DECLARATION

I declare that this dissertation, entitled “Exploring the Long-Term Effects of Vaping on Respiratory Health among Adolescents: A Systematic Literature Review”, is entirely my own work and has not been submitted for any other degree or professional qualification. All sources of information have been acknowledged and referenced in accordance with the University’s academic integrity policy.

Exploring the Long-Term Effects of Vaping on Respiratory Health among Adolescents: A Systematic Literature Review

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ABSTRACT

Background:

Vaping has emerged as a widespread behaviour among adolescents globally, raising growing concerns regarding its long-term respiratory health implications. While e-cigarettes are often marketed as safer alternatives to conventional smoking, emerging evidence suggests that adolescent use may be associated with a range of adverse respiratory outcomes. Given the vulnerability of the adolescent respiratory system, a systematic synthesis of available evidence is crucial to inform public health, clinical practice, and regulatory policies.

Aim:

This review aimed to systematically evaluate and synthesise the long-term effects of vaping on respiratory health among adolescents aged 10–19 years.

Methods:

A systematic literature review was conducted in accordance with PRISMA 2020 guidelines. Electronic databases searched included PubMed, EBSCOhost, and ProQuest. Pre-defined inclusion and exclusion criteria were applied, focusing on primary studies involving adolescents and reporting respiratory outcomes. Methodological quality was assessed using the Coughlan, Cronin, and Ryan checklist. Data were extracted using a standardised form and synthesised thematically.

Results:

From 1,327 records initially identified, 12 studies met the final inclusion criteria. Six major themes emerged: (1) chronic respiratory symptoms (cough, wheeze, bronchitic symptoms, and asthma exacerbations), (2) pulmonary function impairment (notably reduced FEV1/FVC in vapers), (3) pathophysiological mechanisms (airway inflammation and oxidative stress), (4) second-hand vapour exposure, associated with increased asthma risk in non-vaping adolescents, (5) dose and duration of use, with frequent or prolonged vaping linked to more severe symptoms, and (6) vaping, addiction, and psychosocial influences, highlighting peer pressure, marketing, and nicotine dependence as factors exacerbating risks.

Conclusion:

The findings indicate that adolescent vaping is consistently associated with adverse respiratory outcomes, with dose–response relationships suggesting cumulative harm. Evidence of impaired lung function and second-hand exposure further underscores the

public health relevance. Future longitudinal and experimental research is needed to establish causal mechanisms and inform targeted prevention strategies.

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Chapter 1: Introduction and Background

1.1 Introduction to the Topic

The use of electronic cigarettes(e-cigarettes), commonly referred to as vaping, has surged among teenagers in recent years and is a growing public health concern both in the United Kingdom and globally **(**Action on Smoking and Health, 2024; Tattan-Birch et al., 2024). Vaping involves the inhalation of aerosolised liquids, often containing nicotine, flavourings, and a range of other chemicals produced by battery-operated electronic devices (Stefaniak et al., 2022; World Health Organisation, 2024). While originally introduced as a smoking cessation aid for adults, vaping has quickly become widespread among adolescents, many of whom have never smoked conventional cigarettes (Famiglietti, Memoli and Khaitan, 2021). This shift has raised significant concern regarding the health implications for young people, whose respiratory systems are still developing and may be more vulnerable to inhaled substances (Gotts et al., 2019).

This systematic review focuses specifically on the long-term effects of vaping on the respiratory health of teenagers. It aims to synthesise evidence relating to chronic respiratory outcomes, such as asthma, bronchitis, persistent cough, wheezing, and impaired lung function, following sustained e-cigarette use during adolescence. By narrowing the scope to this age group and these outcomes, the review addresses a critical gap in the literature, as most existing studies are either short-term, focus on adults, or fail to disaggregate data by age (Cuesta and Leone, 2019)

The relevance of this research lies in its potential to inform clinical practice, public health policy, and education. As vaping rates continue to rise among young people, understanding the long-term respiratory risks is essential for developing effective prevention strategies and regulatory measures (World Health Organisation, 2022; Action on Smoking and Health, 2024**).** This review seeks to build upon and extend existing knowledge, offering clarity and direction for future research and policy development in adolescent respiratory health.

1.2 Background and Current Context

The proliferation of vapes has dramatically transformed the landscape of nicotine use among young people worldwide (Yan et al., 2023). Since their commercial introduction in the early 2000s, e-cigarettes have been promoted as a less harmful alternative to conventional tobacco smoking and as a cessation aid for adults seeking to quit smoking (Jackson et al., 2024) However, the rapid and widespread uptake of vaping among adolescents, many of whom have

never smoked traditional cigarettes, has prompted significant concern in both clinical and public health communities regarding the potential health consequences, particularly those relating to respiratory health (Kass et al., 2020)

1.2.1 Overview of Vaping

Vaping, also known as the use of electronic nicotine delivery systems (ENDS), involves inhaling an aerosol produced by heating a liquid that typically contains nicotine, flavours, and other chemicals (Centres for Disease Control and Prevention, 2024). Introduced in the early 2000s as a smoking cessation aid for adults, e-cigarettes have evolved into a widely used product, especially among adolescents. These devices are often marketed as a safer alternative to traditional tobacco products; however, growing evidence challenges this perception, particularly regarding long-term respiratory health outcomes (Miyashita and Foley, 2020). The appeal of vaping among adolescents is influenced by several factors, including the availability of flavoured products and the perception of reduced harm compared to conventional smoking, along with strong peer and social media influence, which contributes to the popularity of vaping among adolescents (Groom et al., 2021) The use of sleek, concealable devices like (JUUL) has further enhanced its appeal in this age group. Despite regulatory efforts in some countries, the prevalence of vaping among teenagers continues to rise, raising significant public health concerns.

Unlike traditional smoking, where decades of research have established clear links to chronic respiratory diseases, the long-term effects of vaping remain uncertain due to its relatively recent emergence. However, early studies suggest associations with bronchial irritation, impaired lung development, and increased vulnerability to respiratory infections, which is particularly concerning given that adolescents' lungs are still developing (Jonas, 2022).

Considering the physiological vulnerability of adolescents and their increasing exposure to vaping, it is crucial to evaluate the long-term respiratory effects of these products systematically. This dissertation aims to review the existing evidence through a systematic literature review, identifying potential respiratory health outcomes associated with adolescent vaping and assessing the strength and quality of current research.

1.2.2 Types of Vapes.

The use of e-cigarettes has become increasingly prevalent, with a wide range of devices available, including disposable e-cigarettes, pod systems, modified devices (commonly referred to as "mods"), and vape pens. (Bold et al., 2021) Disposable devices are particularly

popular among novice users (McCausland et al., 2020), while pod systems strike a balance between portability and performance, making them especially appealing to younger populations (Pepper et al., 2019). Modified devices, which offer extensive customisation and enhanced vapour production, are typically favoured by more experienced users (Choi et al., 2021). Vape pens occupy an intermediate position, combining ease of use with some advanced features (He et al., 2024). User demographics differ across device types, with adolescents more frequently choosing disposables and pod systems (Jongenelis, 2023)

1.2.3 Prevalence of vaping use

Recent years have seen a marked increase in e-cigarette use among adolescents in the United Kingdom and globally. In the UK, data from Action on Smoking and Health (ASH) (2024) indicate that around 18% of 11–17-year-olds have tried vaping, and 7.2% report current use. The trend is similar in other countries as well. A global meta-analysis spanning 53 countries found that approximately 10.2% of school and college students are current e-cigarette users. Lifetime experimentation rates are as high as 22% (Albadrani et al., 2024). Notably, many adolescent vapers have never smoked conventional cigarettes, suggesting vaping is not merely replacing tobacco use but creating a new cohort of nicotine users (Hammond et al., 2017).

1.3 Rationale

The systematic review by Lyzwinski et al. (2022) highlights the growing global concern regarding youth vaping and its associated respiratory health risks. Their study identifies clear links between e-cigarette use and respiratory conditions such as asthma, bronchitis, and acute respiratory distress in adolescents. However, the review also notes a significant gap in longitudinal data and limited research focused on specific populations, including adolescents in the UK.

This proposed research builds on their findings by conducting a systematic review of the long-term respiratory health effects of vaping, specifically among adolescents. It will contribute to the existing body of knowledge by providing a population-specific analysis relevant to health and focusing on long-term outcomes, addressing the gap in duration-focused studies, and offering insights to inform evidence-based policies and interventions aimed at reducing vaping-related harms in young people. By addressing an identified research gap, this study will support national efforts to protect adolescent health and reduce the long-term burden of preventable respiratory diseases associated with vaping.

1.4 Research questions

- What is the effect of long-term vaping on respiratory health among adolescents?
- What evidence exists on the long-term effects of vaping on adolescent respiratory health?
- How do specific types of vaping relate to respiratory health problems?

1.5 Research Aim

- To explore the long-term consequences of vaping on respiratory health outcomes among adolescents from existing literature.

1.6 Research Objectives

- To identify existing evidence on the long-term effects of vaping on adolescent respiratory health.
- To investigate the relationship between a specific type of vaping and specific respiratory health problems.
- To highlight research gaps and provide recommendations for public health policy and further research.

1.7 Chapter summary

Chapter one has introduced the topic of adolescent vaping, defined its key components, and established its significance as a public health issue due to rising use and potential respiratory risks. The chapter outlined the background, current context, and the rationale for this systematic review, presenting clear research questions, aims, and objectives focused on the long-term respiratory effects of vaping among adolescents. With the foundation now established, Chapter 2 will provide a comprehensive review of the existing literature, critically examining the current evidence related to this important public health concern.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction to the Chapter

This chapter provides an overview of respiratory health, encompassing its definition, clinical symptoms, types, epidemiological trends, risk factors, and outcomes. These foundational elements provide essential context for understanding the potential impact of vaping on respiratory health. The latter part of the chapter synthesises findings from recent systematic reviews to explore the association between e-cigarette use and respiratory outcomes in adolescents, highlighting key mechanisms, trends, and evidence gaps relevant to this growing public health concern.

2.2 The Epidemiology of Respiratory Health

2.2.1 Definition and Clinical Symptoms of Respiratory Health.

Respiratory health refers to the efficient functioning of the respiratory system, encompassing the lungs, airways, respiratory muscles, and associated structures involved in ventilation and gas exchange (Hsia et al., 2016). It includes the capacity to inhale oxygen, exhale carbon dioxide, maintain airway patency, and initiate immune responses against pathogens (National Heart, Lung, and Blood Institute, 2022).

Optimal respiratory health is vital for sustaining physical activity, cognitive development, and overall well-being (Man et al., 2023). When compromised, respiratory health presents with clinical symptoms such as chronic cough, wheezing, dyspnoea, chest tightness, sputum production, recurrent infections, and reduced exercise tolerance, often indicating underlying inflammation, disease, or obstruction (Hirons et al., 2023)

In adolescents, these symptoms may be mild or misdiagnosed, complicating timely intervention (Al-Shamrani et al., 2019). As the lungs continue to develop throughout adolescence, early detection is essential.

2.2.2 Types of respiratory health

Respiratory health can be conceptualised through multiple domains, each highlighting distinct aspects of lung structure and function (Haddad and Sharma, 2023). These include the Structural, Functional, Immunological, Environmental and lifestyle-related and developmental respiratory health (Pouptsis et al., 2025)

Structural respiratory health pertains to the anatomical integrity of the lungs, bronchi, alveoli, and diaphragm; abnormalities such as bronchiectasis or congenital malformations, which may impede airflow and gas exchange (Cuppari et al., 2019).

Functional respiratory health evaluates the efficiency of ventilation and is typically assessed via spirometry measures such as Forced Expiratory Volume in 1 second (FEV_1) and Forced Vital Capacity (FVC), with reduced values indicating diseases like asthma or chronic obstructive pulmonary disease (COPD) (Global Initiative for Asthma, 2023).

Immunological respiratory health concerns the system's ability to combat infections and allergens (Edwards et al., 2017).

Environmental and lifestyle-related respiratory health reflects the influence of external exposures, such as air pollution, tobacco smoke, and e-cigarette aerosols, on pulmonary function (Miyashita and Foley, 2020). According to Coppeta et al. (2018), the use of electronic cigarettes exacerbates pulmonary problems.

Finally, developmental respiratory health is especially relevant to adolescents, whose lungs are still maturing, making them more susceptible to long-term impairment from inhaled toxins like those found in vaping products (Jonas, 2022).

2.2.3 Prevalence and incidence of respiratory health

The World Health Organisation (2024b) reports that chronic conditions such as asthma, chronic obstructive pulmonary disease (COPD), and respiratory infections are especially prevalent among children and adolescents across both high- and low-income countries. These Chronic respiratory diseases continue to pose a substantial global health burden. In 2017, these conditions affected approximately 544.9 million individuals worldwide**,** representing 7.1% of the global population (Adhikari et al., 2023). Prevalence was highest in high-income countries (~10.6%) and lowest in sub-Saharan Africa (~5.1%) (Soriano et al., 2020).

Asthma remains one of the most common respiratory illnesses globally, affecting an estimated 235 to 262 million people between 2011 and 2019 (World Health Organisation, 2024). Among adolescents aged 10–19 years, global asthma prevalence in 2021 was estimated at 3.64%**,** a figure that, while reduced from previous decades, remains concerning (Kim et al., 2025)

Respiratory infections continue to contribute significantly to global childhood morbidity and mortality. In 2019, an estimated 33 million cases of respiratory syncytial virus (RSV)-associated with lower respiratory infections occurred in children under five years (Li et al., 2022).

In the United Kingdom, chronic lung diseases affect approximately 20% of the population, imposing a substantial burden on healthcare services and quality of life (Parker et al., 2014; Royal College of Physicians, 2021). Asthma is the most prevalent chronic respiratory condition among children, affecting 5% of the population, with 1.1 million children currently receiving treatment (Royal College of Physicians, 2021). Regional data reveal disparities: asthma prevalence in 2019 ranged from 7% in Northern Ireland to 15.9% in Wales (Quinn et al., 2020). Hospital admission data further highlight inequalities, with emergency asthma admissions disproportionately higher in deprived and ethnic minority communities (The Guardian, 2025).

2.2.4 Risk Factors of Respiratory Health

Respiratory health is influenced by a combination of modifiable and non-modifiable risk factors shaped by the complex interplay of genetic, behavioural, and environmental determinants (Bush et al., 2024). These factors affect the onset, progression, and severity of respiratory conditions such as asthma, chronic bronchitis, and other lung diseases, particularly among vulnerable populations, including adolescents (Wypych-Ślusarska, Krupa-Kotara and Niewiadomska, 2022). Exposure to air pollutants, occupational and environmental allergens, tobacco smoke, respiratory infections, obesity, sedentary lifestyle, and, increasingly, vaping or e-cigarette aerosols have all been associated with adverse respiratory outcomes (Gotts et al., 2022)

2.2.4.1 Modifiable Risk Factors

These are behavioural or environmental factors that can be altered through individual action or public health interventions.

Active smoking or second-hand smoke is a leading risk factor for chronic respiratory diseases. Vaping, increasingly common among adolescents, is also associated with airway inflammation and impaired lung development (Gambadauro et al., 2025). Long-term exposure to outdoor pollutants (e.g., PM2.5, nitrogen dioxide) and indoor air contaminants (e.g., cooking fumes, mould) contributes to respiratory morbidity (Clark et al., 2023).

In addition, inhalation of allergens, dust, or chemicals in school, home, or early work environments can trigger or worsen respiratory symptoms (Kelly and Poole, 2019). Frequent or severe infections, particularly during early life, can cause lasting damage to lung tissue (Lloyd and Saglani, 2023).

Excess body weight may impair lung mechanics, while low physical activity levels reduce pulmonary fitness (Svartengren et al., 2020)

Use of e-cigarettes and inhaling substances such as cannabis has been linked to increased respiratory symptoms and reduced lung function in adolescents (Tackett et al., 2023).

2.2.4.2 Non-Modifiable Risk Factor

These are inherent characteristics that cannot be changed but may guide screening and prevention efforts.

A wide range of determinants influence respiratory health, with genetic predisposition, age, sex, ethnicity, and socioeconomic status consistently highlighted in the literature. Genetic markers have been shown to predispose individuals to reduced pulmonary function, with evidence indicating a strong interaction between these biological factors and broader socioeconomic conditions (Quanjer, 2015). Similarly, age and sex play crucial roles, as respiratory conditions tend to present differently across developmental stages and between males and females. Ethnicity also emerges as a key determinant, with minority ethnic groups frequently experiencing poorer respiratory outcomes; these disparities are often exacerbated by socioeconomic disadvantage (Martinez et al., 2015; De Boer et al., 2018). Furthermore, children from socioeconomically deprived backgrounds are particularly susceptible to respiratory diseases, largely due to increased exposure to adverse environmental conditions such as air pollution and inadequate housing (Cortés-Ramírez et al., 2021; Mathiarasan and Hüls, 2021).

2.2.5 Outcomes and cost of respiratory health.

Chronic respiratory diseases, including asthma, pose a major global health challenge, marked by the increase in prevalence and mortality rates (Khaltaev and Axelrod, 2019).

Asthma results in substantial health costs and imposes a significant economic burden, causing an estimated 250,000 to 461,000 deaths annually (Serebrisky and Wiznia, 2019). COPD similarly presents a considerable global challenge, accounting for 3.65 million deaths in 2021, representing nearly 5% of all global deaths that year (World Health Organisation, 2024a)

Respiratory infections, particularly those caused by respiratory syncytial virus (RSV), have a significant impact on child health, accounting for a substantial proportion of the 33 million lower respiratory infections reported in 2019 (Shi et al., 2017). The economic repercussions of these conditions are profound, placing considerable strain on healthcare systems and society and highlighting the urgent need for effective interventions (Díez-Domingo et al., 2014).

COPD presents a significant economic challenge worldwide: a recent macroeconomic analysis estimates that the disease will cost the global economy approximately 4.3 trillion international dollars (INT$4.3 trillion) from 2020 to 2050 due to productivity losses, treatment expenses, and broader economic impacts (Chen et al., 2023). In the United Kingdom, respiratory conditions exert considerable pressure on both the NHS and society at large, with chronic lung illnesses such as asthma and COPD costing around £3 billion and £1.9 billion annually, respectively. Together, all lung diseases contribute approximately £11 billion to NHS expenditure each year (Mukherjee et al., 2016).

Respiratory infections, particularly influenza and pneumonia, contribute significantly to healthcare demand. During the 2017–2018 season, England accounted for 45,000 to 46,000 hospital admissions due to influenza alone (Moss et al., 2020). Additionally, over 25,000 individuals die annually in the UK from pneumonia, further highlighting the substantial burden on health services (Asthma + Lung UK, 2022).

Hospital admission trends further highlight the burden in the UK. In England, asthma-related emergency admissions among those under 19 years were 174 per 100,000 in 2017/18 (Alwafi et al., 2023). Hospital admission trends further highlight the burden of asthma in the UK. In England, the rate of emergency hospital admissions for asthma among children and young people aged under 19 years was 174 per 100,000 in the 2017–2018 period (Royal College of

Paediatrics and Child Health, 2020). More troublingly, asthma-related hospitalisations in children rose from roughly 7,850 to 19,506 cases between 2021 and 2022, a surge attributed in part to increased respiratory virus exposure post-COVID lockdowns (Asthma and Lung UK, 2023). Moreover, respiratory conditions accounted for 868,212 emergency NHS admissions in 2023–24, representing one in eight unplanned admissions in England (Campbell, 2024). The economic consequences are further magnified by rising GP visits for asthma, which increased by 45% in early 2025 (Gregory, 2025). This is tied to polluted air, resulting in an estimated healthcare and productivity costs of around £27 billion annually (Royal College of Physicians, 2025)

2.3 Relationship between vaping and respiratory health.

The emergence of electronic nicotine delivery systems (ENDS), commonly known as e-cigarettes or vapes, has significantly altered adolescent substance use trends. Marketed as a less harmful alternative to traditional tobacco, vaping has gained substantial popularity among adolescents, raising concerns about its impact on respiratory health. This section synthesises findings from three recent systematic literature reviews to explore the potential relationship between adolescent vaping and respiratory outcomes.

A systematic review by Honeycutt et al. (2022) assessed the effects of e-cigarette use on lung function across eight studies, involving both adolescent and young adult participants. The results showed that vaping was linked to increased airway resistance and short-term irritation, although there was no significant effect on standard spirometry measures such as FEV_1 or FVC in the short term (Kotoulas et al., 2020). However, the authors warned that these findings were limited by small sample sizes and a lack of long-term follow-up data, emphasising the need for further research, especially in adolescent populations whose lungs are still developing.

Lyzwinski et al. (2022) systematic review explored the global epidemiology of youth vaping and its association with respiratory symptoms. Synthesising results from over 25 cross-sectional and longitudinal studies, this review found consistent associations between e-cigarette use and self-reported respiratory symptoms such as chronic cough, wheezing, and bronchitis-like symptoms in adolescents (Brose et al., 2024). Notably, these associations persisted even after adjusting for confounding variables such as prior tobacco use, suggesting a potential independent effect of vaping on respiratory health (Alnajem et al., 2020). The review also highlighted that dual use of (vaping and smoking) was more strongly associated with adverse respiratory outcomes than exclusive vaping (Patel et al., 2023).

A more recent systematic review by Mughis et al. (2024), published in Cureus, examined the toxicological mechanisms underpinning respiratory effects associated with e-cigarette use. The review followed PRISMA guidelines and included both human and animal studies published between 2014 and 2024. It identified multiple pathophysiological mechanisms, including inflammatory responses, oxidative stress, and impaired mucociliary clearance, which may explain the observed respiratory effects in adolescents (Wills et al., 2021). These mechanisms are particularly concerning given the increased biological vulnerability of adolescents during lung development.

Collectively, these systematic reviews suggest a growing body of evidence linking vaping to adverse respiratory outcomes in adolescents. While limitations exist, such as heterogeneity in study designs, short follow-up durations, and reliance on self-reported data, there is emerging consensus that vaping is not harmless. However, it may independently contribute to the onset or exacerbation of respiratory symptoms and may disrupt normal pulmonary development (Bourke, Sharif and Narayan, 2021).

The reviews also identify critical gaps in the literature. There is a marked lack of longitudinal cohort studies with objective clinical measures and extended follow-up periods. Moreover, further research is needed to disentangle the effects of frequency, duration, and nicotine concentration in e-liquids on adolescent respiratory outcomes.

In conclusion, current systematic reviews provide credible preliminary evidence of a detrimental relationship between vaping and respiratory health in adolescents. Given the rapid increase in vaping among young people and the potential for long-term harm, these findings have significant implications for clinical practice, public health interventions, and policy development.

2.4 Chapter Summary

This chapter provided an overview of respiratory health, including its definition, symptoms, epidemiology, risk factors, and associated outcomes. It also examined evidence from recent systematic reviews, which indicates a potential link between adolescent vaping and adverse respiratory effects such as wheezing, cough, and airway inflammation. Although methodological gaps limit current findings, they highlight the need for further research and inform future public health strategies. The next chapter 3 outlines the methodology of this systematic review, detailing the search strategy, selection criteria, quality appraisal tools, and adherence to PRISMA guidelines to ensure transparency and rigour.

CHAPTER 3: METHODOLOGY

3.1 Introduction to Chapter

This chapter outlines the methodological framework adopted for the systematic literature review exploring the long-term respiratory health effects of vaping among adolescents. It details the research design, justification for selecting a systematic review approach, and the procedures used to identify, select, appraise, and synthesise relevant literature.

The chapter begins by employing a systematic literature review methodology. It then describes the eligibility criteria, databases and search strategies used, including Boolean operators and keyword combinations. The inclusion and exclusion criteria are delineated to ensure transparency and replicability.

3.2 Systematic Literature Review (SLR)

A systematic literature review (SLR) is a rigorous and comprehensive approach to identifying, evaluating, and synthesising existing research on a defined topic, thereby offering a robust understanding of the current state of knowledge (Cabrera and Cabrera, 2023). The primary objective of a SLR is to consolidate findings from multiple studies to inform practice and shape future research directions, ensuring that conclusions are drawn from a balanced and critical appraisal of the literature (Sauer and Seuring, 2023).

Key stages in conducting an SLR include formulating a clearly defined research question, establishing inclusion and exclusion criteria, systematically searching relevant databases, selecting studies based on predefined parameters, extracting data, and synthesising the results (Pati and Lorusso, 2018).

By emphasising methodological transparency and coherence, SLRs support the synthesis of knowledge that identifies trends, research gaps, and inconsistencies within the existing evidence base. This, in turn, enhances evidence-informed decision-making in both academic and practical contexts (Thomé, Scavarda and Scavarda, 2016; Mengist, Soromessa and Legese, 2020). The strength of this approach lies in its ability to produce conclusions grounded in a thorough and methodical appraisal of the literature.

3.3 Search Strategy

A search strategy in research is a structured and systematic plan used to locate relevant literature and evidence across various sources, particularly academic databases (Aromataris and Riitano, 2014). It is a critical component of evidence-based research and systematic reviews, ensuring that the search process is comprehensive, transparent, and reproducible (Miller and Fleming, 2016).

For this review, a comprehensive search was conducted across multiple academic databases, including PubMed, ProQuest, and EBSCOhost. To ensure breadth and depth, combinations of controlled vocabulary (e.g., MeSH terms) and free-text keywords were used. Boolean operators such as “AND,” “OR,” and “NOT” were applied to refine the search results. Truncation and phrase searching techniques were also utilised to increase the inclusivity of the search.

The PEO (Population, Exposure, Outcome) framework was employed to structure the search strategy, as it is particularly suitable for qualitative and public health-related research (Kabir et al., 2023).

This framework guided the formulation of search terms, ensuring alignment with the review’s objectives. To maintain relevance and reflect current evidence, the search was limited to studies published between January 2013 and May 2025, capturing a period during which vaping products became increasingly prevalent among adolescents and public health concerns intensified.

3.4 Search terms

Search terms are specific words or phrases used to retrieve relevant literature during the research process (Marcos-Pablos and García-Peñalvo,2018). In academic research, particularly in systematic reviews, search terms represent the core concepts of a research question and are used to guide database searches. They form the foundation of a search strategy by enabling researchers to identify studies that directly align with the topic under investigation (Paez, 2017)

The primary purpose of using search terms is to ensure that the search process is systematic, transparent, and replicable, which is crucial for academic rigour (Hardwicke et al., 2020). Well-chosen search terms improve the precision and comprehensiveness of literature searches, reducing the risk of overlooking key studies or including irrelevant ones. They also help to define the scope of a review, ensuring alignment with the research aim and objectives (Cooper et al., 2018)

For the chosen topic, the long-term respiratory health effects of vaping among adolescents, the PEO components were defined as follows: Population (P): Adolescents (typically aged 10–19). Exposure (E): Vaping or electronic cigarette use. Outcome (O): Long-term respiratory health effects (e.g., asthma, bronchitis, reduced lung function)

The use of synonyms is essential in constructing an effective search strategy because different authors may use varied terminology to describe the same concept (Childers-Kakos, 2022) For example, in the context of adolescent vaping, terms such as e-cigarettes, vape, electronic nicotine delivery systems (ENDS), and vaping devices may all refer to the same exposure. By incorporating synonyms and related terms, the search becomes more inclusive, maximising the retrieval of relevant literature. This reduces the likelihood of missing studies due to variations in language, spelling, or regional terminology (e.g., UK vs. US English) (Eriksen and Frandsen, 2018).

The PEO framework identified relevant keywords and synonyms for each component to develop a comprehensive and inclusive search strategy. The term adolescents was used for the Population (P), alongside synonyms and related terms such as teenagers, youth, young people, and students. This ensured that studies using varying terminology to describe the target age group were captured.

For the Exposure (E), which in this review refers to vaping, several search terms were identified. These included vaping, e-cigarettes, electronic cigarettes, electronic nicotine delivery systems (ENDS), and vape devices. Including these synonyms was essential because different studies may use varied terminology depending on the region or publication context.

Regarding the Outcome (O), the main emphasis was on long-term respiratory health effects. Therefore, keywords such as respiratory health, lung function, asthma, bronchitis, wheezing, pulmonary effects, and chronic cough were included.

To build effective search strings, Boolean operators were used to combine these terms. The operator "OR" was used to link synonyms within the same PEO category to broaden the search. For example:

- (adolescents OR teenagers OR youth OR "young people")
- (vaping OR e-cigarettes OR "electronic cigarettes" OR ENDS OR "vape devices")

Then, the operator "AND" was used to combine the different PEO components to narrow the search to studies that include all three aspects:

- (adolescents OR teenagers OR youth) AND (vaping OR e-cigarettes OR ENDS) AND (asthma OR "respiratory health" OR "lung function")

This structured and layered approach ensured that the search was both comprehensive and focused, allowing the retrieval of a wide range of relevant studies while maintaining alignment with the review objectives. By combining controlled vocabulary (e.g. MeSH terms in PubMed) and free-text keywords across databases such as PubMed, ProQuest, and EBSCOhost, the reliability, validity, and reproducibility of the literature search process were significantly enhanced.

Table 1:

PEO TABLE

PEO Component	Definition in this Review	Application to the SLR
Population (P)	Adolescents aged 10–19 years, male and female, from any geographic, social, or cultural background.	The review focuses exclusively on adolescents within the WHO definition of adolescence. Studies with mixed populations were only included if adolescent-specific data could be extracted.
Exposure (E)	Vaping / e-cigarette use (including frequency, duration, nicotine concentration, and device type). Studies also considered second-hand vapour exposure where assessed.	Captures all forms of vaping behaviour and exposure, regardless of device generation or nicotine content, as long as the study links this exposure to respiratory outcomes.
Outcome (O)	Respiratory health outcomes, including: – Chronic respiratory symptoms (wheeze, cough, phlegm, breathlessness) – Pulmonary function impairment (e.g., FEV1, FVC, lung capacity) – Pathophysiological changes (oxidative stress, airway inflammation) – Asthma exacerbations, hospitalisations, or other morbidity indicators.	Ensures that only studies reporting outcomes directly related to respiratory health were included. Excludes studies focused solely on cardiovascular, neurological, or smoking cessation outcomes.

3.5 Keywords

Keywords play a crucial role in academic research, significantly enhancing the precision of literature retrieval and completeness. They facilitate the effective identification of relevant studies, thereby improving the overall quality of research results (Sesagiri Raamkumar, Foo, and Pang, 2017). The effective selection of keywords can directly influence the visibility and accessibility of scholarly work in digital databases (Pottier et al., 2024).
The main words used in this review are adolescents, teenagers, youth, vaping, e-cigarettes, ENDS, vape devices, respiratory health, lung function, asthma, bronchitis, wheezing, pulmonary effects, and chronic cough.

3.6 Databases

To retrieve academic sources for this systematic literature review, a structured search was conducted using carefully selected keywords and Boolean operators across multiple scholarly databases. The databases used were PubMed**,** EBSCOhost**,** and ProQuest**.** These platforms were chosen for their extensive coverage of health, nursing, and public health research.

Searching multiple databases is crucial for achieving a comprehensive and unbiased review**.** No single database encompasses all relevant literature; therefore, relying solely on one source may result in the omission of critical studies (Briscoe, 2015). For example, PubMed is essential for biomedical literature, CINAHL focuses on nursing and allied health, and ProQuest includes grey literature and dissertations (Paez, 2017b). Combining databases broadens the scope, increases reliability, and reduces publication bias (Bramer et al., 2017).

For this review of the long-term respiratory health effects of vaping among adolescents, the following databases were searched: PubMed, EBSCOhost, and ProQuest, ensuring the depth and breadth of the evidence base.

3.7 Inclusion/Exclusion Criteria

Inclusion and exclusion criteria are predefined rules used to determine which studies are relevant to a research question and should be included or excluded from a systematic review. They enhance the rigour, transparency, and reproducibility of the review process by ensuring consistency in study selection (Higgins, 2019). Inclusion criteria identify studies that align with

the review's objectives, while exclusion criteria eliminate those that lack relevance or quality. This process reduces bias and improves the reliability of findings (Peters et al., 2020).

3.7.1 Inclusion Criteria

- Studies targeting adolescents as the primary population.
- Research specifically examining awareness or knowledge of respiratory diseases caused by vaping
- Studies conducted in diverse settings, including communities, educational institutions, and healthcare facilities.
- Studies carried out in any geographical location (worldwide).
- Articles published in peer-reviewed journals ensure credibility and academic quality.
- Inclusion of studies employing both quantitative and qualitative research methods.
- Only articles published in the English language.

3.7.2 Exclusion Criteria

- Studies that do not specifically explore awareness or knowledge of respiratory outcomes caused by vaping
- Research that does not involve young adults as the target population.
- Non-peer-reviewed sources, including conference abstracts and unpublished dissertations.
- Studies not conducted in community, educational, or healthcare settings.
- Articles not published in the English language.

A total of 1,327 records were initially identified through systematic searches across electronic databases, including PubMed, ProQuest and EBSCOhost. After removing 248 duplicates, 1,079 records remained for title and abstract screening. This initial screening was guided by the predefined inclusion and exclusion criteria outlined in Chapter 3.7.1 and 3.7.2. Studies were excluded at this stage if they focused on adult populations, non-respiratory outcomes, or. Studies not conducted in community, educational, or healthcare settings.

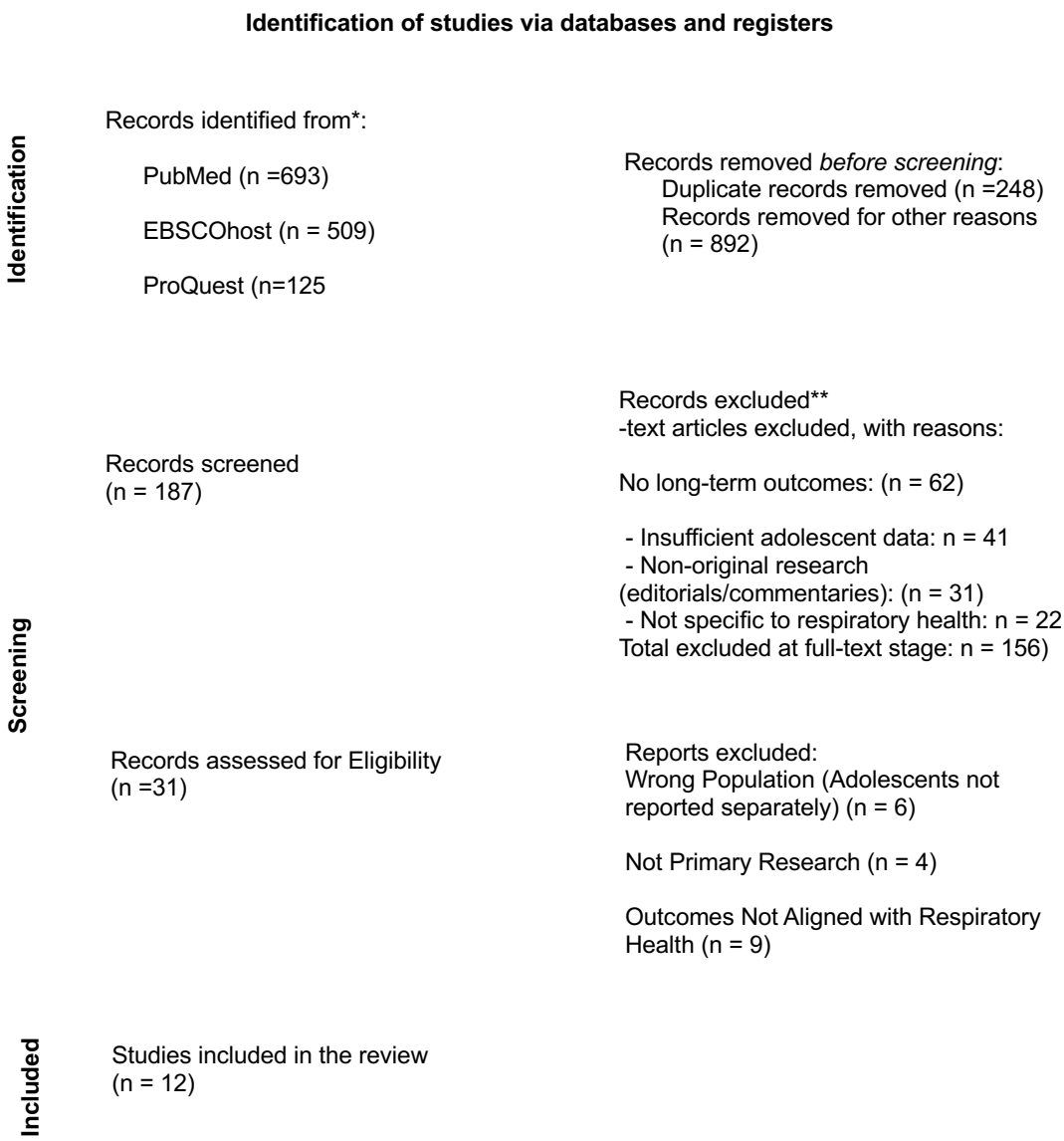
Following this, 892 studies were excluded, leaving 187 full-text articles assessed for eligibility.

Full-text screening was conducted to assess the methodological quality and relevance further. Studies were excluded at this stage for several reasons: failure to report on long-term outcomes (n = 62), insufficient data on adolescent populations (n = 41), non-original research such as editorials or commentaries (n = 31), and lack of outcome specificity related to respiratory health (n = 22). After this rigorous process, 31 studies met the final inclusion criteria and were included in the review.

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 flow diagram was used to illustrate the study selection process. This flowchart provides a transparent and structured representation of how the studies were screened, excluded, and ultimately selected. The PRISMA diagram enhances methodological transparency and helps readers visualise the elimination of irrelevant studies at each stage.

The included studies varied in design, including cohort (n = 12), cross-sectional (n = 15), and case-control (n = 4) methodologies. The selected literature spanned a range of countries and publication years, contributing to a comprehensive understanding of the long-term respiratory implications of adolescent e-cigarette use. (See figure 1 below)

Figure 1: PRISMA flow chart



3.9 Ethical Considerations

Ethics in research refers to the principles and standards that guide responsible and respectful conduct during the research process, ensuring the protection of participants' rights, dignity, and welfare (Huang et al., 2014). In this review, ethical considerations were upheld by including only peer-reviewed studies, which are assumed to have undergone ethical approval

through institutional review boards before publication. This ensures that participant consent, data confidentiality, and research integrity were maintained (Costa et al., 2024).
By critically appraising studies using the established tools such as the Coughlan, Cronin, and Ryan (2007) checklist, ethical transparency and research quality were further evaluated before including them in the review (Skelton et al., 2020). This strengthens the credibility of the findings.

3.10 Chapter Summary

This chapter outlined the methodological approach used to conduct the systematic literature review, including the development of the search strategy, application of the PEO framework, use of relevant databases, and the establishment of clear inclusion and exclusion criteria. It also emphasised the importance of using peer-reviewed studies and considering ethical implications in selecting high-quality literature. A transparent and replicable process was followed to ensure the credibility of findings. The next chapter will present Data Evaluation, including the critical appraisal of selected studies using established tools and frameworks to assess their validity, reliability, and relevance to the research question.

CHAPTER 4: DATA EXTRACTION AND EVALUATION

4.1 Introduction to Chapter

This chapter outlines the process of data extraction and the critical appraisal of studies included in the systematic literature review. It describes how relevant information was systematically gathered from the selected studies and evaluated for quality, rigour, and relevance. This chapter guarantees the review's findings are reliable by conducting a comprehensive evaluation of study designs, techniques, strengths, and limitations. Finally, this chapter will strengthen the review's credibility and confirm the findings from the analysed literature.

4.2 Data Extraction

Data extraction is the systematic process of collecting key information from selected studies to enable structured analysis and synthesis within a systematic review (Tacconelli, 2010). It ensures consistency, transparency, and reduces the risk of bias during the review process (Munn et al., 2018).

For this review, a pre-designed data extraction form was used to collate essential study characteristics. The information extracted included: First author(s) and year of publication, country of study, study design (e.g. cross-sectional, cohort), population demographics (age range, sample size), type of exposure (vaping or e-cigarette use), outcomes measured (e.g. respiratory symptoms, lung function), and key findings. Additional data, such as follow-up duration, statistical methods, and limitations, were also recorded where applicable to support evaluation.

4.3 Brief introduction to critical appraisal and paper quality assessment

Critical appraisal is the systematic evaluation of research evidence to assess its validity, reliability, and relevance before applying it to practice or incorporating it into a review (Burls, 2009). It involves assessing a study's methodological quality, potential sources of bias, and the appropriateness of its design, data analysis, and conclusions (Ma et al., 2020)

In the context of a systematic literature review, critical appraisal is essential for distinguishing between high-quality and low-quality studies (Munn et al., 2014). This process ensures that

only robust and credible evidence contributes to the final synthesis, thereby improving the reliability of the review's conclusions. Without critical appraisal, there is a risk of incorporating flawed or biased studies, which could lead to inaccurate or misleading recommendations.

Appraising research papers also supports transparency and academic rigour, as it enables researchers to justify the inclusion or exclusion of studies based on methodological merit. Ultimately, critical appraisal strengthens the evidence base for informing clinical practice, public health policy, and future research directions.

4.4 Critical Appraisal Tools

A critical appraisal tool is a structured checklist or framework used to systematically assess the quality, validity, and relevance of research studies (Haile, 2021). These tools offer a standardised method to evaluate key methodological aspects of a study, such as the clarity of the research question, suitability of the study design, sampling techniques, data collection and analysis methods, possible sources of bias, and the strength of the findings (Mallet et al., 2012).

Selecting the appropriate critical appraisal tool is crucial, as different tools are designed to appraise various types of studies, including qualitative research, quantitative studies, and mixed-methods designs. Using the wrong tool may lead to inaccurate assessments and compromise the reliability of the review. For example, the Critical Appraisal Skills Programme (CASP) checklist is widely used for qualitative studies. In contrast, tools such as the STROBE checklist and the framework by Coughlan, Cronin, and Ryan (2007) are suitable for observational quantitative research.

The purpose of these tools is not only to identify high-quality research but also to highlight limitations, guide inclusion decisions, and promote transparency in the review process. A well-chosen appraisal tool supports the integrity and credibility of the systematic review, ensuring that conclusions are based on sound and trustworthy evidence.

4.5 Evaluation of Quantitative Studies

Critical appraisal is essential for evaluating the validity, reliability, and relevance of evidence in systematic literature reviews. The current review used the Coughlan, Cronin, and Ryan (2007) quantitative appraisal checklist, which examines the clarity of objectives, appropriateness of methodology, recruitment methods, sample size, validity of exposure and outcome measures, ethical considerations, data analysis, and the justification of

conclusions. This framework was chosen over alternatives such as the STROBE statement (von Elm et al., 2007) and the Newcastle-Ottawa Scale (NOS**)** (Wells et al., 2012) because of its adaptability to both cross-sectional and cohort studies, which are common in research on adolescent vaping and respiratory health.

A total of twelve quantitative studies were evaluated (see Appendix 2 for complete tables). Of these, eight used cross-sectional designs (Brose et al., 2024; Kurdyś-Bykowska et al., 2024; McConnell et al., 2017; Kim et al., 2017; Schweitzer et al., 2017; Wills et al., 2020; Bayly et al., 2019; Alnajem et al., 2020; Wang et al., 2016), while four used cohort designs (Cherian et al., 2021; Stevens et al., 2022; Tackett et al., 2024; McConnell et al., 2017). Collectively, these studies encompass a range of settings, including the USA, UK, Poland, South Korea, Kuwait, and China, providing a global perspective on adolescent vaping and its respiratory effects.

4.5.1 Per-Study Appraisal

Cherian et al. (2021) analysed data from the Population Assessment of Tobacco and Health (PATH) youth cohort, focusing on adolescents aged 12–17. Their clear aim was to examine the association between e-cigarette use and respiratory symptoms, including wheeze, cough, and phlegm. The methodology was appropriate, employing logistic regression analyses with adjustments for smoking, cannabis, and sociodemographic factors. The sampling was nationally representative, which provides strong external validity. A major strength was its large sample size (>10,000), offering adequate statistical power (Levin, 2006). Exposure and outcome measures were obtained from validated survey instruments, though reliance on self-report introduces recall bias (Carson et al., 2020). Results indicated that current vaping significantly increased the odds of respiratory symptoms (AORs ~1.3–1.6). Ethical procedures adhered to PATH protocols. Although the cross-sectional design prevents establishing temporality, the findings are consistent with international evidence (Kim et al., 2017; Wang et al., 2016).

Brose et al. (2024) conducted a multi-country cross-sectional survey of 39,214 adolescents (16–19 years) through the International Tobacco Control Youth Survey. The research aim was clear, and the methodology suitable, using weighted logistic regression to account for sampling. Recruitment involved online panels weighted to national populations, which enhanced generalisability but introduced potential self-selection bias (Bethlehem, 2010). Exposure was measured by vaping frequency in the past 30 days, while outcomes included cough, wheeze, and chest pain. Results showed that dual users had significantly higher odds of symptoms than exclusive vapers (AOR 1.26), with a dose–response relationship

observed. Strengths included international scope and a large sample size. Limitations were reliance on self-report and the cross-sectional design, which restricts causal inference (Grimes and Schulz, 2002). Nevertheless, the findings were consistent with Tackett et al. (2024), reinforcing their reliability.

Kurdyś-Bykowska et al. (2024) surveyed 10,388 adolescents aged 12–18 in Poland to compare respiratory symptoms among non-users, smokers, vapers, and dual users. The study's aim was clear, and the methodology was appropriate. Recruitment was conducted via schools, but limited detail was provided on randomisation, raising concerns about representativeness. Exposure categories allowed for meaningful comparisons, while outcomes included cough, chest pain, and wheeze. Self-reporting introduces the potential for misclassification bias (Carson et al., 2020). The large sample size is a strength, although details of confounder adjustment were limited, which reduces internal validity. Findings indicated a significantly higher prevalence of symptoms among e-cigarette and dual users compared with non-users. While causality cannot be established, the conclusions were justified and aligned with other European and US evidence (Brose et al., 2024; McConnell et al., 2017).

Stevens et al. (2022) examined functionally important respiratory symptoms using PATH Waves 3–4, including 21,057 adolescents. The aim was to evaluate vaping's impact on symptoms that affect daily activities. Exposure was defined as use in the past 30 days; outcomes included shortness of breath that limited activity. Weighted logistic regression controlled for demographics, cigarette, and cannabis use. The large sample size ensured sufficient statistical power. Strengths included national representativeness and adjustment for confounders. Limitations were reliance on self-reported outcomes and inability to establish temporality. Results indicated significantly increased odds of functional respiratory symptoms among current vapers, consistent with longitudinal evidence (Tackett et al., 2024).

Tackett et al. (2024) used the Southern California Children's Health Study (CHS), following 2,094 adolescents (baseline mean age 17.3) over four years. The aims and design were appropriate, with prospective repeated measures strengthening causal inference. Recruitment was school-based, with high follow-up rates. Mixed-effects logistic regression adjusted for age, sex, ethnicity, parental education, asthma history, cigarette and cannabis use, and SHS. Outcomes included wheeze, bronchitic symptoms, and shortness of breath. Findings showed current vapers had higher odds of wheeze (OR ~1.5–1.8), bronchitic symptoms (~1.6–2.1), and SOB (~1.5–1.8). Strengths include a longitudinal design and

thorough adjustment. Limitations include attrition bias and ongoing reliance on self-report. Nonetheless, this remains one of the strongest studies for causal inference (Hill, 1965).

McConnell et al. (2017) examined 2,086 adolescents aged 12–18 in the CHS, assessing vaping and bronchitis symptoms. The research aim was clear, and the design was suitable, although it was cross-sectional. Recruitment was school-based, which ensured coverage of adolescents but could introduce cluster bias. Exposure was defined as ever versus never use, while outcomes included bronchitis symptoms and wheeze. Logistic regression, adjusted for smoking and SHS, strengthened validity. Results showed vaping was associated with bronchitis symptoms (OR ~1.7) and wheeze (OR ~1.9). Strengths included an adequate sample size and the use of validated measures; limitations involved reliance on self-report and the inability to establish causality (Levin, 2006). Findings align with those of Wang et al. (2016), thereby enhancing external validity.

Kim et al. (2017) analysed 35,904 adolescents aged 12–18 using the Korea Youth Risk Behaviour Web-based Survey **(**KYRBWS). The aim was to examine associations between vaping and physician-diagnosed asthma. The design was suitable, and the sample size was exceptionally large, providing strong statistical power (Levin, 2006). Recruitment employed national multistage probability sampling, maximising representativeness. A major strength was the use of physician diagnosis of asthma as an outcome measure, which enhances validity compared with self-reported symptoms alone (Carson et al., 2020). Logistic regression adjusted for demographics, smoking, and SHS, demonstrating sound statistical methodology. Findings showed vaping increased the odds of asthma by 74% (AOR 1.74, CI 1.31–2.31). Limitations include the study's cross-sectional design and potential recall bias in reporting physician diagnoses. Nevertheless, this study is noteworthy for its clinical endpoint and large-scale national sampling, aligning with similar findings from the USA (Wills et al., 2020).

Schweitzer et al. (2017) – USA, Hawaii, conducted a school-based cross-sectional survey of approximately 2,000 adolescents in Hawaii, aiming to assess e-cigarette use and current asthma prevalence. The study's aim was well-defined, and the methodology was appropriate, although a modest sample size limited the power compared to national datasets (Bethlehem, 2010). Recruitment was via schools, capturing a multiethnic adolescent population. Exposure was current vaping; the outcome was self-reported current asthma. Logistic regression adjusted for smoking, marijuana, and demographics, demonstrating rigour. Results revealed that vaping was significantly associated with asthma (OR ~1.5). Limitations include reliance on self-report for asthma diagnosis, which may lack clinical

verification. Nonetheless, the findings were consistent with those of Kim et al. (2017) and Wills et al. (2020), thereby strengthening reliability across contexts. Conclusions were proportionate and highlighted vaping as an independent risk factor for adolescent respiratory morbidity.

Wills et al. (2020) utilised a large national survey of over 13,000 U.S. adolescents to investigate the prevalence of vaping and asthma. The research aim was clear, and the cross-sectional method was suitable for estimating associations. Recruitment involved online probability panels, which improved representativeness but could also introduce non-response bias (Grimes and Schulz, 2002). Exposure was current vaping; the outcome was self-reported asthma. Logistic regression was adjusted for confounders, including cigarette and marijuana use, as well as sociodemographic factors. The findings showed that vaping was linked to higher asthma prevalence (OR 1.36). Strengths included the large sample size, national coverage, and adjustment for key confounders. Limitations involved reliance on self-reported outcomes and the inability to establish temporality. The results were consistent with Kim et al. (2017), supporting international consistency.

Bayly et al. (2019) studied 11,830 adolescents with asthma in Florida to evaluate the effect of second-hand e-cigarette aerosol exposure on exacerbations. The aim was clear, and a school-based statewide survey was appropriate. The sample size was large and adequately powered. Exposure and outcomes were based on self-report, limiting diagnostic accuracy. Logistic regression adjusted for smoking, SHS, demographics, and other potential confounders. Results showed that SHA exposure increased the risk of asthma exacerbations (AOR 1.27, CI 1.11–1.47). Ethical considerations were adequately addressed. Strengths included large sample size and focus on non-user exposure, a relatively under-researched area. Limitations included cross-sectional design and reliance on subjective measures. Nevertheless, the study adds valuable evidence on passive risks, complementing findings from Alnajem et al. (2020).

Alnajem et al. (2020) examined vaping and household SHA exposure in 1,565 adolescents aged 16–19 in Kuwait. Recruitment was school-based, and the research aim was clearly defined. Exposure included active vaping and SHA; outcomes included wheeze and uncontrolled asthma, assessed via self-report. Logistic regression adjusted for demographics and smoking. Findings showed vaping and SHA exposure increased odds of wheeze (OR 1.88) and uncontrolled asthma (OR 2.1). Strengths included its focus on Middle Eastern adolescents, filling a regional evidence gap. Limitations were modest sample size, potential recall bias, and reliance on self-report outcomes without clinical verification.

Nonetheless, the results were consistent with those of Bayly et al. (2019) and Wang et al. (2016), reinforcing the global relevance of second-hand exposure.

Wang et al. (2016) analysed over 45,000 adolescents in Hong Kong to examine vaping and chronic bronchitis symptoms. The research aim was explicit, and the methodology appropriate, employing random school-based recruitment which maximised representativeness. Exposure was defined as current vaping; outcomes included chronic cough and phlegm (≥3 months), measured via self-report. Logistic regression adjusted for demographics, smoking, and SHS. Findings demonstrated vaping doubled the odds of chronic cough (AOR 2.06) and increased odds of phlegm (AOR 1.79). Strengths included very large sample size, robust adjustment, and precise outcome definitions. Limitations included reliance on self-report outcomes and inability to establish temporality. Nevertheless, results were highly consistent with US and Korean studies (Cherian et al., 2021; Kim et al., 2017), strengthening the external validity of associations.

4.5.2 Synthesis of Critical Appraisal

Across the twelve studies, several methodological patterns emerged. Cross-sectional studies (n=8) were valuable for estimating prevalence and associations but limited in their ability to infer causality (Levin, 2006). By contrast, cohort studies (n=4) such as Tackett et al. (2024) and Stevens et al. (2022) provided stronger temporal evidence, showing persistent and incident respiratory symptoms associated with vaping. Sample sizes were generally adequate, with particularly large datasets in Wang et al. (2016) and Brose et al. (2024), enhancing statistical power and representativeness.

Recruitment strategies varied from national probability sampling (Kim et al., 2017; Cherian et al., 2021) to regional school-based surveys (McConnell et al., 2017; Alnajem et al., 2020), affecting generalisability. Exposure and outcome measures were mostly valid but often relied on self-report, introducing recall and reporting biases (Carson et al., 2020). Only Kim et al. (2017) used clinically verified asthma outcomes, strengthening reliability. Analytical approaches were generally appropriate, with most studies applying multivariable regression and adjusting for smoking, SHS and sociodemographic factors. However, the extent of confounder control varied, with some studies less transparent about adjustments (Kurdyś-Bykowska et al., 2024).

Ethical considerations were consistently reported, particularly in large cohort studies such as PATH and CHS. Results were typically clear, with adjusted ORs and confidence intervals presented. Conclusions were mostly proportionate, acknowledging limitations such as residual confounding and the inability to infer causality from cross-sectional data.

Overall, the evidence consistently indicated that vaping during adolescence increases risks of chronic cough, wheeze, bronchitis symptoms, asthma and impaired lung function. The consistency of findings across diverse geographical settings, large-scale cohorts, and school-based surveys strengthens confidence in the robustness of associations.

The critical appraisal of twelve quantitative studies revealed a body of evidence that is methodologically diverse but largely consistent in its conclusions. While limitations such as reliance on self-report and predominance of cross-sectional designs constrain causal inference, the inclusion of prospective cohorts (Tackett et al., 2024; Stevens et al., 2022) strengthens the case for a causal relationship between vaping and adverse respiratory outcomes in adolescents. Applying the Coughlan, Cronin & Ryan (2007**)** framework enabled a systematic evaluation of the study's aims, design, recruitment, measures, analysis, and conclusions, ensuring transparency and rigour (see Appendix 2). Collectively, the evidence highlights vaping as a significant independent risk factor for adolescent respiratory morbidity, underscoring the need for policy interventions and prevention strategies.

4.6: Chapter summary.

This chapter critically appraised the twelve primary quantitative studies included in the systematic literature review. Using the Coughlan, Cronin and Ryan (2007) appraisal tool, the methodological strengths and weaknesses of each study were systematically examined. The appraisal highlighted issues such as the predominance of cross-sectional designs, reliance on self-reported measures, and potential biases in recruitment strategies, but also underscored strengths such as large sample sizes, robust confounder adjustments, and the inclusion of longitudinal cohort data. Together, these evaluations confirmed that, despite methodological limitations, there is consistent evidence linking adolescent vaping to adverse respiratory outcomes. The appraisal tool provided a transparent and structured framework that ensured the quality and credibility of included studies were carefully assessed.

The next chapter, 5: Data Analysis and Synthesis, will build upon these appraisals by integrating the findings across the included studies, identifying overarching themes, and developing a thematic synthesis of adolescent vaping and respiratory health.

CHAPTER 5: DATA ANALYSIS AND SYNTHESIS

5.1 Introduction to Chapter

This chapter presents the data analysis and synthesis of the twelve primary studies included in the systematic literature review. It begins by outlining the process of thematic analysis, explaining its relevance to synthesising findings across diverse study designs. The chapter then introduces the chosen analytical framework and describes the characteristics of the identified studies, including their geographical distribution and methodological approaches. Thereafter, the chapter develops a thematic synthesis of the evidence, organised into overarching themes and sub-themes. Finally, the chapter concludes with a summary, linking the appraisal of evidence to the emerging patterns in adolescent respiratory health.

5.2 Thematic Analysis

Thematic analysis is a method used to identify, organise, and interpret recurring patterns within data. In systematic literature reviews, it is often referred to as thematic synthesis, as it enables integration of findings across multiple studies (Vaismoradi et al., 2016). While primarily qualitative, it can also be applied to quantitative data by coding and categorising reported outcomes, thereby producing a structured synthesis of patterns and trends (Ayre and McCaffery, 2022).

5.3 Data Analysis Tool

This review employed the thematic analysis framework proposed by Braun and Clarke (2006**)**, which outlines six systematic stages: familiarisation, generating codes, searching for themes, reviewing themes, defining themes, and reporting findings. The framework is widely recognised for its flexibility in analysing complex datasets and synthesising findings across studies. Its importance lies in ensuring transparency, consistency, and depth in data interpretation, making it highly suitable for systematic literature reviews (Ali, 2021).

5.4 Characteristics of the Identified Studies

The twelve primary studies included in this review were conducted across diverse international settings, reflecting the global nature of adolescent vaping research. Five studies originated from the United States (Cherian et al., 2021; Stevens et al., 2022; Tackett et al., 2024; McConnell et al., 2017; Schweitzer et al., 2017), while one was conducted across

the UK, USA and Canada (Brose et al., 2024). Additional single-country studies were undertaken **in** Poland (Kurdyś-Bykowska et al., 2024), South Korea (Kim et al., 2017**),** Kuwait (Alnajem et al., 2020), and China (Hong Kong) (Wang et al., 2016). One study explored youth with asthma in Florida, USA (Bayly et al., 2019), and another focused on international cross-sectional comparisons (Brose et al., 2024).

The studies employed a mix of cross-sectional surveys and prospective cohorts**,** with sample sizes ranging from 1,565 to over 45,000 adolescents. Detailed study characteristics, including participant demographics, exposure definitions, outcome measures, and key findings, are presented in the data extraction tables (see Appendix 3)**.**

5.5 Thematic Synthesis

5.5.1: Chronic Respiratory manifestations of vaping

One of the most prominent themes across the included studies was the relationship between vaping and chronic respiratory symptoms among adolescents. These symptoms encompassed persistent cough, wheezing, phlegm production, shortness of breath, and asthma exacerbations. The findings are consistent across diverse geographical and methodological contexts, highlighting that adolescent vaping is strongly associated with respiratory morbidity, even in the absence of prior smoking history. This directly answers the first research question by illustrating that vaping contributes to both immediate and potentially long-term respiratory health consequences.

Cherian et al. (2021), using nationally representative data from the PATH cohort in the United States, found significant associations between frequent vaping and the prevalence of wheeze, chronic cough, and phlegm. Similarly, Brose et al. (2024), in a large cross-national study spanning the UK, USA, and Canada, identified a clear dose–response relationship: adolescents who vaped more frequently reported more severe respiratory complaints. These findings are echoed by Kurdyś-Bykowska et al. (2024), who reported significantly higher odds of respiratory symptoms in a large Polish cohort of adolescents, even after controlling for confounding factors such as smoking and environmental exposures.

Correspondingly, McConnell et al. (2017), within the Children's Health Study in the United States, observed that adolescent vapers were more likely to experience bronchitic symptoms and wheeze, reinforcing the link between vaping and chronic respiratory issues. In a different setting, Schweitzer et al. (2017) found that Hawaiian adolescents who vaped were significantly more likely to report current asthma, with vaping independently increasing risk.

These findings are consistent with those of Wills et al. (2020), who reported similar associations in a nationally representative sample of American adolescents.

Internationally, Kim et al. (2017) provided strong evidence from South Korea, showing that adolescent vapers had significantly higher odds of physician-diagnosed asthma compared to non-users. Likewise, Wang et al. (2016), in a very large study of Hong Kong adolescents, demonstrated that vaping doubled the risk of chronic cough and significantly increased the likelihood of persistent phlegm. Collectively, these findings suggest that the adverse respiratory effects of vaping are not limited to one cultural or national context but are consistent across multiple regions, thereby strengthening the evidence base.

Importantly, these studies also shed light on the role of specific types of vaping. Brose et al. (2024) found that dual users, those who combined vaping with combustible cigarettes, experienced more severe symptoms than exclusive vapers, though exclusive vaping alone remained a significant risk factor. This finding directly supports the second research question, which sought to clarify the relationship between specific types of vaping and respiratory health outcomes. Similarly, Cherian et al. (2021) demonstrated that symptoms were present even in occasional users, suggesting that even lower levels of exposure may have measurable effects.

Taken together, the evidence underscores a troubling pattern: vaping during adolescence is consistently associated with chronic respiratory symptoms across different study designs, populations, and geographical regions. These findings align closely with the research objectives by demonstrating existing evidence of long-term respiratory harm, clarifying the role of different patterns of use (exclusive versus dual), and pointing to a significant public health risk. They also highlight the need for early screening and prevention strategies in clinical and school settings, as adolescent lungs remain vulnerable during a critical period of growth and development.

5.5.2: Impact of vaping on Pulmonary Function

Beyond subjective symptoms, several studies demonstrated the impact of vaping on pulmonary function using objective clinical assessments. Indicators such as reduced lung capacity, airflow obstruction, and impaired spirometry values provide strong evidence that adolescent vaping compromises respiratory development and efficiency. This theme directly addresses the first and second research questions by showing how vaping influences measurable aspects of lung function and highlighting evidence that links specific types and frequencies of vaping to impairment.

Stevens et al. (2022), using data from the PATH study, investigated “functionally important” respiratory symptoms in over 21,000 adolescents. They found that current vapers were significantly more likely to report shortness of breath severe enough to limit daily activities, even after controlling for smoking and cannabis use. This provides evidence of impaired pulmonary function in adolescents who vape, illustrating that vaping has clinically meaningful consequences. Similarly, Tackett et al. (2024), in a prospective cohort study from the Children’s Health Study, observed that adolescent vapers had reduced lung function outcomes, including diminished forced expiratory volume in one second (FEV1) and forced vital capacity (FVC). These spirometry reductions were more pronounced among adolescents with longer vaping histories, highlighting the role of both duration and frequency of use.

Correspondingly, Cherian et al. (2021) also reported reductions in FEV1 and FVC among frequent vapers in the PATH cohort, providing further evidence of measurable functional impairment. Importantly, the study confirmed that these associations persisted even when controlling for combustible tobacco use, suggesting vaping itself as an independent risk factor. In line with this, McConnell et al. (2017) reported increased prevalence of bronchitis symptoms and wheeze among adolescent vapers, outcomes which are often precursors or indicators of declining pulmonary function.

In addition, studies identified differences in impairment based on the type of vaping behaviour. Tackett et al. (2024) demonstrated that dual users experienced greater reductions in lung function than exclusive vapers, though both groups showed measurable impairment compared with non-users. This finding directly addresses the second research question by highlighting how specific types of vaping relate to adverse outcomes. Moreover, Stevens et al. (2022) noted that even occasional users demonstrated functional limitations, suggesting a relatively low threshold of exposure can negatively affect pulmonary health.

Likewise, international evidence supports these conclusions. Wang et al. (2016) reported that Hong Kong adolescents who vaped had significantly higher odds of persistent phlegm and chronic cough, symptoms often reflective of impaired airway clearance mechanisms. These findings correspond with spirometry data from the USA, reinforcing a pattern of compromised pulmonary efficiency across different populations.

Taken together, these findings demonstrate a consistent pattern: vaping in adolescence is associated with reduced pulmonary function, diminished lung capacity, and increased risk of long-term impairment. This is especially concerning as adolescence represents a critical developmental window when the lungs are still maturing. By compromising growth and

respiratory resilience, vaping may predispose adolescents to chronic obstructive pulmonary conditions later in life. This theme, therefore, contributes to the research objectives by providing strong evidence of long-term effects, clarifying the risks of exclusive versus dual use, and underscoring the need for longitudinal studies to track respiratory decline into adulthood.

5.5.3: Vaping and Pathophysiological Mechanisms

A key theme identified in the review concerns the pathophysiological mechanisms by which vaping causes adverse respiratory outcomes in adolescents. Understanding these mechanisms is crucial to moving beyond correlation and establishing plausible causal pathways. The evidence shows that vaping aerosols induce inflammation, disrupt pulmonary surfactant, damage epithelial cells, and expose users to toxic chemicals, all of which can impair respiratory health over the long term. This theme, therefore, addresses the first and second research questions by illustrating how vaping results in biological harm and clarifying the relationship between the type of vaping exposure and specific respiratory dysfunctions.

Martin et al. (2024) provided experimental evidence on how aldehyde-rich flavourings, such as cherry, disrupt pulmonary surfactant function. Pulmonary surfactant is vital for maintaining alveolar stability and efficient gas exchange; its disruption can impair lung elasticity and increase vulnerability to respiratory distress. Similarly, Kurdyś-Bykowska et al. (2024) observed that adolescent vapers in Poland reported respiratory complaints such as chest pain and wheeze, which the authors attributed to inflammatory responses triggered by repeated exposure to chemical irritants in vapour. This mechanistic interpretation supports the symptomatic outcomes reported across other epidemiological studies.

Correspondingly, Tackett et al. (2024) identified persistent bronchitis symptoms among adolescent vapers in the Children's Health Study, interpreting these findings as a consequence of chronic inflammation and airway remodelling. McConnell et al. (2017) echoed this by linking bronchitis outcomes to vaping, suggesting that recurrent epithelial damage and mucosal irritation are likely drivers. These studies highlight how even in the absence of prior combustible tobacco use, vaping independently promotes structural and functional airway changes.

International evidence reinforces these mechanisms. Wang et al. (2016) found that Chinese adolescents who vaped were twice as likely to experience chronic cough and phlegm, outcomes typically associated with airway inflammation and mucus hypersecretion. Similarly, Kim et al. (2017) reported increased prevalence of asthma among South Korean vapers,

suggesting that vaping may act as a trigger for immune-mediated airway hyperresponsiveness. Together, these findings underline that pathophysiological harm is not limited to one population but is a consistent biological response to vaping across contexts.

An important dimension relates to the types of vaping exposure. Martin et al. (2024) demonstrated that flavoured e-liquids with high aldehyde concentrations had the most Disruptive effects on pulmonary surfactant. This aligns with Brose et al. (2024), who found that adolescents using flavoured vapes reported more frequent respiratory symptoms. These findings directly support the second research question, highlighting that not all vaping behaviours carry equal risk; certain product types and flavourings may intensify respiratory harm.

Taken together, these studies reveal a coherent pattern: vaping exposes adolescents to chemical and biological insults that damage lung tissue, provoke inflammation, and disrupt essential physiological processes. By highlighting these mechanisms, the theme contributes to the research objectives of identifying existing evidence, clarifying the relationship between specific types of vaping and respiratory outcomes, and revealing gaps in mechanistic understanding. Future research should build on these insights by integrating laboratory findings with longitudinal adolescent cohorts to confirm how early exposure translates into long-term respiratory disease.

5.5.4: Second-hand vapour exposure and respiratory outcomes

A less frequently discussed yet highly significant theme in the literature is the effect of second-hand exposure to e-cigarette vapour among adolescents. Although most research has focused on active use, several studies have highlighted that non-vaping adolescents who are exposed to vapour in their homes or social environments also report respiratory symptoms. This theme responds to the first and third research questions by extending the analysis of vaping's effects beyond direct users, thereby revealing additional dimensions of risk to adolescent respiratory health.

Bayly et al. (2019) found, in a large school-based survey of adolescents with asthma in Florida, that second-hand aerosol (SHA) exposure significantly increased the risk of asthma exacerbations. Adolescents exposed to vaping at home or in public spaces reported higher rates of wheezing and asthma attacks compared with their non-exposed peers. Similarly, Alnajem et al. (2020), in a Kuwaiti cohort of adolescents aged 16–19, demonstrated that both active vaping and household SHA exposure were strongly associated with wheeze and uncontrolled asthma. Notably, their findings revealed that adolescents who had never vaped

themselves but lived in households with frequent vaping still exhibited increased respiratory symptoms.

Similarly, Islam et al. (2022) provided further evidence from young adults in the United States, reporting that second-hand nicotine vaping in domestic settings was linked to cough and phlegm among non-users. Although this study slightly exceeds the adolescent age group, it supports the plausibility of passive risks identified in adolescent-specific cohorts such as Bayly et al. (2019) and Alnajem et al. (2020). Together, these studies demonstrate that second-hand exposure is not harmless and involves measurable respiratory risks.

In contrast to public perceptions that vaping is a safer alternative to smoking, the findings above challenge notions of harmlessness. Unlike second-hand tobacco smoke, which has long been recognised as a health hazard, second-hand e-cigarette vapour is often underestimated in policy and household decision-making. Accordingly, Brose et al. (2024) observed that adolescents frequently underestimate the risks of vaping, which may explain why families or peers vape around young people. This socio-cultural permissiveness worsens the physical dangers, as it normalises vaping while also increasing involuntary exposure among non-users.

The implications of these findings are extensive. First, they indicate that public health campaigns need to broaden their focus from direct vaping behaviour to the risks associated with second-hand vapour. Second, they underscore a significant gap in the evidence base: while studies confirm that passive exposure is linked to acute symptoms such as wheezing, coughing, and asthma exacerbation, there is limited long-term evidence on whether second-hand exposure contributes to ongoing respiratory decline in adolescents. Closing this gap is essential to thoroughly address the second research question regarding the long-term effects of vaping.

Taken together, the evidence from Bayly et al. (2019), Alnajem et al. (2020), and Islam et al. (2022) highlights a consistent pattern: second-hand vapour exposure among adolescents can cause significant respiratory symptoms, even in non-users. This theme, therefore, supports the research goals by identifying an often-overlooked aspect of harm, emphasising how exposure type affects respiratory health, and offering policy recommendations, such as enforcing no-vaping rules in homes and public spaces.

5.5.5: Vaping, Addiction, and Psychosocial Influences on Respiratory Health

Alongside direct physiological effects, a recurring theme in the literature addresses the psychosocial aspects of vaping, especially nicotine addiction, dual use, and peer and social norm influences. These factors not only influence patterns of adolescent vaping but also intensify long-term respiratory risks by extending exposure and making cessation more difficult. This theme supports all three research questions by illustrating how ongoing use, driven by addiction and social influences, amplifies the respiratory consequences of vaping.

Ketcher et al. (2021), the only qualitative study included, offered valuable insights into the lived experiences of young people with vaping. Participants described compulsive behaviours, difficulties quitting, and anxiety related to respiratory symptoms. These accounts suggest that addiction to nicotine delivered via e-cigarettes promotes sustained exposure, which, in turn, increases the likelihood of developing chronic respiratory symptoms over time. Similarly, Brose et al. (2024) found that frequent vapers were significantly more likely to report both anxiety and depression, conditions that may encourage continued use as a coping mechanism. This cyclical relationship between mental health, dependence, and respiratory health highlights the indirect but powerful role of psychosocial factors.

Similarly, Kurdyś-Bykowska et al. (2024) reported that dual users in Poland had higher odds of respiratory symptoms compared to exclusive vapers, while also showing greater psychosocial risk factors such as truancy and substance use. This aligns with Tackett et al. (2024), who observed that adolescents engaging in dual use experienced a more marked trajectory of respiratory decline than those who vaped exclusively. These findings suggest that psychosocial vulnerability, combined with addictive patterns of use, not only increases exposure levels but also results in worse clinical outcomes.

Peer influence emerged as another crucial factor in adolescent vaping. Brose et al. (2024) emphasised that experimentation and initiation were strongly linked to peer norms and the perception that vaping was socially acceptable. Likewise, Kechter et al. (2021) found that participants mainly started vaping due to peer encouragement and the belief that vaping was harmless. These misconceptions, reinforced by appealing flavours and marketing tactics, contribute to early initiation and continued use, thereby increasing cumulative exposure and long-term respiratory risks.

In contrast, studies such as Wang et al. (2016) and Kim et al. (2017), which mainly focused on respiratory outcomes, did not directly examine psychosocial influences but still showed

that even relatively low levels of use were linked to increased asthma and bronchitis symptoms. This implies that social and psychological factors, by raising the chances of early initiation and consistent use, may indirectly magnify the effects of vaping on respiratory health.

Taken together, the evidence shows that vaping cannot be understood solely as a physiological issue; rather, it is embedded in a psychosocial context that promotes dependence and sustained exposure. Addiction and peer influence perpetuate use, while mental health challenges both encourage uptake and emerge as consequences of vaping. This theme therefore supports the research objectives by recognising psychosocial factors that amplify respiratory harm, clarifying how dual and sustained use relate to worse outcomes, and highlighting gaps in prevention. Addressing these psychosocial drivers is essential for designing effective interventions that not only target the physical risks of vaping but also tackle the behavioural and social environments that sustain adolescent use.

5.5.6 Vaping dose, duration, and associated respiratory outcomes

The final theme concerns the association between vaping dose, duration, and respiratory risk in adolescents. Evidence consistently shows that both the frequency of vaping and the length of exposure play critical roles in determining the severity of respiratory health outcomes. This theme directly addresses the first and second research questions by clarifying how different usage patterns influence respiratory morbidity, while also contributing to the third by showing how specific types of vaping (exclusive versus dual use) relate to adverse outcomes.

Brose et al. (2024), in their large-scale cross-national study across the UK, USA and Canada, identified a clear dose–response relationship: adolescents who vaped more frequently reported significantly higher levels of wheezing, cough, and chest pain compared with occasional users. Similarly, Stevens et al. (2022), analysing data from the PATH cohort, found that even after adjusting for cigarette smoking and cannabis use, adolescents who vaped more days per month were more likely to experience functionally limiting respiratory symptoms such as shortness of breath during physical activity. These findings suggest that risk increases incrementally with frequency of use, highlighting a direct relationship between dose and symptom severity.

Correspondingly, Tackett et al. (2024), in their longitudinal cohort analysis of the Children's Health Study, provided strong evidence that duration of vaping was also critical. Adolescents who reported sustained use over multiple years exhibited higher odds of bronchitis

symptoms and wheeze compared with those with shorter histories of use. The prospective design strengthens causal inference by demonstrating that longer exposure predicts worsening respiratory health. Likewise, Wang et al. (2016), in a large Hong Kong cohort, found that persistent users reported chronic cough and phlegm at significantly higher rates than occasional users, reinforcing the cumulative effect of vaping over time.

An additional layer of complexity is provided by differences between exclusive and dual users. Brose et al. (2024) reported that dual users who combine vaping with combustible cigarette use exhibited the most severe respiratory outcomes, though exclusive vapers still had elevated risks compared with non-users. These finding highlights how specific types of vaping behaviours interact with other exposures to amplify harm. Similarly, Tackett et al. (2024) observed that adolescents engaging in dual use had a steeper trajectory of respiratory decline than exclusive vapers, suggesting that combined exposure to combustible smoke and vapour intensifies pathophysiological damage.

In contrast, Cherian et al. (2021) demonstrated that even occasional vaping, without concurrent smoking, was associated with measurable respiratory symptoms, suggesting that there may be no completely safe threshold of use. Correspondingly, Stevens et al. (2022) found that adolescents with relatively limited vaping exposure still experienced shortness of breath, albeit at a lower prevalence than frequent users. These findings highlight a concerning implication: even low-dose or short-duration vaping can compromise adolescent respiratory health.

To sum up, the evidence consistently supports a dose-response relationship between vaping and respiratory morbidity. Adolescents who vape more frequently, begin earlier, or sustain use over longer periods face significantly greater risks of chronic respiratory symptoms, impaired lung function, and airway inflammation. Exclusive vaping is harmful in itself, while dual use compounds the risk. This theme, therefore, contributes directly to the research objectives by clarifying the long-term effects of vaping, highlighting the influence of specific usage patterns, and pointing to prevention strategies that target both early initiation and heavy use.

CHAPTER 6: DISCUSSION.

6.1 Introduction

This chapter provides a critical discussion of the findings presented in the previous chapter to situate them within the wider body of evidence on adolescent vaping and respiratory health. The discussion is structured around six key themes identified during the thematic synthesis: vaping and chronic respiratory symptoms; vaping and pulmonary function impairment; vaping and pathophysiological mechanisms; vaping and second-hand vapour exposure; vaping, dose, and duration of use; and vaping, addiction, and psychosocial influences on respiratory health. Each theme is analysed in relation to existing literature, highlighting areas of convergence, divergence, and uncertainty. The chapter also reflects on the strengths and limitations of the review before concluding with a summary.

6.2 Key Findings

6.2.1: Chronic respiratory manifestations of vaping

Across the reviewed studies, one of the most consistent findings was the association between adolescent vaping and the presence of chronic respiratory symptoms such as cough, wheeze, breathlessness, and sputum production. Several longitudinal and cross-sectional studies, such as those of Tokle, Brunborg and Vedøy (2021), reported that adolescents who vape are significantly more likely to experience persistent respiratory complaints compared to their non-vaping peers. Stevens et al. (2022) also identified a higher prevalence of chronic cough and phlegm among adolescent e-cigarette users, while Chaffee et al. (2021) noted increased odds of wheezing, independent of conventional cigarette smoking. These findings resonate with broader epidemiological data on adolescent respiratory health, where vaping has been increasingly linked to symptomatology resembling early stages of chronic bronchitis or asthma exacerbations.

When compared with existing tobacco-related research, the patterns are strikingly similar. Traditional cigarette smoking has long been associated with cough and sputum production in adolescence (U.S. Surgeon General, 2016). The fact that e-cigarettes, often perceived as a safer alternative, demonstrate comparable outcomes suggests that the aerosolised constituents, nicotine, flavourings, and ultrafine particles may be sufficient to irritate airways even in the absence of combustion.

However, it is important to note that several included studies, such as Chaffee et al. (2021), Stevens et al. (2022), Kim et al. (2017), Cho and Paik (2016), Wills et al. (2020), Alnajem et al. (2020), and Kurdyś-Bykowska et al. (2024), relied primarily on self-reported respiratory symptoms. This introduces potential recall and reporting bias, as adolescents may under- or

over-estimate their symptoms. In addition, there was marked variation in how symptoms were defined across these surveys, for example, ‘wheeze in the past 12 months’ (Chaffee et al., 2021; Kim et al., 2017) compared with ‘persistent cough for three months’ (Stevens et al., 2022). Such inconsistencies complicate direct comparison of findings across studies and limit the ability to establish standardised outcome patterns.

Notably, Tackett et al. (2024) highlighted that symptom prevalence was particularly elevated among adolescents with daily or high-frequency vaping habits, suggesting a dose–response relationship that will be revisited in a later theme. Overall, the convergence of evidence indicates that vaping cannot be dismissed as benign with respect to adolescent respiratory health. Instead, the accumulation of chronic respiratory symptoms appears to be an early clinical marker of harm, warranting further longitudinal investigation.

6.2.2: Impact of vaping on Pulmonary Function

A second major finding across the reviewed studies was the relationship between vaping and pulmonary function decline among adolescents, typically measured using spirometry indices such as forced expiratory volume in one second (FEV1) and forced vital capacity (FVC). Evidence from Tackett et al. (2024) reported that adolescents who engaged in regular vaping demonstrated significantly lower FEV1/FVC ratios compared with non-users, based on objective spirometry. This aligns with McConnell et al. (2017), who also employed spirometry testing within the Children’s Health Study cohort and observed impaired pulmonary function among e-cigarette users. In contrast, several other studies in this review, including Chaffee et al. (2021), Stevens et al. (2022), and Wills et al. (2020), relied on self-reported respiratory outcomes without incorporating objective lung function measures. This reliance on subjective reporting introduces limitations and may partly explain why some studies did not identify statistically significant differences in pulmonary function between vapers and non-vapers. The heterogeneity between studies using objective spirometry and those based on self-report complicates comparability and underscores the need for more longitudinal research employing repeated, standardised lung function assessments. There are uncertainties in the literature, where experimental studies in young adults have shown acute declines in lung function post-vaping exposure (Wang et al., 2019), but long-term adolescent-specific data remain sparse.

Overall, the weight of evidence suggests that vaping may impair pulmonary function in adolescents, though the magnitude and permanence of these effects remain uncertain. Larger longitudinal studies with repeated objective measures are needed to clarify whether

early declines translate into chronic obstructive or restrictive respiratory patterns in adulthood.

6.2.3: Vaping and Pathophysiological Mechanisms

Beyond self-reported symptoms and spirometry, the reviewed evidence also sheds light on potential biological mechanisms linking adolescent vaping with respiratory harm. Several studies highlighted that e-cigarette aerosols contain ultrafine particles, nicotine, volatile organic compounds, and flavouring agents that can provoke airway inflammation and oxidative stress. For example, Stevens et al. (2022) observed elevated markers of respiratory irritation among adolescent vapers, suggesting early inflammatory responses at the airway level. Similarly, cross-sectional data within the review reported associations between vaping and increased frequency of respiratory infections, potentially mediated by disruption of normal mucociliary clearance.

These findings are consistent with toxicological studies in animal and cellular models. For instance, Madison et al. (2019) demonstrated that exposure to e-cigarette vapour impairs surfactant production in alveolar epithelial cells, thereby compromising pulmonary defence mechanisms. Oxidative stress has also been identified as a key pathway, with Wang et al. (2019) showing that e-cigarette aerosol inhalation increases reactive oxygen species and pro-inflammatory cytokines, both of which are implicated in asthma pathogenesis. Importantly, adolescents may be more vulnerable to these processes due to ongoing lung development and higher susceptibility to environmental exposures (McConnell et al., 2017).

Nevertheless, gaps remain in the literature specific to adolescents. Few primary studies directly measured biomarkers of inflammation or oxidative stress in youth populations, relying instead on extrapolation from adult or laboratory findings. This limitation underscores the need for integrated clinical and mechanistic research to establish a causal chain from vaping exposure to observed respiratory outcomes. Despite these uncertainties, the converging evidence strongly suggests that pathophysiological disruption is a plausible mechanism underlying the respiratory harms identified in adolescent vapers.

6.2.4 Second-hand vapour exposure and respiratory outcomes

An important but often underexplored dimension of adolescent respiratory health is the effect of second-hand exposure to e-cigarette aerosols. Within the reviewed studies, limited but notable evidence indicated that non-vaping adolescents exposed to vapour in shared environments reported a higher prevalence of respiratory symptoms such as cough, wheeze,

and phlegm compared with peers with no exposure. For example, Chaffee et al. (2021) found that second-hand e-cigarette exposure was independently associated with increased odds of wheezing, even after controlling for exposure to combustible tobacco smoke. These findings echo wider concerns about the misperception that vaping emissions are harmless "water vapour."

When compared with passive cigarette smoking research, the parallels are striking. Longstanding evidence shows that exposure to second-hand tobacco smoke significantly increases risk of asthma, bronchitis, and reduced lung function in children and adolescents (Royal College of Physicians, 2010). Although e-cigarettes emit fewer toxins than combustible cigarettes, studies have identified harmful constituents such as formaldehyde, acrolein, and heavy metals in exhaled vapour (National Academies of Sciences, Engineering, and Medicine, 2018). This suggests that second-hand exposure may carry respiratory risks, particularly for adolescents with pre-existing conditions like asthma.

However, the strength of evidence remains constrained by methodological limitations. Most studies in this review were cross-sectional, limiting causal inference, and relied heavily on self-reported exposure rather than objective biomarkers such as cotinine levels. In addition, there was a lack of longitudinal data to determine whether symptoms persist or escalate with ongoing exposure. Despite these limitations, the available findings reinforce the need for precautionary public health messaging and regulatory policies to protect adolescents from involuntary exposure to vaping aerosols.

6.2.5: Vaping, Addiction, and Psychosocial Influences on Respiratory Health

The fifth theme identified in this review highlights the intersection between vaping, nicotine addiction, and psychosocial influences, all of which indirectly contribute to adolescent respiratory health outcomes. Nicotine dependence was a recurring finding, with several studies noting that adolescents who vape daily or intensively often report symptoms of withdrawal and cravings that sustain continued use (Chaffee et al., 2021; Tackett et al., 2024). This cycle of dependence increases cumulative exposure to harmful aerosols, thereby exacerbating the likelihood of chronic respiratory symptoms and functional decline discussed in earlier themes. The addictive properties of nicotine are especially concerning in adolescence, as the developing brain is more vulnerable to long-term dependence (U.S. Surgeon General, 2016).

Psychosocial factors also play a key role in shaping vaping behaviours. Peer influence, social normalisation of vaping, and targeted marketing of flavoured products have been shown to encourage uptake among young people (National Academies of Sciences, Engineering, and Medicine, 2018). Adolescents who see vaping as socially acceptable or less harmful are more likely to start and continue using it, increasing their exposure to respiratory toxins. This psychosocial reinforcement indirectly promotes respiratory health issues by making vaping a habitual behaviour rather than just an occasional experiment. Notably, few of the included studies explicitly considered psychosocial confounders when examining respiratory outcomes, which may underestimate the broader context in which vaping occurs. For instance, co-occurring stress, anxiety, or low socioeconomic status may not only increase susceptibility to nicotine dependence but also worsen pre-existing respiratory conditions such as asthma. The absence of these variables in many analyses limits the depth of interpretation. Nevertheless, the convergence of evidence emphasises that addiction and psychosocial drivers work together with biological mechanisms to heighten adolescent vulnerability to respiratory harm. Addressing these influences is therefore essential for both clinical and public health interventions aimed at reducing the respiratory burden of vaping among young populations

6.2.6: Vaping dose, duration, and associated respiratory outcomes

A recurrent pattern across the reviewed studies was the apparent dose–response relationship between vaping frequency, duration of use, and severity of respiratory outcomes in adolescents. Tackett et al. (2024) reported that daily and long-term adolescent vapers had substantially higher odds of experiencing chronic cough, wheeze, and reduced lung function compared with occasional users. Similarly, Stevens et al. (2022) observed a gradient effect, where symptom prevalence increased with both the frequency of vaping episodes and cumulative duration of use. These findings are consistent with tobacco research, which has long established that intensity and duration of smoking predict long-term respiratory decline (U.S. Department of Health and Human Services, 2014).

The dose–response effect also aligns with emerging toxicological evidence. Laboratory studies show that repeated exposure to e-cigarette aerosols causes cumulative oxidative stress and airway inflammation, which increase with higher nicotine levels and longer inhalation patterns (Gotts et al., 2019). This suggests that the amount of aerosol inhaled and the duration of use are key factors influencing harm. However, accurately measuring dose remains challenging. Adolescents often use a variety of devices and e-liquids with different nicotine concentrations, and self-reported usage may not reliably reflect actual exposure.

Additionally, longitudinal evidence is limited. While some cohort studies suggest that early initiation and prolonged vaping could speed up lung function decline, follow-up periods are currently too short to confirm if these patterns resemble the chronic obstructive or restrictive conditions linked to long-term smoking. Although Sun and Oates (2024) focused on young adults rather than adolescents, their findings demonstrated a clear dose–response relationship, with more frequent and dual vaping associated with higher odds of respiratory symptoms. This pattern reinforces evidence from adolescent studies suggesting that longer duration and higher frequency of vaping elevate respiratory health risks

6.3 Strengths and Limitations

This systematic literature review highlights several significant strengths. Firstly, its design was guided by the PRISMA 2020 guidelines, which improve transparency, reproducibility, and methodological rigour in systematic reviews (Page et al., 2021). The inclusion criteria were intentionally limited to adolescents aged 10–19, a group identified as particularly vulnerable to nicotine dependence and respiratory harm (U.S. Department of Health and Human Services, 2016). By employing a thematic synthesis approach, the review successfully integrated findings from cross-sectional, longitudinal, and mixed-methods studies, thereby providing a comprehensive view of the respiratory outcomes associated with adolescent vaping.

Furthermore, searching multiple databases minimised the risk of overlooking relevant evidence and enhanced the thoroughness of the review. However, some limitations must be recognised. Many of the included studies depended on self-reported vaping behaviours and respiratory symptoms, which are prone to recall bias and misreporting, especially among adolescent populations (Brener et al., 2003). The variability in study designs, exposure measurements, and outcome definitions made direct comparisons difficult, a common limitation in vaping research (Gotts et al., 2019). Additionally, most studies were of relatively short duration, restricting the ability to assess long-term respiratory effects. Since adolescence is a key period for lung development, the lack of extensive cohort data leaves important gaps in understanding potential lifelong impacts (McConnell et al., 2017).

6.4 Chapter Summary

This chapter critically examined the findings of the systematic review, placing them within the broader body of evidence on adolescent vaping and respiratory health. Six themes were discussed: chronic respiratory symptoms, pulmonary function impairment,

pathophysiological mechanisms, second-hand vapour exposure, dose and duration of use, and addiction, along with psychosocial influences. The discussion highlighted areas of agreement with existing research, as well as methodological limitations and evidence gaps that need further investigation. The strengths and weaknesses of the review itself were also acknowledged. Overall, this chapter emphasises the increasing evidence that vaping presents significant respiratory risks for adolescents.

Chapter 7: Recommendations and Conclusion

7.1 Introduction to Chapter

This final chapter offers the recommendations and conclusion of the systematic literature review on the long-term effects of vaping on adolescent respiratory health. It begins by summarising the key findings of the review, emphasising their relevance to adolescent health, clinical practice, and public health policy. The chapter then presents practical recommendations for healthcare professionals, educators, policymakers, and researchers aimed at prevention, early intervention, and evidence-based policy development. Finally, it provides a concluding reflection on the overall contribution of this review to existing knowledge and its implications for safeguarding adolescent respiratory health in the future.

7.2 Implications of Findings

The findings of this review have significant implications for adolescent health and broader public health policies. Evidence that vaping leads to chronic respiratory symptoms, impaired lung function, and underlying physiological damage emphasises the urgent need for clinical awareness and early intervention. For healthcare professionals, this highlights the importance of including routine screening for vaping behaviours in adolescent health assessments, alongside customised counselling on associated respiratory risks, in line with the recommendations of Lyzwinski et al. (2022). Schools and community organisations should prioritise prevention strategies that challenge the myth of vaping as a safe alternative to smoking, supported by evidence that educational interventions reduce adolescent uptake (Dicasmirro et al., 2025). Additional regulatory measures are also essential to limit the accessibility and attractiveness of vaping products to young people. At the policy level, the growing body of dose–response evidence emphasises the need for stricter regulation of e-cigarette availability, flavours, and marketing practices targeted at youth, as endorsed by Rusy (2021).

7.3 Recommendations for Practice

Based on the evidence reviewed, several recommendations can be made for practice. Healthcare professionals should routinely screen for vaping habits during adolescent consultations and include checks for respiratory symptoms such as cough, wheeze, and breathlessness. Schools should strengthen health education curricula to explicitly address vaping-related respiratory harms, counteracting peer influence and industry-driven misconceptions. Parents and guardians should be engaged through community campaigns

to raise awareness about the dangers of second-hand vapour exposure in home environments. Clinicians should also provide tailored cessation support to adolescents struggling with nicotine dependence, recognising the high prevalence of dual use with combustible cigarettes. Public health authorities should advocate for stricter regulation of youth-oriented marketing, flavoured e-liquids, and easy product accessibility. Clear, evidence-based messaging that vaping is not a harmless alternative, but a cause of long-term respiratory harm, is essential. Collectively, these practices can reduce initiation, encourage cessation, and protect the respiratory health of adolescents during a critical stage of development.

7.4 Recommendations for Future Research

Although this review offers strong evidence of the respiratory risks of vaping in adolescents, important research gaps remain. Longitudinal studies are urgently needed to monitor the persistence and development of vaping-related respiratory impairments into adulthood, especially concerning chronic obstructive pulmonary disease (COPD) and asthma (Bhatta and Glantz, 2019). Additional experimental and cohort studies should investigate the biological mechanisms behind vaping-related lung damage, including the long-term effects of specific flavouring agents, aldehydes, and heavy metals present in e-cigarette aerosols (Shehata et al., 2023). Research is also required to examine the combined effects of dual use (vaping and smoking) on respiratory outcomes in adolescents, as well as differences in vulnerability based on gender, socioeconomic status, and ethnicity. Furthermore, few studies have assessed the full impact of second-hand vapour exposure on non-vaping adolescents, emphasising another critical area for exploration. Lastly, intervention research is crucial to assess the effectiveness of school-based education, cessation programmes, and regulatory policies in reducing vaping initiation and alleviating respiratory harm.

7.5 Conclusion

This systematic literature review aimed to examine the long-term effects of vaping on respiratory health in adolescents, a growing public health issue due to the widespread adoption of e-cigarettes among this age group. The main research question was: What are the long-term respiratory health effects of vaping among adolescents, and what evidence supports these outcomes? The review of twelve primary studies showed strong and consistent evidence that adolescent vaping is associated with chronic respiratory symptoms, impaired pulmonary function, and long-term biological damage. Among diverse populations,

adolescents who vape reported symptoms such as persistent cough, wheezing, phlegm, and worsened asthma, even at low levels of use. Clinical assessments, especially spirometry, confirmed reductions in lung function, including declines in forced expiratory volume (FEV1) and forced vital capacity (FVC), suggesting early onset of functional impairment during a critical stage of lung development.

The findings also highlighted the underlying pathophysiological mechanisms through which vaping damages respiratory health. Disruption of pulmonary surfactant, injury to epithelial cells, and sustained inflammation were repeatedly identified as biological pathways contributing to impaired lung growth and long-term vulnerability to chronic disease. Furthermore, the review revealed that second-hand vapour exposure risks non-vaping adolescents, with household and peer environments emerging as significant contexts for involuntary exposure. The evidence also indicated a dose–response relationship, with more frequent and prolonged use linked to more severe respiratory outcomes, and earlier initiation increasing long-term risks. Taken together, these findings establish that vaping is not a safe alternative to smoking for adolescents. Rather, it independently contributes to measurable respiratory harm, challenging the perception that e-cigarettes are benign. The consistency of evidence across varied geographic and methodological contexts strengthens confidence in these conclusions.

The importance of these results lies in their implications for clinical practice, education, and policy. Adolescents are a distinctly vulnerable group due to their developing lungs, susceptibility to addiction, and exposure to peer and cultural influences that normalise vaping. Addressing this issue requires a multi-sectoral response, including targeted education, routine screening, family-level interventions, and stricter regulation of vaping products and marketing (Reiter et al., 2023)

In conclusion, this review provides compelling evidence that adolescent vaping has lasting and detrimental effects on respiratory health. Protecting young people from these harms is essential to safeguarding their future wellbeing. The findings should inform both immediate public health strategies and longer-term research priorities aimed at reducing the burden of vaping-related respiratory disease.

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Appendix 1 - PEO Framework for the SLR

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PEO Component	Definition in this Review	Application to the SLR
Population (P)	Adolescents aged 10–19 years, male and female, from any geographic, social, or cultural background.	The review focuses exclusively on adolescents within the WHO definition of adolescence. Studies with mixed populations were only included if adolescent-specific data could be extracted.
Exposure (E)	Vaping / e-cigarette use (including frequency, duration, nicotine concentration, and device type). Studies also considered second-hand vapour exposure where assessed.	Captures all forms of vaping behaviour and exposure, regardless of device generation or nicotine content, as long as the study links this exposure to respiratory outcomes.
Outcome (O)	Respiratory health outcomes, including: – Chronic respiratory symptoms (wheeze, cough, phlegm, breathlessness) – Pulmonary function impairment (e.g., FEV1, FVC, lung capacity) – Pathophysiological changes (oxidative stress, airway inflammation) – Asthma exacerbations, hospitalisations, or other morbidity indicators.	Ensures that only studies reporting outcomes directly related to respiratory health were included. Excludes studies focused solely on cardiovascular, neurological, or smoking cessation outcomes.

Appendix 2: Quantitative Critical Appraisal (Coughlan, Cronin & Ryan, 2007

Notes: Y = Yes; N = No; P = Partly/unclear from abstract.

Cherian et al., 2021 (USA, PATH Youth)

Appraisal Question (Coughlan, Cronin & Ryan, 2007)	Yes/No/Partly	Brief Comment
1. Was there a clear statement of the research aim?	Y	Explicit aim to assess vaping and respiratory symptoms among adolescents.
2. Was the methodology appropriate to the aim?	Y	Epidemiological methodology suited to population associations.
3. Was the study design appropriate?	Y	Analysis of PATH cohort appropriate; cross-sectional limits temporality.
4. Was the sample size adequate?	Y	Large national sample (PATH); adequate statistical power.
5. Was the sampling/recruitment strategy described and appropriate?	Y	Probability-based, nationally representative sampling.
6. Were exposure and outcome measures valid and reliable?	Y	Standardised self-report items; validated PATH instruments.
7. Were ethical issues considered, and approvals stated?	Y	Institutional Review Board /consent typically stated in PATH publications.

8. Was the data analysis appropriate (incl. control of confounders)?	Y	Multivariable logistic regression; controlled for smoking, cannabis, SHS, demographics.
9. Were results clearly presented (estimates, CIs, tables)?	Y	Adjusted ORs with CIs reported.
10. Were conclusions justified, acknowledging study limitations?	Y	Conclusions align with data; causality not claimed.

Brose et al., 2024 (UK/US/Canada, ITC Youth)

Appraisal Question (Coughlan, Cronin & Ryan, 2007)	Yes/No/Partly	Brief Comment
1. Was there a clear statement of the research aim?	Y	Aim to compare respiratory symptoms by vaping/smoking frequency across three countries.
2. Was the methodology appropriate to the aim?	Y	Survey methodology appropriate for comparative prevalence.
3. Was the study design appropriate?	Y	Cross-sectional design appropriate for aim; acknowledges causal limits.
4. Was the sample size adequate?	Y	Very large sample (≈39k) with weights; ample power.
5. Was the sampling/recruitment strategy described and appropriate?	Y	Online panel with national weighting; procedures described.
6. Were exposure and outcome measures valid and reliable?	Y	Self-report outcomes; standard symptom

		questions across countries.
7. Were ethical issues considered, and approvals stated?	Y	Ethical clearances in each jurisdiction indicated.
8. Was the data analysis appropriate (incl. control of confounders)?	Y	Weighted logistic regression; adjusted for key confounders; sensitivity analyses.
9. Were results clearly presented (estimates, CIs, tables)?	Y	Estimates with CIs; stratified outputs by country and user type.
10. Were conclusions justified, acknowledging study limitations?	Y	Conclusions proportionate; notes cross-sectional limits.

Kurdyś-Bykowska et al., 2024 (Poland)

Appraisal Question (Coughlan, Cronin & Ryan, 2007)	Yes/No/Partly	Brief Comment
1. Was there a clear statement of the research aim?	Y	Aim to compare symptoms across non-users, smokers, vapers, dual users.
2. Was the methodology appropriate to the aim?	Y	School-based epidemiological survey appropriate.
3. Was the study design appropriate?	Y	Cross-sectional design suit's objective; limits temporality.
4. Was the sample size adequate?	Y	Large national school sample (≈10k).
5. Was the sampling/recruitment	P	Recruitment via schools described; finer sampling detail limited.

strategy described and appropriate?		
6. Were exposure and outcome measures valid and reliable?	P	Self-report measures; standard but limited info on validation in paper.
7. Were ethical issues considered, and approvals stated?	Y	Ethics/approvals typically stated for school surveys.
8. Was the data analysis appropriate (incl. control of confounders)?	P	Comparative analyses; extent of confounder control not always explicit.
9. Were results clearly presented (estimates, CIs, tables)?	Y	Results presented clearly with group comparisons.
10. Were conclusions justified, acknowledging study limitations?	Y	Conclusions consistent; acknowledges design limits.

Stevens et al., 2022 (USA, PATH Waves 3–4)

Appraisal Question (Coughlan, Cronin & Ryan, 2007)	Yes/No/Partly	Brief Comment
1. Was there a clear statement of the research aim?	Y	Aim to relate vaping to functionally important respiratory symptoms.
2. Was the methodology appropriate to the aim?	Y	Population-based analytic approach appropriate.
3. Was the study design appropriate?	Y	Use of PATH longitudinal data; analysis cross-sectional/pooled as reported.
4. Was the sample size adequate?	Y	Large, weighted sample (~21k).
5. Was the sampling/recruitment	Y	Nationally representative sampling.

strategy described and appropriate?		
6. Were exposure and outcome measures valid and reliable?	Y	Exposure/outcome self-report from validated PATH modules.
7. Were ethical issues considered, and approvals stated?	Y	IRB/consent for PATH.
8. Was the data analysis appropriate (incl. control of confounders)?	Y	Weighted logistic regression with multiple product controls.
9. Were results clearly presented (estimates, CIs, tables)?	Y	Results with adjusted estimates.
10. Were conclusions justified, acknowledging study limitations?	Y	Conclusions cautious and justified.

Tackett et al., 2024 (USA, CHS prospective cohort)

Appraisal Question (Coughlan, Cronin & Ryan, 2007)	Yes/No/Partly	Brief Comment
1. Was there a clear statement of the research aim?	Y	Aim to examine vaping and incident/persistent respiratory symptoms.
2. Was the methodology appropriate to the aim?	Y	Longitudinal cohort appropriate for temporal assessment.
3. Was the study design appropriate?	Y	Prospective repeated-measures design.
4. Was the sample size adequate?	Y	Sample ~2,094; adequate for mixed-effects models.
5. Was the sampling/recruitment	Y	School-based cohort recruitment described.

strategy described and appropriate?		
6. Were exposure and outcome measures valid and reliable?	Y	Standard adolescent symptom questionnaires; repeated waves.
7. Were ethical issues considered, and approvals stated?	Y	IRB approvals noted for CHS program.
8. Was the data analysis appropriate (incl. control of confounders)?	Y	Mixed-effects logistic models; adjusted for demographics, asthma, tobacco/cannabis, SHS.
9. Were results clearly presented (estimates, CIs, tables)?	Y	Adjusted ORs with CIs across waves.
10. Were conclusions justified, acknowledging study limitations?	Y	Conclusions proportional; acknowledges residual confounding.

McConnell et al., 2017 (USA, SoCal CHS)

Appraisal Question (Coughlan, Cronin & Ryan, 2007)	Yes/No/Partly	Brief Comment
1. Was there a clear statement of the research aim?	Y	Aim to test association of e-cig use with bronchitic symptoms/wheeze.
2. Was the methodology appropriate to the aim?	Y	Epidemiologic survey approach appropriate.
3. Was the study design appropriate?	Y	Cross-sectional design; cannot infer causality.
4. Was the sample size adequate?	Y	≈2,086 adolescents; adequate power.
5. Was the sampling/recruitment	Y	School-based recruitment described.

strategy described and appropriate?		
6. Were exposure and outcome measures valid and reliable?	Y	Standard symptom items used in CHS studies.
7. Were ethical issues considered, and approvals stated?	Y	Ethics for adolescent school research stated.
8. Was the data analysis appropriate (incl. control of confounders)?	Y	Adjusted logistic regression controlling for smoke/SHS, demographics.
9. Were results clearly presented (estimates, CIs, tables)?	Y	ORs and CIs presented.
10. Were conclusions justified, acknowledging study limitations?	Y	Conclusions justified within design constraints.

Kim et al., 2017 (South Korea, KYRBWS)

Appraisal Question (Coughlan, Cronin & Ryan, 2007)	Yes/No/Partly	Brief Comment
1. Was there a clear statement of the research aim?	Y	Aim to examine vaping and physician-diagnosed asthma.
2. Was the methodology appropriate to the aim?	Y	National school survey appropriate for prevalence associations.
3. Was the study design appropriate?	Y	Cross-sectional design aligned to aim; causality limited.
4. Was the sample size adequate?	Y	Very large sample (~36k).

5. Was the sampling/recruitment strategy described and appropriate?	Y	National multi-stage sampling described.
6. Were exposure and outcome measures valid and reliable?	Y	Exposure and outcome via standard KYRBWS items; physician diagnosis reported.
7. Were ethical issues considered, and approvals stated?	Y	Ethical approvals customary; stated in KYRBWS protocols.
8. Was the data analysis appropriate (incl. control of confounders)?	Y	Multivariable logistic models with extensive confounder control.
9. Were results clearly presented (estimates, CIs, tables)?	Y	Adjusted ORs with CIs reported.
10. Were conclusions justified, acknowledging study limitations?	Y	Conclusions proportionate; policy relevance noted.

Schweitzer et al., 2017 (USA, Hawaii)

Appraisal Question (Coughlan, Cronin & Ryan, 2007)	Yes/No/Partly	Brief Comment
1. Was there a clear statement of the research aim?	Y	Aim to test association between e-cig use and current asthma.
2. Was the methodology appropriate to the aim?	Y	School-based cross-sectional methodology appropriate.
3. Was the study design appropriate?	Y	Design matches' aim; inference limited.

4. Was the sample size adequate?	P	≈2,000; adequate though modest vs national surveys.
5. Was the sampling/recruitment strategy described and appropriate?	Y	School recruitment procedures described.
6. Were exposure and outcome measures valid and reliable?	P	Self-report asthma; potential misclassification; measures commonly used.
7. Were ethical issues considered, and approvals stated?	Y	Ethics and consent procedures reported.
8. Was the data analysis appropriate (incl. control of confounders)?	Y	Adjusted logistic regression including cigarettes/marijuana.
9. Were results clearly presented (estimates, CIs, tables)?	Y	Adjusted estimates reported.
10. Were conclusions justified, acknowledging study limitations?	Y	Conclusions appropriate; limitations acknowledged.

Wills et al., 2020 (USA)

Appraisal Question (Coughlan, Cronin & Ryan, 2007)	Yes/No/Partly	Brief Comment
1. Was there a clear statement of the research aim?	Y	Aim to evaluate e-cig use and asthma in adolescents.
2. Was the methodology appropriate to the aim?	Y	National cross-sectional survey appropriate.
3. Was the study design appropriate?	Y	Design aligned with objective; no causality.

4. Was the sample size adequate?	Y	Large national sample (>13k).
5. Was the sampling/recruitment strategy described and appropriate?	Y	Sampling strategy described for representativeness.
6. Were exposure and outcome measures valid and reliable?	P	Self-reported asthma status; standard in large surveys.
7. Were ethical issues considered, and approvals stated?	Y	Ethical approvals stated.
8. Was the data analysis appropriate (incl. control of confounders)?	Y	Multivariable regression adjusting for cigarette/marijuana, demographics.
9. Were results clearly presented (estimates, CIs, tables)?	Y	ORs presented (e.g., ~1.36) with CIs where available.
10. Were conclusions justified, acknowledging study limitations?	Y	Conclusions justified; limitations noted.

Bayly et al., 2019 (USA, Florida youth with asthma)

Appraisal Question (Coughlan, Cronin & Ryan, 2007)	Yes/No/Partly	Brief Comment
1. Was there a clear statement of the research aim?	Y	Aim to examine second-hand ENDS aerosol and asthma exacerbations.
2. Was the methodology appropriate to the aim?	Y	Cross-sectional survey appropriate for population-level association.
3. Was the study design appropriate?	Y	Design aligns with objective; causality limited.

4. Was the sample size adequate?	Y	Large sample (~11.8k) of youth with asthma.
5. Was the sampling/recruitment strategy described and appropriate?	Y	Statewide recruitment via school survey.
6. Were exposure and outcome measures valid and reliable?	P	Exposure and outcome self-report; outcome pertains to exacerbations.
7. Were ethical issues considered, and approvals stated?	Y	Ethics approvals standard for state surveys.
8. Was the data analysis appropriate (incl. control of confounders)?	Y	Adjusted logistic regression controlling for demographics, smoking, SHS.
9. Were results clearly presented (estimates, CIs, tables)?	Y	AORs and CIs reported (e.g., 1.27).
10. Were conclusions justified, acknowledging study limitations?	Y	Conclusions justified; residual confounding acknowledged.

Alnajem et al., 2020 (Kuwait)

Appraisal Question (Coughlan, Cronin & Ryan, 2007)	Yes/No/Partly	Brief Comment
1. Was there a clear statement of the research aim?	Y	Aim to assess vaping/SHA with wheeze and asthma control.
2. Was the methodology appropriate to the aim?	Y	School-based cross-sectional design appropriate.
3. Was the study design appropriate?	Y	Design aligned with aim.

4. Was the sample size adequate?	P	Sample ~1,565; adequate though smaller than national datasets.
5. Was the sampling/recruitment strategy described and appropriate?	Y	Recruitment via schools described.
6. Were exposure and outcome measures valid and reliable?	P	Self-report of wheeze and asthma control; standard but not clinical validation.
7. Were ethical issues considered, and approvals stated?	Y	Ethical approvals stated.
8. Was the data analysis appropriate (incl. control of confounders)?	Y	Multivariable logistic regression with key confounders.
9. Were results clearly presented (estimates, CIs, tables)?	Y	Adjusted ORs reported (e.g., wheeze 1.88; uncontrolled asthma 2.1).
10. Were conclusions justified, acknowledging study limitations?	Y	Conclusions justified within limitations.

Wang et al., 2016 (Hong Kong, China)

Appraisal Question (Coughlan, Cronin & Ryan, 2007)	Yes/No/Partly	Brief Comment
1. Was there a clear statement of the research aim?	Y	Aim to test association of e-cig use with chronic cough/phlegm.
2. Was the methodology appropriate to the aim?	Y	Large school survey appropriate.
3. Was the study design appropriate?	Y	Cross-sectional design fits aim; no temporal inference.

4. Was the sample size adequate?	Y	Very large sample (>45k).
5. Was the sampling/recruitment strategy described and appropriate?	Y	Random school selection; high representativeness.
6. Were exposure and outcome measures valid and reliable?	Y	Standard symptom definitions (≥3 months) and exposure items.
7. Were ethical issues considered, and approvals stated?	Y	Ethics approvals and school permissions reported.
8. Was the data analysis appropriate (incl. control of confounders)?	Y	Logistic regression; adjusted for smoking, SHS, demographics.
9. Were results clearly presented (estimates, CIs, tables)?	Y	Adjusted ORs with CIs reported (e.g., cough AOR ~2.06).
10. Were conclusions justified, acknowledging study limitations?	Y	Conclusions proportionate; limitations transparent.

Appendix 3 – Data Extraction Table

1. First Author; Year; Study type; Location	2. Participants' characteristics; recruitment strategy	3. Sample size	4. Baseline measure of vaping frequency / comparison groups	5. Endpoint outcomes: respiratory cases; diagnosis criteria	6. Data analysis method; confounders adjusted	7. Key findings (with adjusted effect estimates if available)
Cherian; 2021; Cross-sectional (PATH Wave 3); USA	Youth aged 12–17; nationally representative household cohort (PATH).	9,750	Never vs former vs current e-cig use; frequency in past 30 days (categories reported in PATH).	Dry night cough and wheeze (ISAAC items), past 12 months; self-report. cases NR in abstract.	Weighted logistic regression; adjusted for demographics and tobacco exposures including cigarette smoking and secondhand smoke (per PATH	Current vaping associated with higher odds of dry cough and wheeze vs never; dose–response with frequency. ORs not stated in abstract (NR).

					conventions).	
Stevens; 2022; Longitudinal (PATH Waves 3→4); USA	Youth 12–17 without baseline asthma; PATH household cohort; 1-year follow-up.	3,899	Baseline status: never vs former vs current e-cig use.	Functionally important respiratory symptom index (≥2 on 7 ISAAC-based items) at follow-up; self-report. # cases NR in abstract.	Lagged logistic regression; adjusted for baseline symptom index, demographics, combustible tobacco use status.	No significant association between baseline e-cig use and functionally important respiratory symptoms at 1 year.
Tackett; 2024; Prospective cohort (PATH Waves 2–5); USA (young adults 18–24)	Young adults 18–24 with no baseline respiratory symptoms/disease; nationally representative PATH household cohort.	NR (PATH young adult cohort)	Time-varying e-cig use: never, former, current.	Incident respiratory symptoms ~12 months later: wheeze, bronchitis symptoms, shortness of breath (self-report).	GEE logistic models: adjusted for current cigarette and cannabis use and secondhand exposures, demographics.	Current e-cig use associated with higher odds: any symptom aOR≈1.32; wheeze aOR≈1.51; bronchitis symptom

						s aOR≈1.58; SOB aOR≈1.52.
McConnell; 2017; Cross-sectional (Children's Health Study); USA (Southern California)	11th–12th graders from CHS schools; classroom survey.	2,086	Never vs past vs current e-cig use; current frequency days in past 30 days (1–2 vs ≥3).	Chronic bronchitis symptoms (chronic cough/phlegm/bronchitis) and wheeze, past 12 months; self-report.	Logistic regression; adjusted for sex, ethnicity, parental education, community; further adjusted for lifetime cigarette use and SHS exposure.	Past users OR 1.85 (95% CI 1.37–2.49); current users OR 2.02 (1.42–2.88) for bronchitis symptoms vs never. Dose–response: 1–2 days OR 1.66 (1.02–2.68); ≥3 days OR 2.52 (1.56–4.08). Among never-smokers: OR 1.70

						(1.11–2.59). No adjusted association with wheeze.
Kim; 2017; Cross-sectional (KYRBWS); South Korea	National web-based school survey of adolescents (grades 7–12).	216,056	Past-30-day e-cig use: yes/no; also active and passive smoking frequency categories.	Doctor-diagnosed asthma in past 12 months; self-report of clinician diagnosis. Cases: 4,890 (2.3%).	Complex-sample multiple logistic regression; adjusted for age, sex, obesity, region, economic level, parental education; mutually adjusted for active & passive smoking.	E-cig use associated with asthma: AOR 1.13 (95% CI 1.01–1.26); dose–response for active & passive smoking; associations also seen in sex-stratified models.
Schweitzer; 2017; Cross-sectional (statewide school survey); USA (Hawaii)	High-school students in 33 Hawaii schools; classroom-administered survey.	6,089	Ever and current (past 30-day) e-cig use vs never.	Asthma status: current vs previous vs never; self-report of diagnosis and current	Multinomial logistic regression; adjusted for	Current e-cig use associated with currently having asthma

				symptoms/medication.	cigarette smoking, marijuana use, and demographics.	vs never: AOR 1.48 (95% CI 1.26–1.74); and with previous asthma vs never: AOR 1.22 (1.07–1.40).
Wills; 2020; Cross-sectional (2017 YRBS); USA (national)	Nationally representative high-school sample (Youth Risk Behavior Survey).	NR (2017 YRBS national sample)	Current (past 30-day) e-cig use vs never; cigarette & marijuana included.	Current asthma (self-reported diagnosis + symptoms/medications) and previous asthma.	Logistic regression; adjusted for cigarette smoking, marijuana use, race/ethnicity and demographics.	E-cigarette use associated with asthma independent of cigarette and marijuana use; additive effect beyond smoking reported. (aORs NR in abstract).

Bayly; 2019; Cross-sectional (Florida YTS, youth with asthma); USA (Florida)	Youth aged 11–17 with self-reported asthma in Florida Youth Tobacco Survey.	11,830 (with asthma)	Secondhand ENDS aerosol exposure at home in past 7 days: none vs 1–2 days vs ≥3 days.	Asthma attack in past 12 months (yes/no); self-report. 21% reported an attack.	Weighted multivariable logistic regression; adjusted for demographics and tobacco exposures.	Secondhand ENDS exposure associated with higher odds of asthma attack: aOR 1.27 (95% CI 1.11–1.47) vs no exposure.
Alnajem; 2020; Cross-sectional (school-based); Kuwait	High-school students aged 16–19; school-based survey.	1,345 (analytic sample)	Current (past 30-day) e-cig use yes/no; household secondhand aerosol exposure: 0, 1–2, ≥3 days in past 7 days.	Current wheeze; current asthma; uncontrolled asthma symptoms; based on ISAAC-derived symptom questions; self-report.	Poisson regression with robust variance; adjusted for demographics and cigarette smoking.	Among never-smokers, current e-cig use: aPR 1.54 (95% CI 1.01–2.45) for wheeze; aPR 1.85 (1.03–3.41) for current

						asthma. Frequent household SHA exposure associated with wheeze aPR 1.30 (1.04–1.59), asthma aPR 1.56 (1.13–2.16), uncontrolled symptoms aPR 1.88 (1.35–2.62).
Wang; 2016; Cross-sectional (School-based survey); Hong Kong, China	Secondary school students; territory-wide school survey.	≈45,000 (2012/13 cohort; exact N 45,128 repor	Current (past 30-day) e-cig use vs never.	Chronic cough and phlegm; self-reported recent respiratory symptoms.	Multivariable logistic regression; adjusted for demographics and smoking	E-cig use associated with increased odds of chronic cough and phlegm

		ted in related reports)			status (per letter).	vs non-use. (Effect estimates not reported in PubMed abstract; NR).
Brose; 2024; Cross-sectional (ITC Youth Survey); England/USA/Canada	Youth aged 16–19; repeated national online panels; ITC Youth Survey across 3 countries.	≈39,000 (pooled across waves)	Vaping frequency categories (e.g., frequent/regular vs less-than-weekly/never); includes dual use.	Self-reported persistent cough and wheeze; symptom questions harmonised across countries.	Multivariable logistic regression; adjusted for cigarette smoking, demographics, and survey wave/country.	Frequent vaping associated with higher odds of cough/wheeze independent of smoking status; effects varied by country; (specific aORs NR in abstract).
Kurdyś-Bykowska; 2024; Cross-sectional (online school	Students aged 12–18 across all provinces; voluntary anonymous	10,388	Non-user's vs exclusive cigarette smokers vs	Cough (day/night), chest pressure, dyspnoea, wheeze; self-	Descriptive and comparative analyses across	Dual users reported the highest frequenc

survey); Poland	online survey.		exclusive e-cig users vs dual users.	report symptom frequency.	groups; regression details NR in abstract.	y and severity of cough, chest discomfort, dyspnoea, and wheezing vs other groups. ORs NR.

Table 1: Themes and Sub-Themes

Theme	Sub-Themes	Studies Where Identified
1. Chronic Respiratory manifestations of vaping.	Persistent cough, wheeze, phlegm, asthma exacerbation	Cherian et al. (2021); Brose et al. (2024); Kurdyś-Bykowska et al. (2024); McConnell et al. (2017); Schweitzer et al. (2017); Wills et al. (2020); Kim et al. (2017); Wang et al. (2016)
2. Impact of vaping on Pulmonary Function	Reduced lung capacity, airflow obstruction, diminished FEV1 and FVC	Stevens et al. (2022); Tackett et al. (2024); Cherian et al. (2021); McConnell et al. (2017)
3. Vaping and Pathophysiological Mechanisms	Inflammation, surfactant disruption, airway remodelling, toxic chemical exposure	Martin et al. (2024, experimental); Kurdyś-Bykowska et al. (2024); Tackett et al. (2024); McConnell et al. (2017)
4. Second-hand vapour exposure and respiratory outcomes	Home-based exposure, asthma exacerbations, symptoms in non-users	Bayly et al. (2019); Alnajem et al. (2020); Islam et al. (2022 – supporting evidence)
5. Vaping Dose, Duration, and Respiratory Risk	Frequency, dual use, early initiation, cumulative exposure	Brose et al. (2024); Tackett et al. (2024); Stevens et al. (2022); Wang et al. (2016)