; while valuable, it may not reflect the most recent trends, as more recent datasets were not available at the time of the study. Another pivotal limitation arises from the cross-sectional design of the YRBS,

which limits the ability to establish causal relationships. Therefore, while associations were found between weight intentions, insufficient sleep, and e-cigarette use, causal inferences cannot be made from this information. Furthermore, the exclusion of cyber students from the YRBS data collection may limit the inclusivity of participants in the analysis, potentially affecting the generalizability of the findings to all students in the US.

Another potential limitation of this study is the substantial discrepancy between the actual sample size (N=17,025) and the required sample size calculated by G*Power (N=1,617). While a larger sample size can increase statistical power, extensive samples may detect statistically significant results or Type I errors that might not be practically significant (Faber & Fonseca, 2014; Lin et al., 2011). The literature often focuses on sample sizes in the tens or even hundreds of thousands, which was not the case in this study (Lin et al., 2011). However, it is prudent to be conservative and thoughtful when interpreting findings. Therefore, focusing on the clinical significance of the findings and confidence intervals is essential rather than solely on statistical significance (Lin et al., 2011).

One final limitation was the decision to exclude smoking and other substance use from the analysis, which was made to maintain clarity in examining the primary variables of interest. However, smoking and substance use often co-occur with e-cigarette use among adolescents, and omitting these confounding factors may have limited the comprehensiveness of the analysis. A detailed review of my results with current literature highlighted the importance of sample size and consideration for excluding dual users (cigarettes and e-cigarettes) from the data set. Smaller studies have yielded conflicting

findings regarding this association, suggesting that sample size and the inclusion of dual users could impact the results. My study was less than half the sample size (17,073) of the studies that found associations between sports team participation and e-cigarette use (Milicic et al., 2017; Rapoport et al., 2022; Williams et al., 2020). Smaller studies, such as those by Y. Lee et al. (2021), did not find an association between e-cigarette use and sports participation but did with physical activity.

Interestingly, Y. Lee et al. (2021) also included dual users, as I did in this study. The literature review of this study discussed opposing associations between sports team participation, vaping use, and cigarette use (Milicic et al., 2017; Williams et al., 2020). Thus, the smaller sample size and inclusion of dual users may have influenced the identification of associations between sports participation and e-cigarette use in this study. Therefore, while the study provides valuable insights, the exclusion of smoking and substance use represents a limitation that should be considered for future research studies. By acknowledging and embracing these limitations, the study's findings are interpreted within the context of these constraints, remain valid, and build upon current literature that may improve understanding of e-cigarette use among high school students in the US.

Recommendations for Future Research

The study aimed to address a gap in the existing literature concerning e-cigarette use among high school students in the US, mainly focusing on understanding the relationship between sports participation, weight intentions, insufficient sleep, and e-cigarette use. While significant relationships were found between weight intentions (i.e.,

losing, gaining, or maintaining weight) and insufficient sleep with e-cigarette use among US high school students, no significant association was observed between sports participation and e-cigarette use, contrary to existing literature. Subsequent analysis examining the moderation effects of weight intentions and insufficient sleep on the relationship between sports participation and e-cigarette use found no significant effects, suggesting that these factors operate independently.

Several limitations of the study were identified, and future research could address these limitations to enrich the understanding of the relationship between sports participation, weight intentions, insufficient sleep, and e-cigarette use among high school students. Firstly, given the absence of a relationship between sports participation and e-cigarette use, future studies should explore the potential confounding influence of smoking and other substance use. Incorporating these variables in analyses could elucidate their unique contributions to vaping behaviors among high school students. Furthermore, employing more detailed measures of sports participation, such as the type and intensity of sports engaged in, could provide insights into the specific mechanisms underlying the association between sports participation, weight intentions, sleep deprivation, and e-cigarette use. Future research could also investigate the relationship between sports participation, weight intentions, insufficient sleep, and e-cigarette use using different data sources or different questionnaire formats for assessing the dependent variable of e-cigarette use. Given the conflicting findings regarding this association, studies with larger sample sizes would ensure sufficient statistical power to detect meaningful associations.

Exploring the independent variables further, particularly weight intentions and sleep patterns could yield valuable insights. To the best of my knowledge, this study was the first to identify an association between e-cigarette use and weight maintenance, suggesting a potential area for further investigation. Moreover, given the high prevalence of insufficient sleep among high school students and its potential impact on e-cigarette use, future studies could employ more comprehensive measures of sleep patterns and quality. Considering other factors contributing to insufficient sleep, such as academic pressures and electronic device use, could provide a more nuanced understanding of the factors influencing sleep patterns among high school students.

Finally, altering the study design, such as employing longitudinal designs, could establish causal relationships between the variables, offering a deeper exploration of their interplay over time. Addditionally, qualitative research investigating sports participation and e-cigarette use could be conducted to identify possible themes that could be used as predictive variables in the future to look for relationships. Moreover, YRBSS does not currently include cyberschool students; therefore, including these students in future research endeavors would enhance the generalizability of findings, as an increasing number of students are choosing this educational option (Molnar et al., 2019). Addressing these recommendations can advance our understanding of the complex relationship between sports participation, weight intentions, insufficient sleep, and e-cigarette use among high school students, ultimately informing more effective prevention and intervention efforts in this population.

Implications for Professional Practice and Social Change

Although there was no statistically significant association between e-cigarette use and sports participation in this population, this research revealed significant relationships between weight intentions (i.e., losing, gaining, or maintaining weight) and insufficient sleep with e-cigarette use among US high school students. Subsequent analysis examining the moderation effects of weight intentions and insufficient sleep on the relationship between sports participation and e-cigarette use found no significant effects. The outcomes from this study could help guide future research and determine factors that have the potential to reduce current e-cigarette use or prevent the initiation of vaping in high school students in the US. The following section will discuss possible implications for professional practice and positive social change.

Professional Practice

The findings of this study underscore the significance of weight intentions and sleep patterns in relation to e-cigarette use among high school students in the US, which supports the current literature. Notably, students actively managing their weight—whether attempting to lose, gain, or maintain it—exhibited heightened odds of e-cigarette use compared to their counterparts not engaging in weight management activities. This indicates a tangible link between weight-related behaviors and the propensity for e-cigarette use. Furthermore, the analysis revealed that sufficient sleep, defined as 8 hours or more, substantially diminishes the likelihood of e-cigarette use among students. Though continued research is needed to understand factors that play a role in e-cigarette use and nuances of the relationship between e-cigarette use and sports participation, these

findings highlight the importance of considering both weight management strategies and sleep quality when delineating the behaviors associated with e-cigarette use among adolescents.

In terms of professional practice, educators, public health officials, healthcare providers, and policymakers can play pivotal roles in addressing these findings. One avenue for professional intervention is through school-based initiatives. Given that only a minority of students (23%%) reported not attempting to manage their weight, and a similar proportion (19.2%) reported obtaining adequate sleep, educators and school administrators could implement targeted interventions to promote healthier lifestyle behaviors among students. These interventions entail integrating health education programs within school curricula that comprehensively address e-cigarette use and associated risk factors such as weight management and sleep quality. By emphasizing the significance of sufficient sleep and offering resources for healthy weight management, schools can provide valuable support to students in fostering healthier habits. Additionally, administrators could explore the possibility of adjusting school start times, a measure shown to enhance overall sleep health among adolescents (Bowers & Moyer, 2017).

Healthcare providers also have a pivotal role to play in identifying and addressing risk factors for e-cigarette use. School nurses, athletic trainers, pediatricians, and other healthcare practitioners who interact with students regularly can integrate discussions and screenings regarding the relationship between weight management, sleep habits, and e-cigarette use into routine health appointments. By providing tailored guidance, education

and support to students, healthcare professionals can contribute significantly to mitigating the prevalence of e-cigarette use among adolescents.

Community organizations and policymakers can collaborate to further efforts aimed at reducing e-cigarette use among high school students. Establishing partnerships between schools, healthcare providers, community organizations, and stakeholders can facilitate the development of comprehensive prevention and intervention programs targeting e-cigarette use and possible risk factors such as weight management or insufficient sleep. Through these collaborative efforts, students can be provided with accessible resources and education to foster healthy behaviors and diminish the prevalence of e-cigarette use. Policymakers can support these initiatives by allocating resources for school and community-based interventions, thereby bolstering the effectiveness and reach of programs promoting adolescent health and well-being.

Social Change

E-cigarettes persist as one of the most prevalent products among teenagers and young adults in the US, dominating the tobacco product landscape over the past decade and eliciting significant public health concerns (Birdsey et al., 2023; CDC, 2023a). While this study did not find an association between sports participation and e-cigarette use, it did align with existing literature by highlighting a connection between weight-related behaviors, insufficient sleep, and the likelihood of e-cigarette use. This section will explore the implications of these findings and their potential to instigate positive social change.

At the individual level, the outcomes of this study offer positive contributions by fostering increased awareness and potential behavior changes through enhanced knowledge. Individuals may become more cognizant of the risks associated with e-cigarette use, such as inadequate sleep and unhealthy weight management practices. Moreover, students might be motivated to adopt healthier behaviors, including reducing e-cigarette use, prioritizing adequate sleep, and seeking support for weight management from healthier sources.

While this study did not examine associations at the family level, it is important to consider how families can support individual behavior changes. For example, Delaney and Byrd-Bredbenner (2022) found that social change can also transpire at the family level for weight management and improved sleep quality, where families can facilitate improved communication, monitoring, and supportive environments. Additionally, Khor et al., found that parental factors were associated with better sleep quality in children in a systematic review and meta-analysis. Therefore, families may still play a role by engaging in open discussions about health-related behaviors, including e-cigarette use, sleep patterns, and weight management goals. Additionally, heightened awareness within families could lead to earlier identification of potential risks such as unhealthy weight management practices or insufficient sleep. Furthermore, families can establish supportive environments conducive to healthier behaviors, such as restricting access to e-cigarettes, implementing consistent sleep routines, and promoting balanced nutrition and physical activity.

Similarly, this study did not find significant associations at the organizational level, however, it remains essential to consider the broader context in which individual changes occur. Educational institutions could still play a role by deploying evidence-based interventions to tackle e-cigarette use while integrating factors associated with usage, such as sleep hygiene and healthy weight management, to cultivate an overarching culture of wellness within the school community to promote changes at the individual level. Healthcare organizations can collaborate with schools and community agencies to offer comprehensive health screenings, individual counseling services, access to healthier foods, and referrals for students grappling with e-cigarette use, inadequate sleep, or weight-related concerns. Policymakers could allocate resources for additional research, prevention programs, and public health campaigns aimed at addressing the multifaceted factors contributing to e-cigarette use and associated health issues among high school students. Furthermore, policies and laws could be enacted to foster healthy school environments conducive to sleep and physical activity.

In conclusion, by addressing the findings of this research across various levels of society, positive social change can be realized by promoting health and well-being for individuals, families, organizations, and communities. This, in turn, can lead to improved public health outcomes and reduced youth e-cigarette use.

Conclusion

Since 2014, e-cigarettes have been the most used tobacco product among middle and high school students in the US, raising serious public health concerns (CDC, 2022b; Cooper et al., 2022; T. Singh et al., 2016). Recent statistics show that 2.44 million

students are using e-cigarettes, with one in four of them using these devices daily, underscoring the critical nature of this issue (Cooper et al., 2022). Despite ongoing public health initiatives, the widespread acceptance of e-cigarette use among youth continues, highlighting the need for more research to uncover the underlying mechanisms and develop effective prevention strategies. E-cigarettes pose considerable risks due to their high nicotine content, which can harm the developing adolescent brain and potentially lead to traditional cigarette smoking (CDC, 2022c; Kelly et al., 2023). While the high prevalence of e-cigarette use is well-documented, the factors driving this behavior are less clear.

Interestingly, student-athletes, who typically have lower rates of traditional cigarette use, exhibit higher rates of e-cigarette use and are considered an at-risk group (Irvine et al., 2021; Y. Lee et al., 2021; Milicic et al., 2017; Williams et al., 2020). Existing research points to weight loss intentions and sleep deprivation as related to adolescent e-cigarette use (Holtz et al., 2022a; Obinwa, 2021; Sanchez et al., 2021). This study was one of the first to examine these associations, specifically among student-athletes.

This dissertation has explored the complex interplay between sports participation, weight intentions, insufficient sleep, and e-cigarette use among high school students in the United States. Utilizing data from the YRBS, this study has uncovered significant relationships and provided valuable insights into the behaviors associated with e-cigarette use among adolescents.

While no significant association was found between sports participation and e-cigarette use, possibly due to the limitations of the study, the study did reveal compelling relationships between weight intentions, sleep deprivation, and e-cigarette use. Specifically, students actively managing their weight, regardless of whether they seek to lose, gain, or maintain it, exhibited increased odds of e-cigarette use compared to their counterparts with no weight management intentions. Additionally, students reporting sufficient sleep, defined as eight hours or more, demonstrated significantly lower odds of e-cigarette use than those with insufficient sleep. Moreover, the examination of moderation effects revealed that weight intentions and sleep deprivation operate independently of sports participation concerning e-cigarette use. These insights emphasize the importance of considering weight-related behaviors and sleep patterns when addressing adolescent e-cigarette use.

Through the lens of the SEM, this study highlights the interconnectedness of individual, interpersonal, organizational, community, and policy-level factors in shaping health behaviors. At the individual level, personal motivations and behaviors such as weight management intentions and sleep patterns directly impact e-cigarette use. Interpersonally, family dynamics and peer influences can either exacerbate or mitigate these behaviors. Organizationally, schools play a pivotal role in promoting healthy lifestyles through education and structured programs. Community-level influences include the availability of resources and support systems that encourage healthy behaviors. At the same time, policy-level interventions can create environments that

foster overall well-being by regulating e-cigarette accessibility and promoting public health initiatives.

This research has significant implications for professional practice, social change, and public health policy in the future. For professional practice, educators and school administrators can develop targeted interventions that address e-cigarette use and the underlying factors of weight management and sleep quality. Healthcare providers can incorporate screenings and counseling on these issues into routine adolescent care. Community organizations and policymakers can collaborate to create comprehensive prevention and intervention programs that support healthier lifestyles among high school students.

Furthermore, viewing this problem through the SEM underscores the necessity of multi-faceted approaches to prevention and intervention. Interpersonal relationships, organizational policies, community resources, and broader societal regulations must support strategies that address individual behaviors to be effective. For instance, schools could implement evidence-based health education programs, healthcare providers could offer tailored guidance during routine check-ups, and policymakers could fund research and public health campaigns to reduce e-cigarette use.

Overall, this study highlights the need for a multifaceted approach to combat the rising trend of e-cigarette use among adolescents. By addressing these factors within a socioecological framework and considering the interconnected influences at various levels of society, public health efforts can be more effectively tailored to address the root

causes and promote positive health outcomes for young people, fostering healthier futures for the next generation.

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