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Cannabis Vaping in Youth: A Systematic Review and Meta-Analysis of Risk Factors in Adolescents and Young Adults

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Abstract

Objective: The use of electronic vaporisers to deliver cannabis ('cannabis vaping') has increased rapidly among young people. This systematic review and meta-analysis aimed to summarise current evidence on the psychosocial characteristics of adolescents and young adults who vape cannabis.

Method: PubMed, PsycINFO, Scopus, and Web of Science were searched for original publications since 2003. We summarised and meta-analysed studies on adolescents (12-18 years) and young adults (19-34 years) that reported sociodemographic, mental health, and other substance use correlates of cannabis vaping.

Results: Thirty-one studies from the U.S., Canada, England, New Zealand, and Switzerland met eligibility criteria (n=568,304): twenty-six on adolescents (12-18 years; n=554,934), five on young adults (19-34 years, n=13,370). Among adolescents who currently used cannabis (n=114,595), the odds of cannabis vaping were significantly higher in males than females (7 studies; pooled OR=1.79, 95%CI=1.38-2.34); in older than younger adolescents (3 studies; pooled OR=1.26, 95%CI=1.07-1.50), in adolescents who currently use tobacco (3 studies; pooled OR=1.62, 95%CI=1.11-2.36) or alcohol (3 studies; pooled OR=2.52, 95%CI=1.27-5.01), but significantly lower in non-Hispanic Blacks than Whites (4 studies; pooled OR=0.55, 95%CI=0.39-0.77). The relationship between adolescent cannabis vaping and mental health, and factors among young adults, was inconclusive due to insufficient studies.

Conclusions: Adolescents who were male, older, non-Hispanic White, and currently using alcohol or tobacco had higher odds of vaping cannabis. Findings highlighted the need to tailor

prevention initiatives for these populations, and to conduct further research on the association

between cannabis vaping and mental health disorders.

Keywords: cannabis; vaping; mental health; young adults; adolescents; meta-analysis;

systematic review; correlates

Introduction

Cannabis use among young people is strongly associated with e-cigarette use. Previous reviews have found that adolescents and young adults who used e-cigarettes to deliver nicotine ('vaped') were 3.5 times more likely to use cannabis than those who did not vape (Chadi et al., 2019). Recently, cannabis in the form of liquid, oil, dried flower, or wax can also be vaped via a vaping device or e-cigarette, allowing for the inhalation of cannabinoids, including cannabidiol (CBD) and the psychoactive delta-9-tetrahydrocannabinol (THC). The popularity of cannabis vaping has increased among adolescents and young adults in the United States (U.S.) and Canada over the years (Wadsworth et al., 2022). A recent systematic review found a more than 5-fold increase in the past 30-day prevalence of cannabis vaping, increasing from 1.6% in 2013 to 8.4% in 2020, among U.S. and Canadian adolescents (Lim et al., 2021). The increasing prevalence of cannabis vaping in young people could be driven by the discreet and convenient delivery method, and the perception that vaping is less harmful than smoking cannabis (Fisher et al., 2025; Gartner, 2015).

Cannabis can be vaped for recreational or medical purposes, which involves vaping cannabinoids such as CBD or THC or a combination of both (Jenssen et al., 2019). THC is the primary compound that produces effects of 'euphoric high', whereas CBD is non-psychoactive and does not produce any intoxicating effects. The rising popularity of cannabis vaping has raised health concerns as people who vape cannabis are increasingly preferring products with higher potency, such as oils and concentrates, instead of traditional cannabis flower (Lim et al., 2022). The use of highly potent products is particularly concerning as it can increase the risk of acute adverse effects on psychomotor and cognitive functions (Spindle et al., 2018), mental

health (Connor et al., 2021), whereas prolonged use of high THC products also increases the risk of cannabis use disorder, compared to smoking dried cannabis (Connor et al., 2021). Due to the continued adolescence neurodevelopment until approximately 25 years of age, adolescents and young adults are more vulnerable to the effects of vaping cannabis, including impairments in executive functioning and cognition, which may extend into adulthood (Debenham et al., 2021; Lorenzetti et al., 2020).

In the U.S., although cannabis is not legally accessible to youths under the age of 21, 11.2% of adolescents (12 to 17 years) used cannabis in the past year with 63.4% vaping it; whereas 36.5% of young adults (18 to 25 years) reported using cannabis in the past year with 52.2% vaping it in 2023 (SAMHSA, 2024). Vaping cannabis is perceived to be safer than smoking because the lack of combustion results in reduced exposure to carcinogens and toxicants (Fisher et al., 2025). However, various toxic substances such as polyethylene glycols, medium-chain triglycerides and vitamin E acetate have been found in cannabis vaping products (Friedman, 2021; Guo et al., 2021). The addition of vitamin E acetate was responsible for the outbreak of e-cigarette, or vaping, associated product-use lung injury (EVALI), which resulted in over 68 deaths and more than 2,500 hospitalisations between 2019 and 2020 in the U.S. Despite the increasing prevalence of cannabis vaping among adolescents and young adults, and serious health concerns such as EVALI, there is a lack of up-to-date, comprehensive synthesis on the factors associated with cannabis vaping, as existing reviews are either focused on cannabis use (Chadi et al., 2019; Guxensa et al., 2007; Ramo et al., 2012) or dated (Harrell et al., 2022).

Given the increased risks of dependence and rising popularity of cannabis vaping among adolescents and young adults, there is a need to understand this population further. The

significant gap in the evidence base hinders our ability to allocate resources to harm reduction and preventive interventions optimally. This systematic review aimed to summarise and meta-analyse studies reporting sociodemographic, mental health, and substance use correlates of cannabis vaping among adolescents and young adults.

Methods

Reporting Guidelines

This review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) (Supplemental Table A), and Meta-Analysis of Observational Studies in Epidemiology (MOOSE) guidelines (Supplemental Table B). The review protocol can be found on PROSPERO (ref: CRD42021236725) (Chung et al., 2021). Two pre-registration deviations were made (Supplemental Table C) (Willroth & Atherton, 2024).

Study Eligibility

Our inclusion criteria were studies: 1) with a clear definition of cannabis vaping (e.g., use of an electronic vaporiser to vape herbal cannabis or oils); 2) recruiting adolescents (12-18 years old) or young adults (19-34 years old) from the general population (i.e., the age range was adopted based on definitions from the U.S. Census Bureau and the American Psychological Association (APA, 2023; Vespa, 2017)); 3) reporting sociodemographic, mental health, or substance use behavioural correlates of cannabis vaping in the form of odds ratios, or with raw prevalence data; 4) that were observational; 5) from all geographical locations. Our exclusion criteria were studies of: 1) special populations (e.g., clinical patients, studies that focused on populations prescribed with medicinal cannabis); 2) animals; 3) experimental; 4) clinical trials;

5) commentaries, reviews, conference proceedings, and qualitative; and 6) publications before

2003, the year when electronic vaping device was first patented (Lim et al., 2021).

Data Sources and Search Strategy

The initial database search was conducted on 19 August 2020 on PubMed, PsycINFO,

Scopus, and Web of Science. Search terms and controlled vocabularies (i.e., medical subject

headings (MeSH)) were used for cannabis (e.g., marijuana, marihuana), and vaping (e.g., e-cig*,

vape*), and adapted from a published meta-analysis on the prevalence of cannabis vaping (Lim

et al., 2021). A research librarian was consulted before finalising these search terms

(Supplemental Table D). A follow-up search was performed on 4 March 2024. The reference list

for all included studies, and existing cannabis reviews was manually reviewed to identify

additional studies.

Data Screening

EndNote X9 (EndNote, 2013) was used to remove duplicate records (1,242). Unique

records were imported and screened using Covidence (Covidence, 2024). Two reviewers (J.C.,

C.C.W.L.) independently examined all titles and abstracts. Preliminary screening found 319

potential studies for full-text screening. Both researchers independently screened all full texts.

Any discrepancy in screening was resolved with a discussion between the two reviewers. A

third reviewer (V.C.) was consulted to resolve conflicts.

Data Extraction

Study characteristics, including the study design, sampling strategy, population type,

timing of cannabis vaping measure, type of electronic device and cannabis product, and

correlate estimates were extracted for each included study (Table 1). Crude odds ratios were derived for studies with sufficient information (number of exposed individuals with and without the outcome, and number of unexposed individuals with and without the outcome) (Boisvert et al., 2020). Studies reporting percentages only as correlate estimates were not extracted.

Quality Assessment

The Newcastle-Ottawa Quality Assessment was adapted for cross-sectional studies to assess the risk of bias for each study (Lim et al., 2021). This scale assessed each study on five domains: i) representativeness of the study sample; ii) adequacy of sample size; iii) response rates; iv) assessment of cannabis vaping; v) appropriate reporting of correlates (Table 1).

Comparison Group

Cannabis vaping was measured as a dichotomous outcome in all studies. Studies were categorised according to their measurement timeframe on cannabis vaping (e.g., current or lifetime use), and population group (e.g., recruiting the general population or population with current cannabis use). This review defined current use as past year use, past 6-month use and past 30-day use of cannabis vaping.

Meta-Analysis

Meta-analysis was only conducted on correlates of cannabis vaping with more than three comparable estimates, based on study design, timeframe, and study population. Random effects meta-analysis was conducted using the DerSimonian and Laird method (DerSimonian & Laird, 1986). Multilevel meta-analysis was used when the included study reported more than one estimate. Heterogeneity between studies was assessed using Q-statistics and I^2. Sensitivity

analyses were conducted by identifying studies with specific timeframes and geographical location peculiarities, and excluding them from the sensitivity analyses. The trim-and-fill method was used to explore potential impacts of publication bias by estimating missing studies and adjusting the overall effect size accordingly (Shi & Lin, 2019). Meta-analysis and sensitivity analyses were performed with '*metafor*' (version 3.8.1) package in R (Viechtbauer, 2010). Code for the analysis can be found on GitHub (FloppyBirdPirate, 2024).

Results

Study Characteristics and Quality

Screening

A total of 4,689 records were retrieved (2,265 from 2020; 2,424 additional from 2024; and 45 from snowballing). After removing duplicate records, 2,214 titles were available for title and abstract screening, and 319 studies were eligible for full-text screening. Thirty-one studies met the inclusion criteria (Figure 1).

Study Characteristics

The characteristics of the 31 included studies are summarised in Table 1. Sample sizes across the studies ranged from 270 to 45,500 participants, with a cumulative total of 568,304 individuals. However, some studies were based on overlapping samples of the same year (see Table 1). Twenty-six studies focused on adolescents (12 to 18 years old or grades 6 to 12, n=554,934), and five examined young adults (19 to 34 years old, n=13,370). Twenty-five studies were conducted in the U.S., two in Canada, one in New Zealand, one in Switzerland, and two were cross-country studies of the U.S., Canada, and England populations. All of the 26 adolescent studies were either school-based surveys that were national, state representative,

or cross-country studies. The five young adult (19 to 34 years old) studies were conducted through university or army recruitment (Table 1).

Four studies had a prospective cohort design, and the remaining 27 were cross-sectional studies. Eight cross-sectional studies reported lifetime use and ten reported current use of cannabis vaping among the general population, whereas ten studies reported current cannabis vaping among people who currently use cannabis. The past 30-day cannabis vaping prevalence ranged from 1.2% to 10.5% among adolescents and 5.8% to 22.8% among young adults. All included studies were published between 2015 and 2024 (Table 1).

Study Quality

The mean study quality score was 6.25 (*SD*=1.37, range=2-8) on a scale of 1 (low quality) to 8 (high quality), indicating most studies were of moderate to high quality. Studies with a quality score of 3 or lower, based on sampling methodology, sample size, and response rate, were excluded from the meta-analysis (Table 1).

Narrative Summary and Meta-Analysis

Summary of cannabis vaping correlates were categorised into cross-sectional studies on current use (Table 2), cross-sectional studies on lifetime use (Supplemental Table E, Supplemental Figure K-N) and longitudinal studies on future initiation (Table 3). The pooled odds ratio was reported for *'sex'*, *'age'*, *'ethnicity'*, *'current tobacco use'*, and *'current alcohol use'* for current cannabis vaping among adolescents that currently use cannabis, and *'sex*, *'age'*, and *'ethnicity'* for current cannabis vaping among the general population (Supplemental Figure A-Q).

Sociodemographic Correlates

Biological Sex. Among the thirteen cross-sectional adolescent studies reporting data on sex and current cannabis vaping, nine found significantly higher odds of vaping cannabis among males than females (Table 2). Similar findings on young adults were reported in two cross-sectional and a longitudinal study (Table 2).

A meta-analysis was conducted on the six studies evaluating associations between sex and current cannabis vaping, where a significant pooled odds ratio indicated males had 1.41 times (95%CI=1.09-1.82) the odds of vaping cannabis than females (Supplemental Figure A.1). Although moderate heterogeneity was observed (I^2=50.69%, τ^2=0.09), the test for heterogeneity was non-significant ($Q(df$=5)=9.97, p=.08). A sensitivity analysis was performed by including past 30-day use only, with a similar effect size (Supplemental Figure A.2). A further trim-and-fill analysis imputed no studies (Supplemental Figure A.3).

Among individuals who currently use cannabis, a multilevel meta-analysis of seven studies on within-study variations, revealed males had 1.79 times (95%CI=1.38-2.34) higher odds of vaping cannabis than females (Supplemental Figure B.1). However, there was substantial heterogeneity (I^2=72.50%, τ^2=0.05), and the test for heterogeneity was statistically significant ($Q(df$=7)=23.55, p<.01). A sensitivity analysis was performed by excluding Ball et al.'s study (2023) due to its study location (the only study outside of North America in this analysis), but heterogeneity remained high (Supplemental Figure B.2). A further trim-and-fill analysis imputed one study, resulting in a new effect size of 1.89 (95%CI=1.47-2.43) (Supplemental Figure B.3, B.4). A meta-analysis was not conducted for young adult samples due to insufficient studies.

Age. Eight cross-sectional adolescent studies reported an association between age and cannabis vaping. All studies found higher odds of cannabis vaping in older compared to younger adolescents (Table 2). A similar observation was found in the two longitudinal studies (Table 2). However, no significant age association was found among young adults (*n*=3) (Table 2).

A meta-analysis was performed to assess the association between age and adolescent current cannabis vaping (Supplemental Figure C). The results indicated that older adolescents had 1.26 times (3 studies; 95%CI=1.07-1.50) the odds of reporting current cannabis vaping than younger adolescents. Heterogeneity was low in this analysis (I^2=0%, τ^2=0) and was non-significant (Q(df=2)=0.57, *p*=.75), which could be driven by the small number of studies. Sensitivity analyses were not performed due to insufficient studies.

Ethnicity. Eleven adolescent studies analysed the association between ethnicity and cannabis vaping. Most studies compared ethnic groups to non-Hispanic whites (Table 2). Non-Hispanic Blacks had lower odds of vaping cannabis than non-Hispanic Whites among four studies on adolescents who currently use cannabis (OR=0.50, 95%CI=0.20-1.20 to OR=0.68, 95%CI=0.30-1.51) (Table 2). However, results were inconclusive for Hispanics and Asians when compared to non-Hispanic Whites.

Meta-analyses were performed on ethnic group comparisons with more than three estimates. We found that non-Hispanic Black adolescents had lower odds of vaping cannabis than non-Hispanic Whites (4 studies; pooledOR=0.55, 95%CI=0.39-0.77) (Supplemental Figure D, E). Heterogeneity was low (I^2=0%, τ^2=0) and non-significant (Q(df=3)=0.65, *p*=.89), but could be due to the small number of studies. Additionally, non-significant associations were observed

between Asian adolescents (Supplemental Figure F) and between Hispanics (Supplemental

Figure G, H) versus non-Hispanic Whites on current cannabis vaping. Sensitivity analyses were

not performed due to insufficient studies. The only significant comparison was that non-

Hispanic Blacks were less likely to engage in cannabis vaping than non-Hispanic Whites.

Social-Economic Status (SES) and Education Status. Six studies reported the

associations between SES and cannabis vaping (Table 2). Jones et al.'s study (2016) found young

adults with higher family SES had higher odds of vaping cannabis (OR=1.36, 95%CI=1.04-1.78).

Four other adolescent studies reporting SES correlates found weak effects (Table 2). Only one

study reported that high school students had 3 times the odds of vaping cannabis (95%CI=1.60-

5.30) if they had higher student income (Ball et al., 2023). Although seven studies reported an

association between SES and cannabis vaping, it was not possible to conduct a meta-analysis

due to measurement differences.

The effect of adolescents' educational achievement was consistent across studies. Three

studies showed adolescents with lower academic achievements had higher odds of cannabis

vaping (OR=1.44, 95%CI=1.04-2.10 to OR=1.90, 95%CI=1.43-2.53) (Table 2). Additionally, Lee et

al. (2021) and Mammen et al. (2016) found adolescents had lower odds of vaping cannabis if

their father or mother completed university education compared to those whose parents did

not complete high school (OR=0.51, 95%CI=0.33-0.80 to OR=0.71, 95%CI=0.43-1.18). Patrick et

al. (2020) found that adolescents who currently use cannabis had higher odds of vaping

cannabis if they had over one parent with a university degree (OR=1.59, 95%CI=1.26-2.01).

Area of Residence. One study reported associations between U.S. state laws and cannabis vaping. Maynard et al. (2023) found non-significant results of state policy, where adolescents living in medicinal and recreational cannabis legal states had similar odds to living in cannabis prohibited states. Parks et al. (2022) reported adolescents living in rural areas had lower odds of vaping cannabis versus living in urban areas (OR=0.40, 95%CI=0.24-0.65). Smith et al.'s (2021) cross-country study found U.S. adolescents had higher odds of vaping cannabis versus living in Canada (OR=0.38, 95%CI=0.22-0.65) or England (OR=0.31, 95%CI=0.17-0.58). Adolescents living in German-speaking regions in Switzerland had higher odds of cannabis vaping than in French-speaking regions (OR=2.70, 95%CI=1.71-4.25) (Fuster et al., 2021).

Sexual Orientation. Two studies explored the association between sexual orientation and cannabis vaping. Mattingly et al. (2024) found non-significant effects of sexual orientation when comparing lesbians/ gays or bisexuals with heterosexuals. Ball et al. (2023) found adolescents who reported being attracted to the same or both sexes had 2.5 times (95%CI=1.20-5.20) the odds of vaping cannabis than heterosexuals.

Mental Health and Psychological Characteristics

A meta-analysis was not conducted on any *'mental health and psychological characteristics'* correlates due to high study heterogeneity in mental health outcomes, timeframes, and populations; therefore, results were summarised narratively.

Mental Health. Two studies summarised the associations between anxiety, depression and cannabis vaping who currently use cannabis, and reported no significant differences (Table 2). Jones et al. (2016) reported non-significant associations of young adults' cannabis vaping

with depression or anxiety, and psychotic-like experiences. Smith et al. (2021) reported similar findings: adolescents experiencing depressive or anxiety symptoms were not significantly associated with current vaping dried cannabis flowers or herbs, oils or liquids. Despite previous literature reliably showing poor mental health to be associated with cannabis use (Hall, Hoch, et al., 2019; Hudson & Hudson, 2021; Lowe et al., 2019), studies in this review found non-significant associations between cannabis vaping and depression, anxiety symptoms and psychotic-like experiences in youth.

In contrast, two studies found significant results on psychological distress and cannabis vaping. Mattingly et al. (2024) reported adolescents had higher odds of vaping cannabis if they experienced severe (OR=1.46, 95%CI=1.09-1.96) or moderate psychological distress (OR=1.22, 95%CI=0.92-1.63) compared to none. Ball et al. (2023) found similar results, where adolescents experiencing high to moderate psychological distress had higher odds of vaping cannabis than those with low levels (OR=1.80, 95%CI=1.10-3.10). Among longitudinal studies, adolescents experiencing high externalising and internalising symptoms had 1.6 (OR=1.64, 95%CI=1.32-2.05 to OR=1.66, 95%CI=1.14-2.41) and 1.5 (OR=1.49, 95%CI=1.10-2.02) times higher odds of initiating future cannabis vaping (Lee et al., 2021; Lee et al., 2023).

Attitudes/ Personal Characteristics. Three studies found young people with higher harm perception of cannabis had significantly lower odds of vaping cannabis among adolescents and young adults (OR=0.24, 95%CI=0.20-0.28 to OR=0.66, 95%CI=0.41-1.08) (Table 2). Another study found higher odds of cannabis vaping with higher impulsivity (OR=1.18, 95%CI=1.03-1.35) (Kreitzberg et al., 2019). On the other hand, three studies found a non-significant association between sensation seeking and cannabis vaping in the young adult

population (Table 2). One study found non-significant effects of self-esteem and cannabis vaping (Ball et al., 2023).

Healthy Lifestyles/ Social Media Use/ Bullying Victimisation. Jackson et al. (2020) found that engaging in any unhealthy behaviours, including intake of nutritious food, low levels of physical activities and short sleep duration, were not significantly associated with cannabis vaping. Ball et al. (2023) reported that adolescents having social media exposure in the past week had 2.5 times (95%CI=1.40-4.60) higher odds of vaping cannabis. Lee et al. (2023) demonstrated that adolescents using social media daily had 2.68 times (95%CI=2.05-3.49) the odds of initiating future cannabis vaping. Adolescents experiencing verbal or cyberbullying were also significantly associated with 1.30 times and 1.18 times the odds of cannabis vaping respectively (Boccio et al., 2022).

Alcohol, Tobacco, and Other Substance Use

Meta-analysis was only conducted on associations between *'current alcohol use,'* *'current tobacco use,'* and current cannabis vaping among adolescents, which had more than three comparable odds estimates for the timeframe and population.

Cannabis Use. Four studies reported using other forms of cannabis were positively associated with cannabis vaping among the general young adult population (OR=2.65, 95%CI=2.02-3.48), and young adult previous non-initiators of cannabis vaping (OR=4.73, 95%CI=2.64-8.84 to OR=7.78, 95%CI=3.74-16.15) and adolescents who currently use cannabis (OR=12.26, 95%CI=8.63-17.43) (Table 2). Among adolescents, Johnson et al. (2016) indicated that frequent use of other forms of cannabis was not associated with current cannabis vaping.

However, among young adults, two studies reported that more frequent use of cannabis was associated with higher odds of vaping cannabis (OR=3.68, 95%CI=2.50-5.41 to OR=3.73, 95%CI=2.40-5.81) (Table 2).

E-cigarette Use. Eight studies examined the association between e-cigarette use and cannabis vaping (Table 2). Current use of e-cigarettes was positively associated with vaping cannabis products (OR=3.66, 95%CI=1.99-6.74 to OR=7.58, 95%CI=5.88-9.77) and future initiation (OR=2.00, 95%CI=1.16-3.45 to OR=2.16, 95%CI=1.20-3.89) (Table 2). Adolescents currently engaging in exclusive nicotine e-cigarette use had higher odds of vaping cannabis oil or liquids (OR=4.96, 95%CI=2.23-11.06), but not dried cannabis or herbs (Table 2). Among young adults, frequent use of e-cigarettes was associated with higher odds of vaping cannabis (OR=1.73, 95%CI=1.30-2.30) and future initiation (OR=5.18, 95%CI=2.54-10.57) (Table 2).

Tobacco Use. Eight studies reported associations between current cigarette use and cannabis vaping (Table 2). Adolescents who currently used cigarettes had higher odds of vaping cannabis (OR=1.89, 95%CI=1.35-2.64 to OR=4.11, 95%CI=2.71-6.22) (Table 2). A multilevel meta-analysis of four adolescence studies found a pooled odds ratio of 1.62 (95%CI=1.11-2.36) (Supplemental Figure I.1). Moderate heterogeneity was observed among studies (I^2=53.88%, τ^2=0.10) but the test for heterogeneity was non-significant (Q(df=4)=8.87, p=.06). A sensitivity analysis was conducted by including past 30-day use only with a similar effect (Supplemental Figure I.2). A trim-and-fill analysis imputed no studies (Supplemental Figure I.3). Two longitudinal studies found significant positive associations between current cigarette use and future cannabis vaping initiation in adolescents (OR=2.65, 95%CI=1.10-6.35) and young adults (OR=2.23, 95%CI=1.11-4.51) respectively (Table 2).

Alcohol Use. Eight studies have examined the associations between cannabis vaping and current alcohol use, current binge drinking, ever use of alcohol, frequency of use, and alcohol use disorder (Table 2). These studies showed a positive significant relationship between adolescent current alcohol use and cannabis vaping among the general population (OR=3.92, 95%CI=2.91-5.29), those currently using cannabis (OR=1.70, 95%CI=0.72-4.03 to OR=4.80, 95%CI=2.88-8.00), and future initiation (OR=1.98, 95%CI=1.35-2.91) (Table 2). Among adolescents, our meta-analysis found a pooled odds ratio of 2.52 (95%CI=1.27-5.01) of vaping cannabis on the three studies reporting current alcohol use (Supplemental Figure J). Moderate heterogeneity was observed among studies (I^2=76.09%, τ^2=0.52), and the test for heterogeneity was significant ($Q(df$=2)=9.06, p<.05). A sensitivity analysis was not conducted due to insufficient studies. Two studies on young adults reported similar findings (Table 2).

Other Illicit Substance Use. Six studies reported associations between other illicit substance use and cannabis vaping (Table 2). These studies demonstrated a significant positive association between current other illicit substance use and cannabis vaping among adolescents currently using cannabis (OR=5.08, 95%CI=1.29-20.05), young adults currently using cannabis (OR=1.88, 95%CI=1.23-2.87) and initiating future cannabis vaping among adolescents (OR=1.17, 95%CI=0.72-1.90 to OR=1.82, 95%CI=1.44-2.31) (Table 2). Adolescents' current synthetic cannabinoid use was associated with higher odds of vaping cannabis (OR=12.65, 95%CI=3.78-42.33) (Table 2).

Family and Peer Tobacco Smoking and Vaping. Five studies summarised the effects of family and peer smoking and vaping on individuals' cannabis vaping (Table 2). They found a significant positive association between adolescent cannabis vaping, current exposure to family

smoking or vaping (OR=1.74, 95%CI=1.37-2.21), and current exposure to family smoking (OR=4.90, 95%CI=3.10-7.80) (Table 2). Lee et al. (2021, 2023) found that e-cigarette-using peers had higher odds of initiating future cannabis vaping (OR=2.31, 95%CI=1.81-2.96 to OR=2.45, 95%CI=2.03-2.95).

Access to Vaping Devices. Adolescents in the general population had 2.25 to 3.12 times (95%CI=1.37-3.71 to 95%CI=0.61-20.48) the odds of vaping cannabis if they had easy access to vaping devices (Table 2). Adolescents who currently use cannabis had 1.59 times (95%CI=0.94-2.67) and 8.85 times (95%CI=4.53-17.28) the odds of vaping cannabis if they had easy access to vaping devices and cannabis respectively (Table 2).

Discussion

This systematic review and meta-analysis highlighted key multifactorial correlates associated with youth cannabis vaping. Cannabis vaping was more common among (i) males than females, (ii) older than younger adolescents, or (iii) non-Hispanic White adolescents than non-Hispanic Black adolescents. Additionally, it was also positively associated with those who currently use (v) tobacco cigarette products, or (vi) alcohol. Associations were less clear between cannabis vaping and mental health conditions, socioeconomic status, and other ethnicities due to the limited studies. Although our review identified similar associations among young adults, such as those between biological sex, tobacco use, and e-cigarette use with cannabis vaping, the limited number of studies focusing on this population precluded the ability to draw definitive conclusions.

Our findings are in line with the literature focusing on the characteristics of youths who use cannabis. Previous reviews also suggested males had higher odds of using electronic vaporisers to vape nicotine and non-nicotine products (Harrell et al., 2022; Yoong et al., 2021). This review found that older adolescents had higher odds of vaping cannabis, which is consistent with research on the adolescent trajectory of cannabis and e-cigarette use (Chapman & Wu, 2014; Cho et al., 2021). Males also had higher odds of using cannabis than females, although there is evidence that this gap is narrowing (Mattingly et al., 2024; Maynard & Schwartz, 2023). Additionally, this review revealed that young people who used cannabis, tobacco products and other illicit substances had higher odds of vaping cannabis. This finding aligns with previous research on the co-use of tobacco, cannabis and other illicit drugs (Jackson et al., 2020; Lemyre et al., 2019). However, it remains unclear how these substances were used together, which may affect the risk of dependence and adverse outcomes. While previous studies indicated that nicotine vaping was closely associated with minimising the harms of tobacco smoking, cannabis vaping was more closely related to circumventing the social issues of cannabis smoking (Smith et al., 2021). This systematic review demonstrated that peer or family substance use, accessibility to vaping devices and low perception of harm play an essential role in cannabis vaping. Understanding adolescents' reasons and broader patterns of cannabis vaping and polysubstance use is a crucial step towards preventing adverse outcomes later in life (Connor et al., 2021).

Only a small number of studies focused on the association between cannabis vaping and mental health in youth. Adolescents had higher odds of vaping cannabis if they experienced high or severe psychological distress, or high externalising tendencies as demonstrated by

Mattingly et al.'s (2024), Ball et al.'s (2023) and Lee et al.'s (2021, 2023) studies respectively. However, Jones et al. (2016) and Smith et al.'s (2021) studies indicated mental health conditions such as anxiety, depression and psychotic-like experiences were non-significantly associated with adolescent cannabis vaping. Despite these findings, the International Cannabis Policy Study with over 27,000 adult participants, found that those who vaped cannabis were more likely to report anxiety and depression (Rup et al., 2021). Conversely, their findings indicated that bipolar disorder and psychosis were not significantly related to vaping cannabis. Further high-quality studies are needed to clarify the relationship between mental health and youth cannabis vaping, such as the potency of cannabis products used.

It is important to draw lessons from the implementation of cannabis policies in both legal and quasi-legal markets, particularly for countries considering the legalisation of cannabis. In the U.S., where recreational cannabis has been legalised in 24 states to date (NCSL, 2025), research indicated that young individuals residing in areas with a higher density of cannabis dispensaries or longer duration of legalisation, are more likely to engage in cannabis vaping (Borodovsky et al., 2016; Borodovsky et al., 2017). This trend is especially concerning given the legalisation has been associated with increased affordability and accessibility of cannabis products—factors that have contributed to a rise in cannabis use in both Canada and the U.S. (Goodman et al., 2020; Hall, Stjepanović, et al., 2019). On the other hand, in Australia, where cannabis remains illegal under federal law, a recent study found that one in three young adults would be inclined to try or use cannabis if it were legalised (Leung et al., 2021). These findings underscore the importance of ongoing surveillance and evaluation of the long-term public health impacts of cannabis policy reforms, particularly with the potential increase in cannabis

vaping among youth. This review offers directions on targeted harm reduction strategies for youth populations with a higher propensity of vaping cannabis, particularly males, older adolescents, non-Hispanic White individuals, and those who currently use alcohol or tobacco.

Limitations

Certain limitations should be considered when interpreting this study's findings. First, while this review allows for conclusions to be drawn regarding factors of cannabis vaping among adolescents, the limited number of studies that focused on young adults prevented meaningful conclusions from being drawn for this group. Future research on cannabis vaping should prioritise young adults to better understand this group and the behavioural and psychosocial factors associated with cannabis vaping in this population. This focus will help understand these changing trends and develop effective prevention and intervention strategies. Additionally, the included studies were primarily from North America, which may limit the review's generalisability to other jurisdictions where cannabis laws are more or less permissive. Moreover, this study is based on adolescents and young adults recruited from the general population, excluding studies that focused only on people who used e-cigarettes and cannabis, which may underestimate the strength of observations observed in individuals with more frequent or established use. Further, this review only includes studies that report odds ratios and raw prevalence data, which may exclude studies that report other forms of descriptive prevalence data. The majority of included studies were observational and cross-sectional, and had different adjustments for confounders, which could affect the meta-analysis estimates.

The included studies also used different definitions and measurements of cannabis vaping, contributing to heterogeneity between studies. Additionally, most included studies did not differentiate vaping of THC or CBD, which may have varied reasons for use and potential effects. Yet, the differences in sociodemographic and mental health profiles of individuals who vape CBD and THC are not clear. Furthermore, the definition of current use employed in this meta-analysis is broadly defined, ranging from past-month use to past-year use, and does not differentiate between the frequency and potency of use. This may limit the differentiation of problematic, heavy cannabis vaping and current one-time use. With the increasing momentum to legalise cannabis, and the rising potency observed in cannabis oils and concentrates, future studies need to collect more information on the cannabis products that young people are vaping and focus on identifying correlates of problematic heavy use, as well as the long-term health impacts of cannabis vaping.

Conclusions

This systematic review and meta-analysis summarised current evidence about the sociodemographic, mental health, and other substance use correlates of cannabis vaping. Adolescents who were male, older, non-Hispanic White, and currently using alcohol or tobacco had higher odds of vaping cannabis. The relationship between mental health conditions and cannabis vaping was inconclusive. This review suggests that certain populations had higher odds of vaping cannabis and provides evidence that informs policies on discouraging cannabis vaping among targeted groups of youths.

References

APA. (2023, 15/11/2023). *APA Dictionary of Psychology — adulthood*. American Psychological Association. https://dictionary.apa.org/adulthood

Ball, J., Zhang, J., Stanley, J., Boden, J., Waa, A., Hammond, D., & Edwards, R. (2023). Early-onset smoking and vaping of cannabis: Prevalence, correlates and trends in New Zealand 14-15-year-olds. Drug and Alcohol Review, *42*(3), 592–603. doi:10.1111/dar.13597. Medline

Boccio, C. M., Leal, W. E., & Jackson, D. B. (2022). Bullying victimization and nicotine and marijuana vaping among Florida adolescents. Drug and Alcohol Dependence, *237*, 109536. doi:10.1016/j.drugalcdep.2022.109536. Medline

Ewusi Boisvert, E., Bae, D., Pang, R. D., Davis, J. P., Kelley-Quon, L. I., Barrington-Trimis, J. L., et al. (2020). Subjective effects of combustible, vaporized, and edible cannabis: Results from a survey of adolescent cannabis users. Drug and Alcohol Dependence, *206*, 107716. doi:10.1016/j.drugalcdep.2019.107716. Medline

Borodovsky, J. T., Crosier, B. S., Lee, D. C., Sargent, J. D., & Budney, A. J. (2016). Smoking, vaping, eating: Is legalization impacting the way people use cannabis? The International Journal on Drug Policy, *36*, 141–147. doi:10.1016/j.drugpo.2016.02.022. Medline

Borodovsky, J. T., Lee, D. C., Crosier, B. S., Gabrielli, J. L., Sargent, J. D., & Budney, A. J. (2017). U.S. cannabis legalization and use of vaping and edible products among youth. Drug and Alcohol Dependence, *177*, 299–306. doi:10.1016/j.drugalcdep.2017.02.017. Medline

Chadi, N., Schroeder, R., Jensen, J. W., & Levy, S. (2019). Association between electronic cigarette use and marijuana use among adolescents and young adults: a systematic review and meta-analysis. JAMA Pediatrics, *173*(10), e192574–e192574. doi:10.1001/jamapediatrics.2019.2574. Medline

Carroll Chapman, S. L., & Wu, L.-T. (2014). E-cigarette prevalence and correlates of use among adolescents versus adults: a review and comparison. Journal of Psychiatric Research, *54*, 43–54. doi:10.1016/j.jpsychires.2014.03.005. Medline

Cho, J., Goldenson, N. I., Kirkpatrick, M. G., Barrington-Trimis, J. L., Pang, R. D., & Leventhal, A. M. (2021). Developmental patterns of tobacco product and cannabis use initiation in high school. Addiction (Abingdon, England), *116*(2), 382–393. doi:10.1111/add.15161. Medline

Chung, J., Lim, C., Leung, J., Sun, T., Stjepanovic, D., & Chan, G. (2021). *A Systematic Review and Meta-analysis on Sociodemographic Correlates and Risk Factors of Cannabis Vaping* (PROSPERO https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42021236725

Connor, J. P., Stjepanović, D., Le Foll, B., Hoch, E., Budney, A. J., & Hall, W. D. (2021). Cannabis use and cannabis use disorder. Nature Reviews. Disease Primers, *7*(1), 16. doi:10.1038/s41572-021-00247-4. Medline

Covidence. (2024). *Covidence systematic review software, Veritas Health Innovation*. www.covidence.org

Debenham, J., Birrell, L., Champion, K., Lees, B., Yücel, M., & Newton, N. (2021). Neuropsychological and neurophysiological predictors and consequences of cannabis and

illicit substance use during neurodevelopment: a systematic review of longitudinal studies. The Lancet. Child & Adolescent Health, *5*(8), 589–604. doi:10.1016/S2352-4642(21)00051-1. Medline

DerSimonian, R., & Laird, N. (1986). Meta-analysis in clinical trials. Controlled Clinical Trials, *7*(3), 177–188. doi:10.1016/0197-2456(86)90046-2. Medline

EndNote. (2013). *EndNote, The EndNote Team*. In Clarivate.

Fisher, J. M., Boyd, L. D., & Vineyard, J. (2025). Cannabis User Perceptions: General and Oral Health Benefits and Harms of Vaping *Versus* Smoking. Substance Use & Misuse, *60*(8), 1157–1163. doi:10.1080/10826084.2025.2491766. Medline

FloppyBirdPirate. (2024). *Cannabis vaping review*. GitHub. https://github.com/FloppyBirdPirate/Cannabis-Vaping-Review

Friedman, A. S. (2021). Association of vaping-related lung injuries with rates of e-cigarette and cannabis use across US states. Addiction (Abingdon, England), *116*(3), 651–657. doi:10.1111/add.15235. Medline

Fuster, D., Studer, J., Gmel, G., & Bertholet, N. (2021). Correlates of the use of electronic devices to vape cannabis in a cohort of young Swiss male reporting current cannabis use. European Journal of Public Health, *31*(2), 437–441. doi:10.1093/eurpub/ckaa176. Medline

Gartner, C. E. (2015). Mull it over: cannabis vaporizers and harm reduction. Addiction (Abingdon, England), *110*(11), 1709–1710. doi:10.1111/add.13139. Medline

Goodman, S., Wadsworth, E., Leos-Toro, C., & Hammond, D., & the International Cannabis Policy Study team. (2020). Prevalence and forms of cannabis use in legal vs. illegal recreational cannabis markets. The International Journal on Drug Policy, *76*, 102658. doi:10.1016/j.drugpo.2019.102658. Medline

Guo, W., Vrdoljak, G., Liao, V.-C., & Moezzi, B. (2021). Major Constituents of Cannabis Vape Oil Liquid, Vapor and Aerosol in California Vape Oil Cartridge Samples. Frontiers in Chemistry, *9*, 694905. doi:10.3389/fchem.2021.694905. Medline

Guxens, M., Nebot, M., Ariza, C., & Ochoa, D. (2007). Factors associated with the onset of cannabis use: a systematic review of cohort studies. Gaceta Sanitaria, *21*(3), 252–260. doi:10.1157/13106812. Medline

Hall, W., Hoch, E., & Lorenzetti, V. (2019). Cannabis use and mental health: risks and benefits. European Archives of Psychiatry and Clinical Neuroscience, *269*(1), 1–3. doi:10.1007/s00406-019-00986-2. Medline

Hall, W., Stjepanović, D., Caulkins, J., Lynskey, M., Leung, J., Campbell, G., & Degenhardt, L. (2019). Public health implications of legalising the production and sale of cannabis for medicinal and recreational use. Lancet, *394*(10208), 1580–1590. doi:10.1016/S0140-6736(19)31789-1. Medline

Harrell, M. B., Clendennen, S. L., Sumbe, A., Case, K. R., Mantey, D. S., & Swan, S. (2022). Cannabis vaping among youth and young adults: A scoping review. Current Addiction Reports, *9*(3), 217–234. doi:10.1007/s40429-022-00413-y. Medline

Hudson, A., & Hudson, P. (2021). Risk factors for cannabis-related mental health harms in older adults: a review. Clinical Gerontologist, *44*(1), 3–15. doi:10.1080/07317115.2020.1808134. Medline

Jackson, K. M., Sokolovsky, A. W., Gunn, R. L., & White, H. R. (2020). Consequences of alcohol and marijuana use among college students: Prevalence rates and attributions to substance-specific versus simultaneous use. Psychology of Addictive Behaviors, *34*(2), 370–381. doi:10.1037/adb0000545. Medline

Jenssen, B. P., Walley, S. C., Groner, J. A., Rahmandar, M., Boykan, R., Mih, B., et al., & the SECTION ON TOBACCO CONTROL. (2019). E-cigarettes and similar devices. Pediatrics, *143*(2), e20183652. doi:10.1542/peds.2018-3652. Medline

Kreitzberg, D. S., Hinds, J. T., Pasch, K. E., Loukas, A., & Perry, C. L. (2019). Exposure to ENDS advertising and use of marijuana in ENDS among college students. Addictive Behaviors, *93*, 9–13. doi:10.1016/j.addbeh.2019.01.012. Medline

Lee, J., Kong, G., Kassas, B., & Salloum, R. G. (2021). Predictors of vaping marijuana initiation among US adolescents: Results from the Population Assessment of Tobacco and Health (PATH) study Wave 3 (2015-2016) and Wave 4 (2016-2018). Drug and Alcohol Dependence, *226*, 108905. doi:10.1016/j.drugalcdep.2021.108905. Medline

Lee, J., Krishnan-Sarin, S., & Kong, G. (2023). Social media use and cannabis vaping initiation among US youth. Drug and Alcohol Dependence, *249*, 109949. doi:10.1016/j.drugalcdep.2023.109949. Medline

Lemyre, A., Poliakova, N., & Bélanger, R. E. (2019). The relationship between tobacco and cannabis use: a review. Substance Use & Misuse, *54*(1), 130–145. doi:10.1080/10826084.2018.1512623. Medline

Leung, J., Stjepanović, D., Dawson, D., & Hall, W. D. (2021). Do cannabis users reduce their THC dosages when using more potent cannabis products? A review. Frontiers in Psychiatry, *12*, 630602. doi:10.3389/fpsyt.2021.630602. Medline

Lim, C. C. W., Chan, G. C. K., Wadsworth, E., Stjepanović, D., Chiu, V., Chung, J. Y. C., et al. (2022). Trends and socio-demographic differences of cannabis vaping in the USA and Canada. International Journal of Environmental Research and Public Health, *19*(21), 14394. doi:10.3390/ijerph192114394. Medline

Lim, C. C. W., Sun, T., Leung, J., Chung, J. Y. C., Gartner, C., Connor, J., et al. (2022). Prevalence of adolescent cannabis vaping: a systematic review and meta-analysis of US and Canadian studies. JAMA Pediatrics, *176*(1), 42–51. doi:10.1001/jamapediatrics.2021.4102. Medline

Lorenzetti, V., Hoch, E., & Hall, W. (2020). Adolescent cannabis use, cognition, brain health and educational outcomes: A review of the evidence. European Neuropsychopharmacology, *36*, 169–180. doi:10.1016/j.euroneuro.2020.03.012. Medline

Lowe, D. J. E., Sasiadek, J. D., Coles, A. S., & George, T. P. (2019). Cannabis and mental illness: a review. European Archives of Psychiatry and Clinical Neuroscience, *269*(1), 107–120. doi:10.1007/s00406-018-0970-7. Medline

Mattingly, D. T., Agbonlahor, O., Hart, J. L., McLeish, A. C., & Walker, K. L. (2024). Psychological distress and cannabis vaping among US adolescents. American Journal of Preventive Medicine, *66*(3), 534–539. doi:10.1016/j.amepre.2023.10.013. Medline

Maynard, C. P., & Schwartz, J. (2023). Cannabis vaping among high school seniors in adult-use, medical, and prohibited legal contexts. Drug and Alcohol Dependence Reports, *6*, 100136. doi:10.1016/j.dadr.2023.100136. Medline

NCSL. (2025, March 06, 2025). *Report: State Medical Cannabis Laws*. https://www.ncsl.org/health/state-medical-cannabis-laws

Ramo, D. E., Liu, H., & Prochaska, J. J. (2012). Tobacco and marijuana use among adolescents and young adults: a systematic review of their co-use. Clinical Psychology Review, *32*(2), 105–121. doi:10.1016/j.cpr.2011.12.002. Medline

Rup, J., Freeman, T. P., Perlman, C., & Hammond, D. (2021). Cannabis and mental health: Prevalence of use and modes of cannabis administration by mental health status. Addictive Behaviors, *121*, 106991. doi:10.1016/j.addbeh.2021.106991. Medline

SAMHSA. (2024). Key substance use and mental health indicators in the United States: Results from the 2023 National Survey on Drug Use and Health. *HHS Publication No. PEP24-07-021, NSDUH Series H-59*, 11-15. https://www.samhsa.gov/data/sites/default/files/reports/rpt47095/National%20Report/National%20Report/2023-nsduh-annual-national.pdf

Shi, L., & Lin, L. (2019). The trim-and-fill method for publication bias: practical guidelines and recommendations based on a large database of meta-analyses. Medicine, *98*(23), e15987. doi:10.1097/MD.0000000000015987. Medline

Smith, D. M., Kozlowski, L., O'Connor, R. J., Hyland, A., & Collins, R. L. (2021). Reasons for individual and concurrent use of vaped nicotine and cannabis: their similarities, differences, and association with product use. Journal of Cannabis Research, *3*(1), 39. doi:10.1186/s42238-021-00097-7. Medline

Spindle, T. R., Cone, E. J., Schlienz, N. J., Mitchell, J. M., Bigelow, G. E., Flegel, R., et al. (2018). Acute effects of smoked and vaporized cannabis in healthy adults who infrequently use cannabis: a crossover trial. JAMA Network Open, *1*(7), e184841–e184841. doi:10.1001/jamanetworkopen.2018.4841. Medline

Vespa, J. (2017). *The Changing Economics and Demographics of Young Adulthood: 1975–2016*. https://www.census.gov/content/dam/Census/library/publications/2017/demo/p20-579.pdf

Viechtbauer, W. (2010). Conducting meta-analyses in R with the metafor package. Journal of Statistical Software, *36*(3), 1–48. https://www.jstatsoft.org/article/view/v036i03/409. doi:10.18637/jss.v036.i03.

Wadsworth, E., Craft, S., Calder, R., & Hammond, D. (2022). Prevalence and use of cannabis products and routes of administration among youth and young adults in Canada and the United States: A systematic review. Addictive Behaviors, *129*, 107258. doi:10.1016/j.addbeh.2022.107258. Medline

Willroth, E. C., & Atherton, O. E. (2024). Best laid plans: A guide to reporting preregistration deviations. Advances in Methods and Practices in Psychological Science, *7*(1), 25152459231213802. doi:10.1177/25152459231213802.

Yoong, S. L., Hall, A., Leonard, A., McCrabb, S., Wiggers, J., Tursan d'Espaignet, E., et al. (2021). Prevalence of electronic nicotine delivery systems and electronic non-nicotine delivery systems in children and adolescents: a systematic review and meta-analysis. The Lancet. Public Health, *6*(9), e661–e673. doi:10.1016/S2468-2667(21)00106-7. Medline

Tables

Table 1. Included Studies and Quality Assessment

i.   *Cross-sectional Studies on the General Population, Current Cannabis Vaping (Within the Past Year) (10 studies)*

Study	Country	Cohort, Study Design	Sampling	RR (%)	Sample size	Year	Timing	Prevalence	Reported measurement	Age	NoS[a]	Correlates and/or risk factors assessed in each study
Boccio (2022a)	USA, Florida	FYSAS, CS	-[b]; school survey	-[b]	9,800	2019	30d	8.01%	Cannabis	10-19	5	Bullying victimisation
Dai (2020)	USA, National	MTF, CS	Multi-stage cluster; school survey	87.0	14,560	2017	30d	3.6%, (95% C.I. = 3.2-3.9%)	Cannabis	Grade 8-12	7	Sex, age, ethnicity, tobacco use
Jackson (2020)	USA, National	MTF, CS	Multi-stage cluster; school survey	75.9	10,047	2017	30d	3.05%	Cannabis	Grade 8 and 10	7	Risky health behaviours
Kreitzberg (2019)	USA, Texas	M-PACT, CS	Convenience; undergraduates	81.0	5,482	2015, 2016	6m	10%	Cannabis	21.4 (SD=2.3)	6	Sex, ethnicity, age, tobacco use, cannabis use, personal characteristics
Mammen (2016)	Canada, Ontario	OSDUHS, CS	Multi-stage cluster; school survey	60.0	3,171	2015	12m	8.2%, [257/3,146]	Cannabis, hash oils, liquids or waxes	15-18	5	Sex, age, ethnicity, SES, education
Mattingly (2024)	USA, National	NYTS, CS	Multi-stage cluster; school survey	76.1	37,172	2022	30d	7.6%	Cannabis	11-18	7	Sex, age, ethnicity, education, peer use, tobacco use, e-cigarette use, mental health, sexual orientation
Maynard (2023)	USA, National	MTF, CS	Multi-stage cluster; school survey	79.0	3,770	2020	12m	Medical use legal state: 27% Prohibited and recreational use legal state: 19%	Cannabis	Grade 12	7	Sex, ethnicity, SES, state policy, attitudes, opportunities
Parks (2022)	USA, National	MTF, CS	Multi-stage cluster; school survey	-[b]	41,737	2017-19	30d	8.3%	Cannabis	Grade 12	6	Sex, ethnicity, education, SES, country, alcohol use, tobacco use, opportunities, attitudes

Study	Country	Cohort, Study Design	Sampling	RR (%)	Sample size	Year	Timing	Prevalence	Reported measurement	Age	NoS[a]	Correlates and/or risk factors assessed in each study
Peters (2018)[c]	USA, Los Angeles	HHS, CS	Convenience; school survey	93.5	3,177	2015	30d	10.5%, [333/3,177]	THCs, hash oils, dabbing, liquid pots	Grade 10	7	Sex, ethnicity
Tai (2020)	USA, National	MTF, CS	Multi-stage cluster; school survey	79.0-83.0	41,600-45,500 (Grade 8 to 12)	2014-2018 (Grade 8-12)	30d	Grade 12 total cannabis use (21.3-22.9%); Using vaporisers as RoA (19.8-34.5%)	Cannabis concentrates, waxes, THCs, or hash oils	Grade 12	8	E-cigarette use, other illicit drug use

ii.   Cross-sectional Studies on the General Population, Lifetime Ever Cannabis Vaping (8 studies)

Study	Country	Cohort, Study Design	Sampling	RR (%)	Sample size	Year	Timing	Prevalence	Reported measurement	Age	NoS[a]	Correlates and/or risk factors assessed in each study
Boccio (2022b)	USA, Florida	FYSAS, CS	Two-stage cluster; school survey	-[b]	27,126	2020	LT	22.31%	Cannabis	10-19	5	Sex, ethnicity, country, mental health, alcohol use
Eggers (2017)	USA, Florida	FYTS, CS	-[b]; school survey	-	12,320	2015	LT	High school: 11.5%; Middle school: 3.4%	Cannabis oils	Grade 6-12	6	Sex, age, ethnicity, tobacco use
Frohe (2018)	USA, Northeastern states	-[b], CS	Convenience; undergraduates	84.4	270	2016	LT	10.7%	Cannabis	18–22	2	Reason of cannabis vaping, alcohol use, peer use, cannabis use
Jackson (2019)	USA, National	MTF, CS	Multi-stage cluster; school survey	75.9	10,047	2017	LT	7.5%	Cannabis	Grade 8 and 10	6	Delinquent acts
Kowitt (2019)	USA, North Carolina	NCYTS, CS	Multi-stage cluster; school survey	64.5	2,835	2017	LT	9.6%, [253/2,835]	Cannabis, THCs, hash oils, or waxes	Grade 6-12	6	Sex, age, ethnicity, tobacco use, e-cigarette-use
Morean (2015)	USA, Connecticut	-[b], CS	Convenience; school survey	100.0	3,847	2014	LT	5.4%, (Herbs: 6.7%; Oil: 4.5%; Wax: 3.0%)	Dried cannabis, waxes, hash oils or others	16.0 (SD=1.26)	6	Sex, age, SES, e-cigarette use

Study	Country	Cohort, Study Design	Sampling	RR (%)	Sample size	Year	Timing	Prevalence	Reported measurement	Age	NoS[a]	Correlates and/or risk factors assessed in each study
Peters (2018)[c]	USA, Los Angeles	HHS, CS	Convenience; school survey	93.5	3,177	2015	LT	10.5%, [333/3,177]	THCs, hash oils, dabbing, liquid pots	Grade 10	7	Sex, ethnicity
Taleb (2020)	USA, National	NYTS, CS	Multi-stage cluster; school survey	68.2	10,680	2018	LT	26.2%, (95% C.I. = 25.17–27.23%)	Cannabis concentrates, waxes, THCs, or hash oils	Grade 6-12	7	Sex, age, ethnicity, tobacco use, e-cigarette use, characteristics

iii.   *Cross-sectional Studies on Population that Uses Cannabis, Current Cannabis Vaping (Within the Past Year) (10 studies)*

Study	Country	Cohort, Study Design	Sampling	RR (%)	Sample size	Year	Timing	Prevalence	Reported measurement	Age	NoS[a]	Correlates and/or risk factors assessed in each study
Ball (2023)	New Zealand, National	YIS, CS	Two-stage cluster; school survey	65, 64, 59	11,445 (pooled)	2012, 2014-16, 2018	30d	2.5%, (95%CI = 2.0-3.0%)	Cannabis or hash oils	14-15	8	Sex, age, ethnicity, SES, sexual orientation, family tobacco use, social media use, personal characteristics, social connectedness, mental health
Boisvert (2020)	USA, Los Angeles	HHS, CS	Convenience; school survey	82.8	3,177	2015	6m	4.5%, [144/3,177]	Cannabis	15-16	5	Sex, ethnicity, SES, cannabis use
Fuster (2021)	Switzerland, National	C-SURF, CS	Convenience; army recruits	73.0	7,556	2016-18	12m	5.8%	Illegal cannabis, flowers, haschisch, cannabis oil, wax, BHO	25.38 (SD= 1.20)	7	Age, education, linguistic region, alcohol use, tobacco use, cannabis use, other illicit drug use, cannabis use disorder, personal characteristics
Hammond (2021)	USA, Canada, England	ITC, CS	Mixed-sampling; consumer panel	3.7, 2.3, 1.6	12,128, 11,753, 11,609	2017, 2018, 2019	30d	-[b]	Dried cannabis leaves or herbs, oils or liquids	16-19	7	Country, state policy

Study	Country	Cohort, Study Design	Sampling	RR (%)	Sample size	Year	Timing	Prevalence	Reported measurement	Age	NoS[a]	Correlates and/or risk factors assessed in each study
Johnson (2016)	USA, Colorado	HKCS, CS	Multi-stage stratified; school survey	58.2	25,197	2013	30d	Total cannabis use (19.7%, 95% C.I. = 18.7-20.6%); Using vaporisers as RoA (6.2%, 95% C.I. = 4.2-8.2%)	Cannabis	Grade 9-12	5	Sex, age, ethnicity, cannabis use, tobacco use, alcohol use
Jones (2016)	USA, Southwestern states	-[b], CS	Random; psychology students	-[b]	482	2016	12m	22.5%, [110/482]	Cannabis	19.55 (SD=2.78)	3	Sex, age, SES, tobacco use, e-cigarette use, alcohol use, cannabis use, other illicit drug use, reason of cannabis vaping, attitudes, mental health
Kolar (2020)	Canada, Ontario	OSDUHS, CS	Two-stage cluster; school survey	61.0	3,289	2017	12m	25.8% , (95%CI = 20.1%-32.5%)	Cannabis	13-20	7	Sex, age, SES, alcohol use, tobacco use
Kritikos (2021)	USA, National	MTF, CS	Multi-stage stratified; school survey	86-88	14,836	2018	30d	Grade 8: 2.7%; Grade 10: 7.2%	Cannabis	Grade 8 and 10	7	Sex, age, ethnicity, education, alcohol use, tobacco use, other illicit drug use, opportunities, attitudes, delinquent acts
Patrick (2020)	USA, National	MTF, CS	Multi-stage stratified; school survey	80.7	9,097	2015-18	12m	Total cannabis use (32.9%); Using vaporisers as RoA (34.1%)	THC, hash oils, dabbing, liquid pots	Grade 12	7	Sex, ethnicity, SES
Smith (2020)	USA, Canada, England	ITC, CS	Mixed-sampling; consumer panel	63.9-79.2	12,064	2017	30d	Total cannabis use (12.5%, 95% C.I. = 11.3-13.7%); Using vaporisers as RoA (16.6%-17.1%)	Dried cannabis leaves or herbs; cannabis oils or liquids	16-19	6	Sex, age, ethnicity, country, mental health, alcohol use, attitudes, tobacco use, e-cigarette use

iv.   Cohort Studies on Cannabis Vaping Initiation (4 studies)

Study	Country	Cohort, Study Design	Sampling	RR (%)	Sample size	Year	Timing	Prevalence of cannabis vaping	Reported measurement	Age	NoS[a]	Correlates and/or risk factors assessed in each study
Bentivegna (2017)	USA, National	PATH, PC	-[b]; household survey	-[b]	13,651	2013-16	LT	-[b]	Cannabis, cannabis concentrates, waxes, THC, or hash oils	12-17	7	E-cigarette use
Cassidy (2018)	USA, Northeastern states	-[b], PC	Convenience; Facebook users	79.3	1,342	2016	LT	22.8%, [301/1,342]	Cannabis concentrates (e.g., dab, hash oil)	18.6 (SD=0.51)	5	Sex, tobacco use, cannabis use, e-cigarette use, personal characteristics
Lee (2021)	USA, National	PATH, PC	-[b]; household survey	83.8, 79.5	7,842	2015-16, 2017-18	LT	6.8% reported initiation at subsequent wave	Cannabis, cannabis concentrates, waxes, THC, or hash oils	12-17	8	Sex, age, ethnicity, education, alcohol use, tobacco use, cannabis use, other illicit drug use, peer use, mental health
Lee (2023)	USA, National	PATH. PC	Multi-stage cluster; household survey	72.3, 79.5	8,357	2016-17, 2018-19	LT	14.0% (weighted; n=1183) reported initiation at subsequent wave	Cannabis, cannabis concentrates, waxes, THC, or hash oils	12-17	8	Social media use, age, e-cigarette use, cannabis use, other illicit drug use, peer use, mental health, exposure to ads

Abbreviations: **BRFSS**, Behavioral Risk Factor Surveillance System; **C-SURF**, Cohort Study on Substance Use Risk Factors; **FYSAS**, Florida Youth Substance Abuse Survey; **FYTS**, Florida Youth Tobacco Survey**; HHS**, Happiness and Health Study; **HKCS**, Health Kids Colorado Survey; **ITC**, International Tobacco Control Survey; **M-PACT**, Marketing and Promotions across Colleges in Texas; **MTF**, Monitoring the Future**; NCYTS**, North Carolina Youth Tobacco Survey; **NYTS**, National Youth Tobacco Survey; **OSDUHS**, Ontario Student Drug Use and Health Survey; **PATH**, Population Assessment of Tobacco and Health; **YIS**, Youth Insights Survey

CS, Cross-sectional; **PC**, Prospective cohort; **NoS**, Newcastle-Ottawa Scale; **RR**, Response Rates; **LT**, Lifetime; **12m**, 12-month; **6m**, 6-month; **30d**, 30-day; **SES**, Socioeconomic status; **RoA**, Route of administration

[a] Quality assessment was based on the modified Newcastle-Ottawa for cross-sectional studies

[b] Not specified in the study, or available somewhere else

[c] Peters (2018) reported both lifetime ever use and past 30 days current use of cannabis vaping

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Table 2. Correlates of Current Cannabis Vaping (Cross-sectional Studies)

i. Adolescents in the General Population

Exposure (Comparison)	k (ref)	Effect size [95%CI]	Pooled effect size [95%CI]	Q (p-value), I^2	Conclusions
Socio-demographic correlates					
I. Sex					
Male (Female)	6 (Dai 2020, Mammen 2016, Mattingly 2024, Maynard 2023, Parks 2022, Peters 2018)	OR=0.85 [0.66-1.10] to 2.21 [1.46-3.35]	**OR=1.41 [1.09-1.82], p<.01**	9.97 (p=.076), 50.69%	Higher odds among adolescent males
II. Age					
Grade 10/ Age 14-15 (Grade 8/ Age 11-13)	2 (Dai 2020, Mattingly 2024)	OR= 2.30 [1.60-3.10] to 5.30 [3.59-7.80]	--	--	--
Grade 12/ Age 16-18 (Grade 8/ Age 11-13)	2 (Dai 2020, Mattingly 2024)	OR=2.10 [1.50-2.90] to 9.05 [6.18-13.26]	--	--	--
Age (as continuous variable)	1 (Mammen 2016)	OR=1.36 [1.16-1.58]	--	--	--
III. Ethnicity					
Non-Hispanic Black (Non-Hispanic White)	4 (Dai 2020, Mattingly 2024, Maynard 2023, Parks 2022)	OR=0.60 [0.30-1.00] to 1.06 [0.75-1.48]	OR=0.85 [0.63-1.15], p>.05	2.97 (p=.396), 20.7%	Inconclusive
Hispanic (Non-Hispanic White)	3 (Dai 2020, Mattingly 2024, Parks 2022)	OR=1.10 [0.80-1.50] to 1.29 [0.83-2.01]	OR=1.20 [0.98-1.48], p>.05	0.53 (p=.77), 0.0%	Inconclusive
Asians (Non-Hispanic White)	2 (Parks 2022, Peters 2018)	OR=0.35 [0.18-0.68] to 1.08 [0.57-2.05]	--	--	--
Others (Non-Hispanic White)	3 (Dai 2020, Mattingly 2024, Parks 2022)	OR=0.48 [0.28-0.83] to 1.80 [1.19-2.70]	OR=1.06 [0.50-2.25], p>.05	14.96 (p<.05), 90.3%	Inconclusive
IV. Socio-economic status					
Level of assets: High (Low)	1 (Parks 2022)	OR=0.16 [0.08-0.31]	--	--	--
Household median income	1 (Mammen 2016)	OR=0.97 [0.86-1.10]	--	--	--
V. Education/ Parental education					
School grades: mostly B's (mostly A's)	1 (Mattingly 2024)	OR=1.45 [0.97-2.17]	--	--	--
School grades: mostly C's/ D's/ E's (mostly A's)	1 (Mattingly 2024)	OR=1.90 [1.43-2.53]	--	--	--

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Father's education: with degree (no high school)	1 (Mammen 2016)	OR=0.71 [0.43-1.18]	--	--	--
Mother's education: with degree (no high school)	1 (Mammen 2016)	OR=0.51 [0.33-0.80]	--	--	--
VI. Area of residence					
Small city (Urban)	1 (Parks 2022)	OR=0.91[0.63-1.32]	--	--	--
Rural (Urban)	1 (Parks 2022)	OR=0.40 [0.24-0.65]	--	--	--
State policy: Medically legal (Prohibited)	1 (Maynard 2023)	OR=1.74 [0.49-6.22]	--	--	--
State policy: Recreationally legal (Prohibited)	1 (Maynard 2023)	OR=1.10 [0.46-2.60]	--	--	--
VII. Sexual orientation					
Lesbian/gay (Heterosexual)	1 (Mattingly 2024)	OR=1.22 [0.81-1.84]	--	--	--
Bisexual (Heterosexual)	1 (Mattingly 2024)	OR=1.12 [0.81-1.55]	--	--	--
Mental health and psychological correlates					
I. Mental health					
Psychological distress (PHQ-4): Severe (None)	1 (Mattingly 2024)	OR=1.46 [1.09-1.96]	--	--	--
Psychological distress: Moderate (None)	1 (Mattingly 2024)	OR=1.22 [0.92-1.63]	--	--	--
Psychological distress: Mild (None)	1 (Mattingly 2024)	OR=1.16 [0.83-1.62]	--	--	--
II. Attitudes					
Harm perception of regular cannabis use: High (Low)	1 (Maynard 2023)	OR=0.24 [0.20-0.28]	--	--	--
III. Healthy lifestyles					
Low health foods consumption (High)	1 (Jackson 2020)	OR=1.13 [0.63-2.00]	--	--	--
Low physical exercise (High)	1 (Jackson 2020)	OR=1.18 [0.63-2.21]	--	--	--
Short sleep duration (Long)	1 (Jackson 2020)	OR=1.33 [0.79-2.26]	--	--	--
Any risky healthy lifestyles	1 (Jackson 2020)	OR=1.19 [0.80-1.79]	--	--	--

IV. Bullying victimisation					
Physical Bullying	1 (Boccio 2022a)	OR=1.18	--	--	--
Verbal Bullying	1 (Boccio 2022a)	OR=1.30	--	--	--
Cyber Bullying	1 (Boccio 2022a)	OR=1.73	--	--	--
Substance use behavioural correlates					
I. Cannabis use					
Ever blunt use (None)	1 (Mattingly 2024)	OR=13.50 [10.53-17.32]	--	--	--
II. E-cigarette use					
Current use (None)	2 (Mattingly 2024, Tai 2020)	OR=3.66 [1.99-6.74] to 7.58 [5.88-9.77]	--	--	--
III. Tobacco use					
Current cigarette use (None)	2 (Mattingly 2024, Parks 2022)	OR=1.89 [1.35-2.64] to 4.11 [2.71-6.22]	--	--	--
Current use >= 1/2 pack per day (None)	1 (Dai 2020)	OR=18.60 [10.00-34.30]	--	--	--
IV. Alcohol use					
Current use (None)	1 (Parks 2022)	OR=3.92 [2.91-5.29]	--	--	--
Current binge drinking (None)	1 (Parks 2022)	OR=1.81[1.32-2.50] to	--	--	--
V. Other illicit substance use					
Current synthetic cannabinoid use (None)	1 (Tai 2020)	OR=12.65 [3.78-42.33]	--	--	--
VI. Opportunity					
Easy to obtain vaping devices (Not easy)	2 (Maynard 2023, Parks 2022)	OR=2.25 [1.37-3.71] to 3.12 [0.61-20.48]	--	--	--
VII. Peer/ Family substance use					
Current family smoking/vaping (None)	1 (Mattingly 2024)	OR=1.74 [1.37-2.21]	--	--	--

ii.   Young Adults in the General Population

Exposure (Comparison)	k (ref)	Effect size [95%CI]	Conclusions
Socio-demographic correlates			
I. Sex			
Male (Female)	1 (Kreitzberg 2019)	OR=1.30 [1.20-1.50]	--
II. Age			
Age (as continuous variable)	1 (Kreitzberg 2019)	OR=1.12 [1.01-1.25]	--
III. Personal characteristics			
Sensation seeking	1 (Kreitzberg 2019)	OR=1.00 [0.88-1.14]	--
Impulsivity	1 (Kreitzberg 2019)	OR=1.18 [1.03-1.35]	--
Substance use behavioural correlates			
I. Cannabis use			
Current other cannabis use (None)	1 (Kreitzberg 2019)	OR=2.65 [2.02-3.48]	--
II. Tobacco use			
Current cigarette use (None)	1 (Kreitzberg 2019)	OR=1.84 [1.43-2.36]	--

iii. Adolescent Population that Use Cannabis

Exposure (Comparison)	k (ref)	Effect size [95%CI]	Pooled effect size [95%CI]	Q (p-value), I^2	Conclusions
Socio-demographic correlates					
I. Sex					
Male (Female)	7 (Ball 2023, Boisvert 2020, Johnson 2016, Kolar 2020, Kritikos 2021, Patrick 2020, Smith 2020[a])	OR=1.10 [0.70-1.60] to 3.10 [2.20-4.50]	**OR=1.79 [1.38-2.34], p<.001**	23.55 (p<.05), 72.5%	Increased odds among adolescent males
II. Age					
Grade 12 (Grade 9)	2 (Johnson 2016, Kolar 2020)	OR=1.37 [0.45-4.17] to 2.80 [1.50-5.00]	--	--	--
Grade 10/ Age 15 (Grade 8-9/ Age 14)	3 (Ball 2023, Johnson 2016, Kritikos 2021)	OR=1.23 [1.02-1.48] to 1.50 [0.90-2.50]	**OR=1.26 [1.07-1.50], p<.01**	0.57 (p=.75), 0%	Increased odds among older adolescents
Age (as continuous variable)	1 (Smith 2020[a])	OR=1.19 [0.94-0.50] to 1.58 [1.21-2.05]	--	--	--
III. Ethnicity					
Non-Hispanic Black (Non-Hispanic White)	4 (Boisvert 2020, Johnson 2016, Kritikos 2021, Patrick 2020)	OR=0.50 [0.20-1.20] to 0.68 [0.30-1.51]	**OR=0.55 [0.39-0.77], p<.001**	0.65 (p=.89), 0%	Decreased odds in black compared to white adolescents
Hispanic (Non-Hispanic White)	4 (Boisvert 2020, Johnson 2016, Kritikos 2021, Patrick 2020)	OR=0.30 [0.20-0.70] to 1.12 [0.76-1.66]	OR=0.76 [0.44-1.32], p>.05	13.55 (p<.01), 83.3%	Inconclusive
Asians (Non-Hispanic White)	4 (Ball 2023, Boisvert 2020, Johnson 2016, Patrick 2020)	OR=0.10 [0.10-0.30] to 2.60 [1.00-6.80]	OR=0.52 [0.12-2.20], p>.05	67.87 (p<.01), 95.5%	Inconclusive
White (Non-white)	1 (Smith 2020[a])	OR=0.73 [0.46-1.15] to 0.77 [0.49-1.22]	--	--	--
IV. Socio-economic status (SES)					
Family SES/ Perceived SES	2 (Boisvert 2020, Kolar 2020)	OR=1.01 [0.81-1.26] to 1.06 [0.73-1.54]	--	--	--
Student income: Over $50/week ($10 or less)	1 (Ball 2023)	OR=3.00 [1.60-5.30]	--	--	--
1st Generation Immigrant (3rd Generation immigrant or longer)	1 (Kolar 2020)	OR=0.37 [0.17-0.80]	--	--	--

V. Education/ Parental education

Low grade point average	1 (Kritikos 2021)	OR=1.44 [1.04-2.10]	--	--	--
Post-secondary schooling (Primary schooling)	1 (Fuster 2021)	OR=0.37 [0.16-0.86]	--	--	--
Vocational training (Primary schooling)	1 (Fuster 2021)	OR=0.41 [0.17-0.99]	--	--	--
>= 1 parent with degree (< 1)	1 (Patrick 2020)	OR=1.59 [1.26-2.01]	--	--	--

VI. Area of residence

Canada (U.S.)	1 (Smith 2021[a])	OR=0.38 [0.22-0.65] to 0.71 [0.42-1.21]	--	--	--
England (U.S.)	1 (Smith 2021[a])	OR=0.31 [0.17-0.58] to 0.26 [0.14-0.49]	--	--	--

VII. Language

German speaking (French speaking)	1 (Fuster 2021)	OR=2.70 [1.71-4.25]	--	--	--

VIII. Sexual orientation

Same or both sexes attracted (Opposite sex)	1 (Ball 2023)	OR=2.50 [1.20-5.20]	--	--	--

Mental health and psychological correlates

I. Mental health

Depression	1 (Smith 2021[a])	OR=0.98 [0.88-1.10] to 1.08 [0.97-1.20]	--	--	--
Anxiety	1 (Smith 2021[a])	OR=1.02 [0.92-1.14] to 1.04 [0.93-1.17]	--	--	--
Psychological distress (MHI-5): High/ moderate (Low)	1 (Ball 2023)	OR=1.80 [1.10-3.10]	--	--	--

II. Attitudes

Harm perception of cannabis smoking: High (Low)	1 (Smith 2021[a])	OR=1.00 [0.99-1.02] to 1.01 [0.99-1.03]	--	--	--
Harm perception of regular cannabis use: High (Low)	1 (Kritikos 2021)	OR=0.66 [0.41-1.08]	--	--	--
Harm perception of regular cannabis use: Occasion (Low)	1 (Kritikos 2021)	OR=0.66 [0.41-1.05]	--	--	--

Harm perception of vaping nicotine: High (Low)	1 (Kritikos 2021)	OR=1.09 [0.68-1.73]	--	--	--
Approval of nicotine vaping: No (Yes)	1 (Kritikos 2021)	OR=0.64 [0.43-0.94]	--	--	--
III. Personal characteristics					
Self-esteem: Low/ moderate (High)	1 (Ball 2023)	OR=1.30 [0.80-2.10]	--	--	--
IV. Healthy lifestyle					
Past week social media exposure (None)	1 (Ball 2023)	OR=2.50 [1.40-4.60]	--	--	--
Social connectedness: Low (Moderate/ High)	1 (Ball 2023)	OR=1.50 [0.90-2.60]	--	--	--
Substance use behavioural correlates					
I. Cannabis use					
Current other cannabis use (None)	1 (Boisvert 2020)	OR=12.26 [8.63-17.43]	--	--	--
Higher frequency of use (Less)	1 (Johnson 2016)	OR=1.20 [0.70-2.00]	--	--	--
II. E-cigarette use					
Current use (None)	1 (Smith 2021[a])	OR=1.71 [0.73-4.01] to 4.96 [2.23-11.06]	--	--	--
III. Tobacco use					
Current cigarette use (None)	4 (Johnson 2016, Kolar 2020, Kritikos 2021, Smith 2021[a])	OR= 1.00[0.60-1.50] to 2.77 [1.68-4.57]	**OR=1.62 [1.11-2.36], p<.05**	8.87 (p>.05), 53.9%	Increased odds among adolescents who currently use tobacco cigarettes
IV. Alcohol use					
Current use (None)	3 (Johnson 2016, Kolar 2020, Kritikos 2021)	OR=1.70 [0.72-4.03] to 4.80 [2.88-8.00]	**OR=2.52 [1.27-5.01], p<.01**	9.06 (p<.05), 76.1%	Increased odds among adolescents who currently use alcohol
Ever use (None)	1 (Smith 2021[a])	OR=0.54 [0.27-1.08] to 0.74 [0.34-1.61]	--	--	--
Current binge drinking (None)	1 (Kritikos 2021)	OR=3.67 [2.56-5.26]	--	--	--
V. Other illicit substance use					
Current illicit substance use (None)	1 (Kritikos 2021)	OR=5.08[1.29-20.05]	--	--	--

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VI. Opportunity					
Easy to obtain vaping device (Not easy)	1 (Kritikos 2021)	OR=1.59 [0.94-2.67]	--	--	--
Easy to obtain cannabis (Not easy)	1 (Kritikos 2021)	OR=8.85 [4.53-17.28]	--	--	--
VII. Peer/ Family substance use					
Current exposure to tobacco smoking at home (None)	1 (Ball 2023)	OR=4.90 [3.10-7.80]	--	--	--

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iv. Young Adult Population that Use Cannabis

Exposure (Comparison)	k (ref)	Effect size [95%CI]	Conclusions
Socio-demographic correlates			
I. Sex			
Male (Female)	1 (Jones 2016)	OR=1.76 [1.01-3.05]	--
II. Age			
Age (as continuous variable)	1 (Fuster 2021, Jones 2016)	OR=0.85 [0.52-1.39] to 1.01 [0.88-1.27]	--
III. Socio-economic status (SES)			
Family SES/ Perceived SES	1 (Jones 2016)	OR=1.36 [1.04-1.78]	--
Mental health and psychological correlates			
I. Mental health			
Psychotic-like experience	1 (Jones 2016)	OR=1.23 [0.94-1.62]	--
Depression or anxiety combined	1 (Jones 2016)	OR=0.94 [0.70-1.26]	--
II. Attitudes			
Harm perception of cannabis smoking: High (Low)	1 (Jones 2016)	OR=0.64 [0.45-0.89]	--
Harm perception of regular cannabis use: High (Low)	1 (Jones 2016)	OR=0.47 [0.30-0.72]	--
III. Personal characteristics			
Sensation seeking	1 (Fuster 2021)	OR=1.04 [0.77-1.40]	--
Substance use behavioural correlates			
I. Cannabis use			
Higher frequency of use (Less)	2 (Fuster 2021, Jones 2016)	OR=3.68 [2.50-5.41] to 3.73 [2.40-5.81]	--
Cannabis use disorder	1 (Fuster 2021)	OR=4.19 [2.70-6.50]	--
II. E-cigarette use			

Higher frequency of use (Less)	1 (Jones 2016)	OR=1.73 [1.30-2.30]	--
III. Tobacco use			
Higher frequency of use (Less)	2 (Fuster 2021, Jones 2016)	OR=0.86 [0.51-1.45] to 1.60 [1.21-2.12]	--
IV. Alcohol use			
Higher frequency of use (Less)	1 (Jones 2016)	OR=2.07 [1.39-3.09]	--
Current binge drinking (None)	1 (Fuster 2021)	OR=1.09 [0.50-2.41]	--
Alcohol use disorder	1 (Fuster 2021)	OR=1.59 [0.96-2.65]	--
V. Other illicit substance use			
Higher frequency of use (Less)	1 (Jones 2016)	OR=1.79 [1.33-2.41]	--
Current illicit substance use (None)	1 (Fuster 2021)	OR=1.88 [1.23-2.87]	--

Table 3. Correlates of Cannabis Vaping Initiation (Cohort Studies)

i.   Adolescent population

Exposure (Comparison)	k (ref)	Effect size [95%CI]	Conclusions
Socio-demographic correlates			
I. Sex			
Male (Female)	1 (Lee 2021)	OR=1.00 [0.81-1.24]	--
II. Age			
Age 15-17 (Age 12-14)	2 (Lee 2021, Lee 2023)	OR=1.43 [1.23-1.67] to 1.51 [1.19-1.90]	--
III. Ethnicity			
Hispanic (Non-Hispanic)	1 (Lee 2021)	OR=1.37 [1.08-1.76]	--
Black (White)	1 (Lee 2021)	OR=1.34 [0.99-1.83]	--
Others (White)	1 (Lee 2021)	OR=1.01 [0.77-1.34]	--
IV. Parental education			
Parental education level: Less than college (College degree or higher)	1 (Lee 2021)	OR=1.35 [1.07-1.70]	--
Mental health and psychological correlates			
I. Mental health			
Internalising tendency: High (Low)	1 (Lee 2021)	OR=1.49 [1.10-2.02]	--
Externalising tendency: High (Low)	2 (Lee 2021, Lee 2023)	OR=1.64 [1.32-2.05] to 1.66 [1.14-2.41]	--
II. Healthy lifestyle			
E-cigarette ads exposure (None)	1 (Lee 2023)	OR=1.36 [1.14-1.62]	--
Social media use: Daily (None)	1 (Lee 2023)	OR=2.68 [2.05-3.49]	--
Social media use: Non-daily (None)	1 (Lee 2023)	OR=1.54 [1.14-2.09]	--

Substance use behavioural correlates

I. Cannabis use

Current other cannabis use (None)	2 (Lee 2021, Lee 2023)	OR=4.73 [2.64-8.84] to 7.78 [3.74-16.15]	--

II. E-cigarette use

Current use (None)	2 (Lee 2021, Lee 2023)	OR=2.00 [1.16-3.45] to 2.16 [1.20-3.89]	--
Ever use (None)	1 (Bentivegna 2021)	OR=2.26 [1.56-3.28]	--

III. Tobacco use

Current cigarette use (None)	1 (Lee 2021)	OR=2.65 [1.10-6.35]	--
Current other tobacco use (None)	1 (Lee 2021)	OR=1.53 [0.63-3.75]	--

IV. Alcohol use

Current use (None)	1 (Lee 2021)	OR=1.98 [1.35-2.91]	--

V. Other illicit substance use

Current illicit substance use (None)	2 (Lee 2021, Lee 2023)	OR=1.17 [0.72-1.90] to 1.82 [1.44-2.31]	--

VI. Peer/ Family substance use

Having e-cigarette using peers (None)	2 (Lee 2021, Lee 2023)	OR=2.31 [1.81-2.96] to 2.45 [2.03-2.95]	--
Having e-cigarette using parents (None)	1 (Lee 2021)	OR=1.48 [0.91-2.41]	--

[a]Smith et al. (2021) reported two correlate odds ratios in their logistic regression analyses: participants who vaped dried cannabis leaves or herb; or vaped cannabis oil or liquid, which was treated as two independent results in the meta-analyses.

i.   Young Adult Population

Exposure (Comparison)	k (ref)	Effect size [95%CI]	Conclusions
Socio-demographic correlates			
I. Sex			
Male (Female)	1 (Cassidy 2018)	OR=1.20 [0.69-2.09]	--
II. Personal characteristics			
Sensation seeking	1 (Cassidy 2018)	OR=0.99 [0.90-1.10]	--
Substance use behavioural correlates			
I. E-cigarette use			
Current use (None)	1 (Cassidy 2018)	OR=5.18 [2.54-10.57]	--
II. Tobacco use			
Current cigarette use (None)	1 (Cassidy 2018)	OR=2.23 [1.11-4.51]	--
III. Peer/ Family substance use			
Number of peers who used cannabis	1 (Cassidy 2018)	OR=1.17 [0.89-1.54]	--
Number of peers who use e-cigarette	1 (Cassidy 2018)	OR=0.99 [0.73-1.35]	--
Number of peers who initiated vaping cannabis	1 (Cassidy 2018)	OR=1.69 [1.06-2.70]	--
Number of peers who abstained from vaping cannabis	1 (Cassidy 2018)	OR=0.87 [0.73-1.04]	--
Number of peers who discontinued vaping cannabis	1 (Cassidy 2018)	OR=0.98 [0.63-1.53]	--
Number of peers who sustained vaping cannabis	1 (Cassidy 2018)	OR=1.34 [0.82-2.20]	--

Figures

Figure 1. PRISMA Flow Diagram.
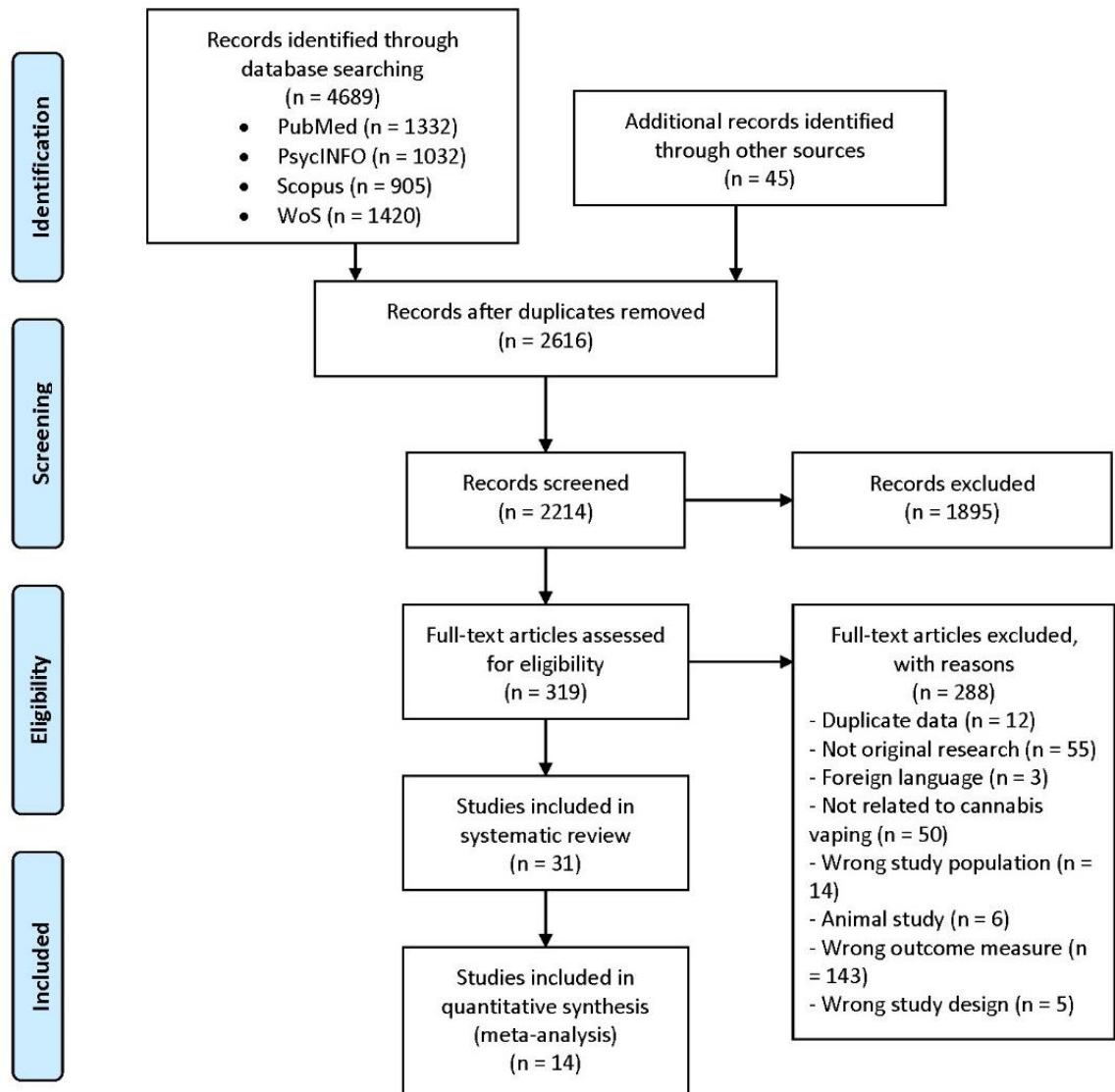
Supplemental Tables

Supplemental Table A. Updated PRISMA 2020 Statement Checklist

Section and Topic		#	Checklist item	Page
TITLE	Title	1	Identify the report as a systematic review.	1
ABSTRACT	Abstract	2	<u>Title, Background, Methods, Results, Discussion, Other Funding, Registration</u>	5
INTRODUCTION	Rationale	3	Describe the rationale for the review in the context of existing knowledge.	6-7
	Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	6-7
METHODS	Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	7-8
	Information sources	6	Specify all databases, registers, websites, organizations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	8
	Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	STC
	Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	8-9
	Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	8-9
	Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each	9

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			study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	
		10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	9
	Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	9
	Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	8-9
	Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis.	8-9
		13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	8-9
		13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	8-9
		13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	8-9
		13e	Describe any methods used to explore possible causes of heterogeneity among study results.	9
		13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	9
	Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	9
	Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	9

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RESULTS	Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram (see Figure 1).	F1
		16b	Cite studies that met many but not all inclusion criteria ('near-misses') and explain why they were excluded.	11
	Study characteristics	17	Cite each included study and present its characteristics.	10-11
	Risk of bias in studies	18	Present assessments of risk of bias for each included study.	11, T1
	Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	T2-3
	Results of syntheses	20a	For each synthesis, briefly summarize the characteristics and risk of bias among contributing studies.	10-11, T1
		20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	10-19, T2-3,
		20c	Present results of all investigations of possible causes of heterogeneity among study results.	10-19, T2-3
		20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	10-19, SFA-N
	Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	SFA-N
	Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	10-19, T2-3,

				SFA-N
DISCUSSION	Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	19-21
		23b	Discuss any limitations of the evidence included in the review.	21
		23c	Discuss any limitations of the review processes used.	21
		23d	Discuss implications of the results for practice, policy, and future research.	19-21
OTHER INFORMATION	Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	7
		24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	7
		24c	Describe and explain any amendments to information provided at registration or in the protocol.	n/a
	Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	2
	Competing interests	26	Declare any competing interests of review authors.	2
	Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	8-9

Supplemental Table B. MOOSE Guideline Checklist

Items	Page
1) Reporting of background should include	
Problem definition	6-7
Hypothesis statement	6-7
Description of study outcome(s)	6-7
Type of exposure or intervention used Type of study designs used	7-8
Study population	8-9
2) Reporting of search strategy should include	
Qualifications of searchers (eg, librarians and investigators)	8-9
Search strategy, including time period included in the synthesis and keywords	8-9, STC
Effort to include all available studies, including contact with authors	7-9
Databases and registries searched	7-8, STC
Search software used, name and version, including special features used (eg, explosion)	7-9
Use of hand searching (eg, reference lists of obtained articles)	7-8
List of citations located and those excluded, including justification	7-8, F1
Method of addressing articles published in languages other than English	7-8
Method of handling abstracts and unpublished studies	7-8
Description of any contact with authors	n/a
3) Reporting of methods should include	
Description of relevance or appropriateness of studies assembled for assessing the hypothesis to be tested	7-9
Rationale for the selection and coding of data (eg, sound clinical principles or convenience) Documentation of how data were classified and coded (eg, multiple raters, blinding, and interrater reliability)	7-9
Assessment of confounding (eg, comparability of cases and controls in studies where appropriate)	7-9
Assessment of study quality, including blinding of quality assessors; stratification or regression on possible predictors of study results	9
Assessment of heterogeneity	9
Description of statistical methods (eg, complete description of fixed or random effects models, justification of whether the chosen models account for predictors of	9

study results, dose-response models, or cumulative meta-analysis) in sufficient detail to be replicated	
Provision of appropriate tables and graphics	T1-3, F1, SFA-N
4) Reporting of results should include	
Graphic summarizing individual study estimates and overall estimate Table giving descriptive information for each study included	T1
Results of sensitivity testing (eg, subgroup analysis)	10-19, SFA-N
Indication of statistical uncertainty of findings	10-19, SFA-N
5) Reporting of discussion should include	
Quantitative assessment of bias (eg, publication bias)	21
Justification for exclusion (eg, exclusion of non–English-language citations) Assessment of quality of included studies	21
6) Reporting of conclusions should include	
Consideration of alternative explanations for observed results	19-21
Generalization of the conclusions (ie, appropriate for the data presented and within the domain of the literature review)	19-21
Guidelines for future research	19-21
Disclosure of funding source	2

Supplemental Table C. Preregistration Deviations

#	Details		Original Wording	Deviation Description	Reader Impact
1	Type	Sample	All populations that met our inclusion criteria, and where a clear definition of cannabis vaping (use of a vaporiser to consume cannabis plant matter, oil or extracts) was reported.	Modified criteria on age restriction on sample population, to focus on adolescents and young adults.	This deviation may have a moderate impact on readers' interpretations of the findings as the review now generalises to specific age ranges, rather than the general population. However, this deviation was due to a typing error during the preregistration writing process, which was corrected before the database search in 2020.
	Reason	Typo/Error			
	Timing	Before data collection			
2	Type	Data Preparation	Review timeline\n\nStart date: 01 December 2020. End date: 01 July 2021	An initial database search was conducted on 19 August 2020. However, did not produce sufficient studies for the meta-analyses. A follow-up search was therefore performed on 4 March 2024.	This deviation has a small impact on readers' interpretations of the findings. This deviation was due to the limited studies available at the time of initial planning, and to include more studies to deduce meaningful conclusions at follow-up.
	Reason	Plan not possible			
	Timing	After data access			
	Timing	Select One			

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Supplemental Table D. Search Terms for Each Database

Database	Search terms for original studies
PUBMED Search Query	((cannabis[Title/Abstract]) OR (marijuana [Title/Abstract]) OR (marihuana[Title/Abstract]) OR cannabis[MeSH Terms] OR marijuana use[MeSH Terms])) AND ((ecig*[Title/Abstract]) OR (e - cig*[Title/Abstract]) OR ("electronic cigarette"[Title/Abstract]) OR ("electronic cigarettes"[Title/Abstract]) OR ("electronic nicotine delivery"[Title/Abstract]) OR (eliquid*[Title/Abstract]) OR (e-liquid*[Title/Abstract]) OR (vape[Title/Abstract]) OR (vaping[Title/Abstract]) OR (vaporize*[Title/Abstract]) OR (EVALI[Title/Abstract]) OR ("vaping associated lung injury"[Title/Abstract]) OR (Electronic nicotine delivery systems[MeSH Terms]) OR (vaping[MeSH Terms]) OR ("vaping/adverse effects"[MeSH Terms)) Filters: from 2003 - 2024
SCOPUS Search Query	(TITLE-ABS-KEY (ecig*) OR TITLE-ABS-KEY (e-cig*) OR TITLE-ABS-KEY ("electronic cigarette") OR TITLE-ABS-KEY ("electronic cigarettes") OR TITLE-ABS-KEY ("electronic nicotine delivery") OR TITLE-ABS-KEY (eliquid*) OR TITLE-ABS-KEY (e-liquid*) OR TITLE-ABS-KEY (vape*) OR TITLE-ABS- KEY (vaping) OR TITLE-ABS-KEY (vaporize*) OR TITLE-ABS-KEY (EVALI) OR TITLE-ABS-KEY ("vaping associated lung injury")) AND (TITLE-ABS-KEY (cannabis) OR TITLE-ABS-KEY (marijuana) OR TITLE-ABS-KEY (marihuana)) AND (PUBYEAR > 2002)
PsycInfo Search Query	(((title: (cannabis) OR title: (marijuana) OR title: (marihuana)) OR (abstract: (cannabis) OR abstract: (marijuana) OR abstract: (marihuana)) OR (Index Terms: (cannabis)) OR (Index Terms: (marijuana))) AND ((Year: [2003 TO 2020]))) AND ((((title: (ecig*) OR title: (e-cig*) OR title: ("electronic cigarette") OR title: ("electronic cigarettes") OR title: ("electronic nicotine delivery") ORtitle: (eliquid*) OR title: (e-liquid*) OR title: (vape*) OR title: (vaping) OR title: (vaporize*) OR title: (EVALI) OR title: ("vaping associate lung injury")) OR (abstract: (ecig*) OR abstract: (e -cig*) OR abstract: ("electronic cigarette") OR abstract: ("electronic cigarettes") ORabstract: ("electronic nicotine delivery") OR abstract: (eliquid*) ORabstract: (e-liquid*) OR abstract: (vape*) OR abstract: (vaping) OR abstract: (vaporize*) OR abstract: (EVALI) OR abstract: ("vaping associate lung injury")) OR (Index Terms: (electronic cigarettes))) AND ((Year: [2003 TO 2024])))
Web of Science Search Query	TOPIC: ((ecig* OR e-cig* OR "electronic cigarette" OR "electronic cigarettes" OR "electronic nicotine delivery" OR eliquid* OR e-liquid* OR vape* OR vaping OR vaporize* OR EVALI OR "vaping associated lung injury")) AND TOPIC:((cannabis OR marijuana OR marihuana)) Timespan: 2003-2024

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Database	Search terms for existing reviews
PUBMED Search Query	(Meta-review [TIAB]) OR (Meta-Analysis [TIAB]) OR (meta-ana [TIAB]) OR (meta analysis [TIAB]) OR (meta ana [TIAB]) OR (metaanalysis [TIAB]) OR (metaana* [TIAB]) OR (Review [TIAB]) OR (Systematic Review [TIAB]) OR (META-ANALYSIS AS TOPIC [MeSH Terms]) OR (SYSTEMATIC REVIEWS AS TOPIC [MeSH Terms])
SCOPUS Search Query	(TITLE-ABS-KEY("meta-review") OR TITLE-ABS-KEY("meta-analysis") OR TITLE-ABS-KEY("meta-ana") OR TITLE-ABS-KEY("meta analysis") OR TITLE-ABS-KEY(meta ana) OR TITLE-ABS-KEY(metaanalysis) OR TITLE-ABS-KEY(metaana*) OR TITLE-ABS-KEY(review) OR TITLE-ABS-KEY("systematic review"))
PsycInfo Search Query	(title: (meta-review OR meta-analysis OR meta-ana OR "meta analysis" OR "meta ana" OR metaanalysis OR metaana* OR review OR "systematic review) OR Abstract:(meta-review OR meta- analysis OR meta-ana OR " meta analysis " OR " meta ana " OR metaanalysis OR metaana* OR review OR " systematic review) OR (Index Terms: ("systematic review")) OR (Index Terms: (review)) OR (Index Terms: ("meta analysis"))
Web of Science Search Query	meta-review OR meta-analysis OR meta-ana OR 'meta analysis' OR 'meta ana' OR metaanalysis OR metaana* OR 'systematic review' OR review

Supplemental Table E. Correlates of Lifetime Ever Cannabis Vaping, Cross-Sectional Studies on the General Population

Exposure (Comparison)	Adolescents					Young adults		
	k (ref)	Effect size [95%CI]	Pooled effect size [95%CI]	Q (p-value), I^2	Conclusions	k (ref)	Effect size [95%CI]	Conclusions
Socio-demographic correlates								
I. Sex								
Male (Female)	6 (Boccio 2020, Eggers 2017, Kowitt 2019, Morean 2015, Peters 2018, Taleb 2020)	OR=0.75 [0.58-0.96] to 2.05 [1.48-2.85]	OR=1.12 [0.83-1.52], p>.05	40.69 (p<.0001, 88.6%	No difference	0	--	--
II. Age								
Grade 10 (Grade 9)	2 (Eggers 2017, Kowitt 2019)	OR=1.20 [0.88-1.64] to 1.87 [1.01-3.47]	--	--	--	0	--	--
Grade 11 (Grade 9)	2 (Eggers 2017, Kowitt 2019)	OR=1.48 [1.07-2.05] to 1.99 [1.21-3.26]	--	--	--	0	--	--
Grade 12 (Grade 9)	2 (Eggers 2017, Kowitt 2019)	OR=1.26 [0.92-1.74] to 2.88 [1.46-5.67]	--	--	--	0	--	--
High school (Middle school)	1 (Taleb 2020)	OR=2.16 [1.76-2.67]	--	--	--	0	--	--
Age (as continuous variable)	1 (Morean 2015)	OR=0.64 [0.61-0.67]	--	--	--	0	--	--
III. Ethnicity								
Non-Hispanic Black (Non-Hispanic White)	5 (Boccio 2020, Eggers 2017, Kowitt 2019, Peters 2018, Taleb 2020)	OR=0.51 [0.22-1.16] to 1.93 [1.15-3.23]	OR=1.08 [0.75-1.56], p>.05	12.84 (p<.05), 72.1%	No difference	0	--	--
Hispanic (Non-Hispanic White)	5 (Boccio 2020, Eggers 2017, Kowitt 2019, Peters 2018, Taleb 2020)	OR=0.98 [0.76-1.28] to 2.73 [1.94-3.86]	OR=1.49 [0.98-2.27], p>.05	49.51 (p<.05), 91.8%	No difference	0	--	--
Asians (Non-Hispanic White)	1 (Peters 2018)	OR=0.50 [0.75-0.34]	--	--	--	0	--	--
Others (Non-Hispanic White)	5 (Boccio 2020, Eggers 2017, Kowitt 2019, Peters 2018, Taleb 2020)	OR=0.83 [0.54-1.29] to 1.89 [1.19-3.01]	OR=1.18 [0.90-1.54], p>.05	7.43 (p=0.11), 47.8%	No difference	0	--	--
IV. Socio-economic status								

Level of assets: High (Low)	2 (Morean 2015, Peters 2018)	OR=1.04 [0.79-1.38] to 1.13 [0.74-1.73]	--	--	--	0	--	--
V. Area of residence								
Rural (Urban)	1 (Boccio 2022)	OR=1.37 [0.97-1.95]	--	--	--	0	--	--
Mental health and psychological correlates								
I. Adverse Childhood Events								
One event (None)	1 (Boccio 2020)	OR=1.29 [0.84-1.99]	--	--	--	0	--	--
Two events (None)	1 (Boccio 2020)	OR=1.40 [0.98-2.23]	--	--	--	0	--	--
Three events (None)	1 (Boccio 2020)	OR=1.78 [1.17-2.66]	--	--	--	0	--	--
Four events (None)	1 (Boccio 2020)	OR=2.34 [1.42-3.86]	--	--	--	0	--	--
Five events (None)	1 (Boccio 2020)	OR=2.63 [1.60-4.31]	--	--	--	0	--	--
Six events (None)	1 (Boccio 2020)	OR=1.84 [1.11-3.06]	--	--	--	0	--	--
II. Delinquent acts								
Violent	1 (Jackson 2019)	OR=2.77 [2.35-3.25]	--	--	--	0	--	--
Property	1 (Jackson 2019)	OR=2.97 [2.55-3.46]	--	--	--	0	--	--
Other	1 (Jackson 2019)	OR=2.71 [2.32-3.16]	--	--	--	0	--	--
III. Personal characteristics								
Difficulty Focusing	1 (Taleb 2020)	OR=1.21 [1.00-1.48]	--	--	--	--	0	--	--
Substance use behavioural correlates								
I. Cannabis use								
Any lifetime use (None)	1 (Morean 2015)	OR=40.89 [20.15-82.98]	--	--	--	0	--	--
Frequency of use	0	--	--	--	--	1 (Frohe 2018)	OR=139.92 [6.81-2,873.50]	
II. E-cigarette use								
Current use (None)	2 (Kowitt 2019, Taleb 2020)	OR=1.67 [1.32-2.11] to 3.18 [2.38-4.25]	--	--	--	0	--	--

Any lifetime use (None)	1 (Morean 2015)	OR=5.27 [3.27-8.49]	--	--	--	0	--	--
III. Tobacco use								
Current cigarette use (None)	2 (Kowitt 2019, Taleb 2020)	OR=0.85 [0.61-1.18] to 1.27 [0.71-2.29]	--	--	--	0	--	--
Current cigar use (None)	2 (Kowitt 2019, Taleb 2020)	OR=1.38 [1.01-1.92] to 3.76 [2.33-6.07]	--	--	--	0	--	--
Current hookah/ waterpipe use (None)	2 (Kowitt 2019, Taleb 2020)	OR=1.32 [0.77-2.27] to 2.32 [1.37-3.93]	--	--	--	0	--	--
Current snus/ smokeless tobacco use (None)	2 (Kowitt 2019, Taleb 2020)	OR=0.89 [0.42-1.91] to 1.31 [0.78-2.19]	--	--	--	0	--	--
Ever cigarette use (None)	2 (Eggers 2017, Taleb 2020)	OR=1.63 [1.29-2.06] to 2.04 [1.55-2.68]	--	--	--	0	--	--
Ever cigar use (None)	2 (Eggers 2017, Taleb 2020)	OR=2.62 [2.08-3.30] to 3.22 [2.44-4.24]	--	--	--	0	--	--
Ever hookah/ waterpipe use (None)	2 (Eggers 2017, Taleb 2020)	OR=2.88 [2.14-3.89] to 5.01 [3.85-6.51]	--	--	--	0	--	--
Ever snus/ smokeless tobacco use (None)	2 (Eggers 2017, Taleb 2020)	OR=1.01 [0.71-1.44] to 1.03 [0.73-1.44]	--	--	--	0	--	--
IV. Alcohol use								
Any lifetime use (None)	1 (Boccio 2020)	OR=7.84 [5.75-11.70]	--	--	--	0	--	--
Drinks per drinking day	0	--	--	--	--	1 (Frohe 2018)	OR=12.49 [1.48-105.65]	--
V. Reason of use								
Positive Expectancies	0	--	--	--	--	1 (Frohe 2018)	OR=1.04 [1.01-1.06]	--
VI. Peer substance use								
Cannabis peer injunctive norms	0	--	--	--	--	1 (Frohe	OR=3.75 [1.79-7.86]	--

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8)

Supplemental Figures

Supplemental Figure A. Meta-Analysis Results of Sex on Current Cannabis Vaping, Adjusted Odds of Male (Ref: Female), among General Adolescent Population

Supplemental Figure A.1. Meta-analysis results
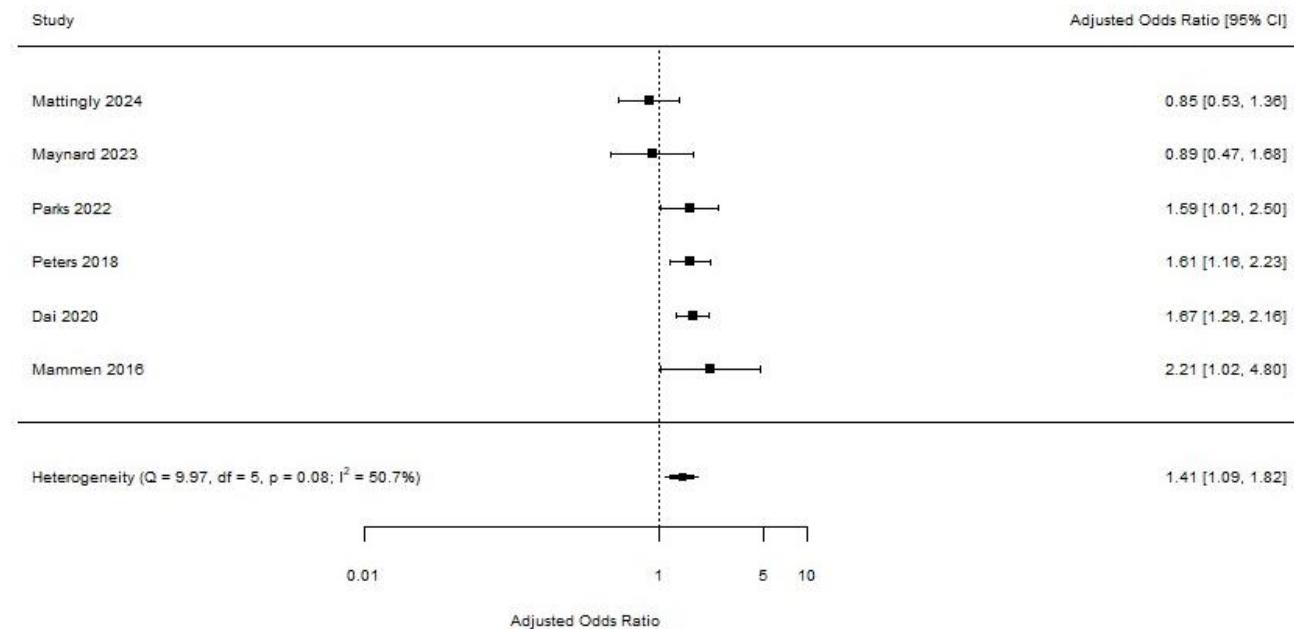
Supplemental Figure A.2. Sensitivity analysis results (past 30-day cannabis vaping only)

Study		Adjusted Odds Ratio [95% CI]
Mattingly 2024		0.85 [0.53, 1.36]
Parks 2022		1.59 [1.01, 2.50]
Peters 2018		1.61 [1.16, 2.23]
Dai 2020		1.67 [1.29, 2.16]
Heterogeneity (Q = 6.47, df = 3, p = 0.09; I^2 = 54.9%)		1.44 [1.10, 1.88]

0.01   1   5   10

Adjusted Odds Ratio
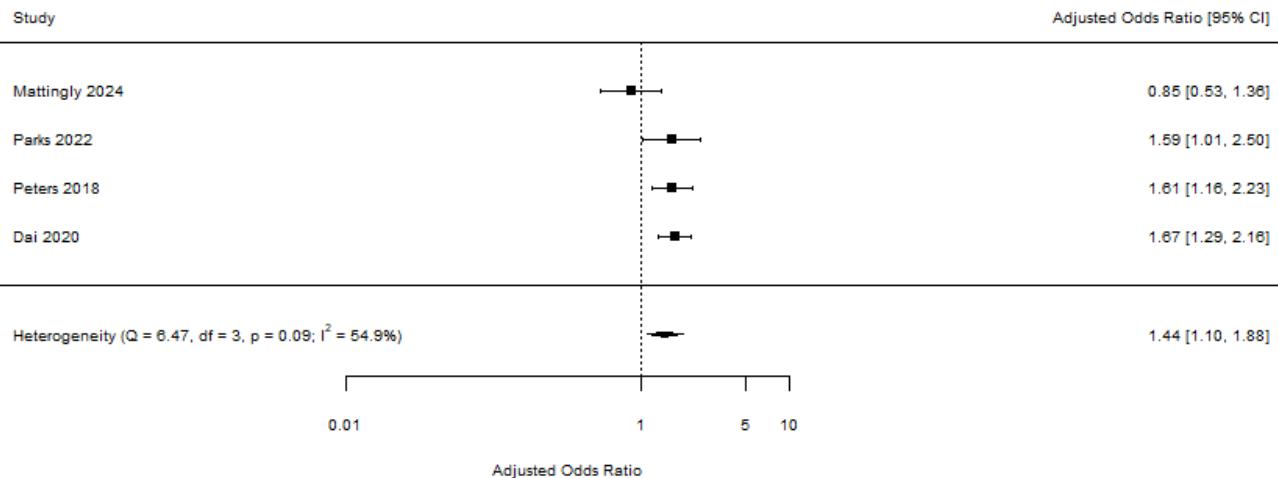
Supplemental Figure A.3. Funnel plot of trim-and-fill-analysis results
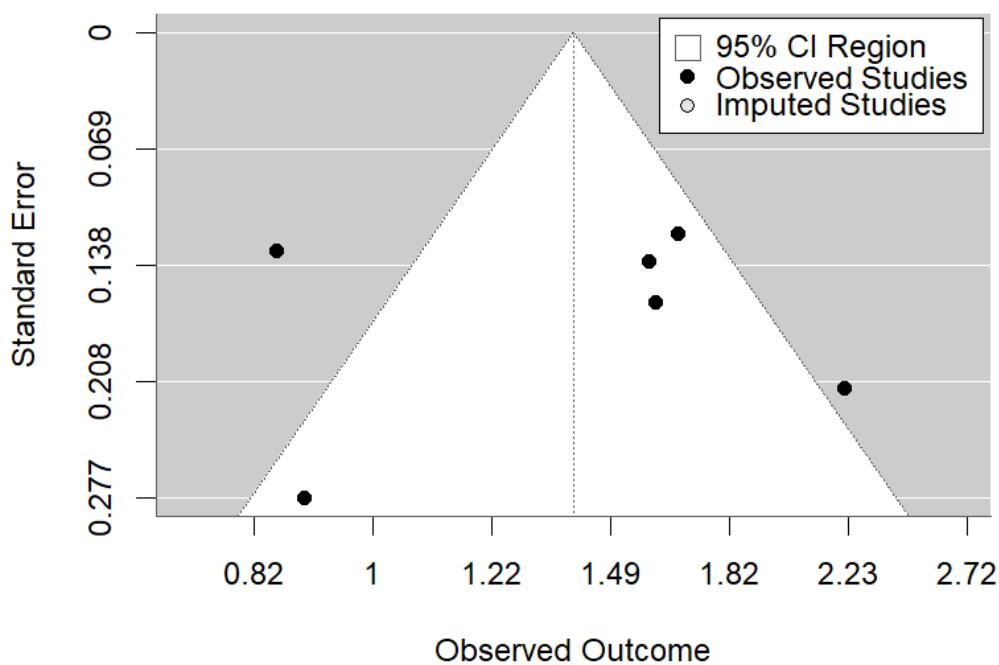
**Supplemental Figure B. Meta-Analysis Results of Sex on Current Cannabis Vaping, Adjusted Odds of Male (Ref: Female), among Adolescents who Currently Use Cannabis (Past Year)**

Supplemental Figure B.1. Meta-analysis results

Study	Adjusted Odds Ratio [95% CI]
Ball 2023	1.10 [0.73, 1.66]
Boisvert 2016	1.49 [1.07, 2.08]
Smith 2020.2	1.68 [1.03, 2.74]
Kolar 2020	2.70 [1.78, 4.09]
Smith 2020.1	1.38 [0.84, 2.27]
Johnson 2016	3.10 [2.17, 4.43]
Patrick 2020	2.02 [1.63, 2.50]
Kritikos 2021	1.40 [1.00, 1.96]
Heterogeneity (Q = 23.55, df = 7, p = 0.00; I^2 = %)	1.79 [1.38, 2.34]
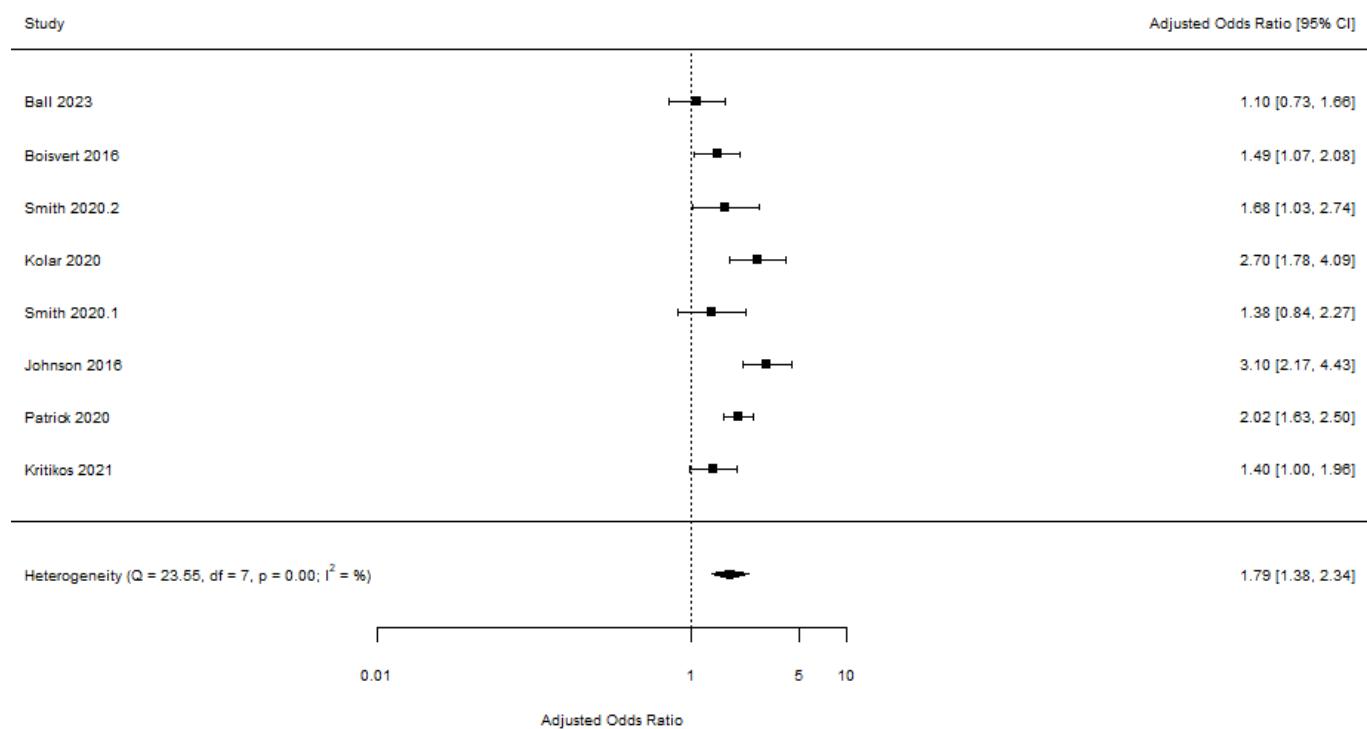
Supplemental Figure B.2. Sensitivity analysis results (excluding study from New Zealand due to cannabis not being legal for recreational use as of 2023)

Study	Adjusted Odds Ratio [95% CI]
Boisvert 2016	1.49 [1.07, 2.08]
Smith 2020.2	1.68 [1.03, 2.74]
Kolar 2020	2.70 [1.78, 4.09]
Smith 2020.1	1.38 [0.84, 2.27]
Johnson 2016	3.10 [2.17, 4.43]
Patrick 2020	2.02 [1.63, 2.50]
Kritikos 2021	1.40 [1.00, 1.96]
Heterogeneity (Q = 17.21, df = 6, p = 0.01; I^2 = 67.6%)	1.92 [1.69, 2.18]

Adjusted Odds Ratio
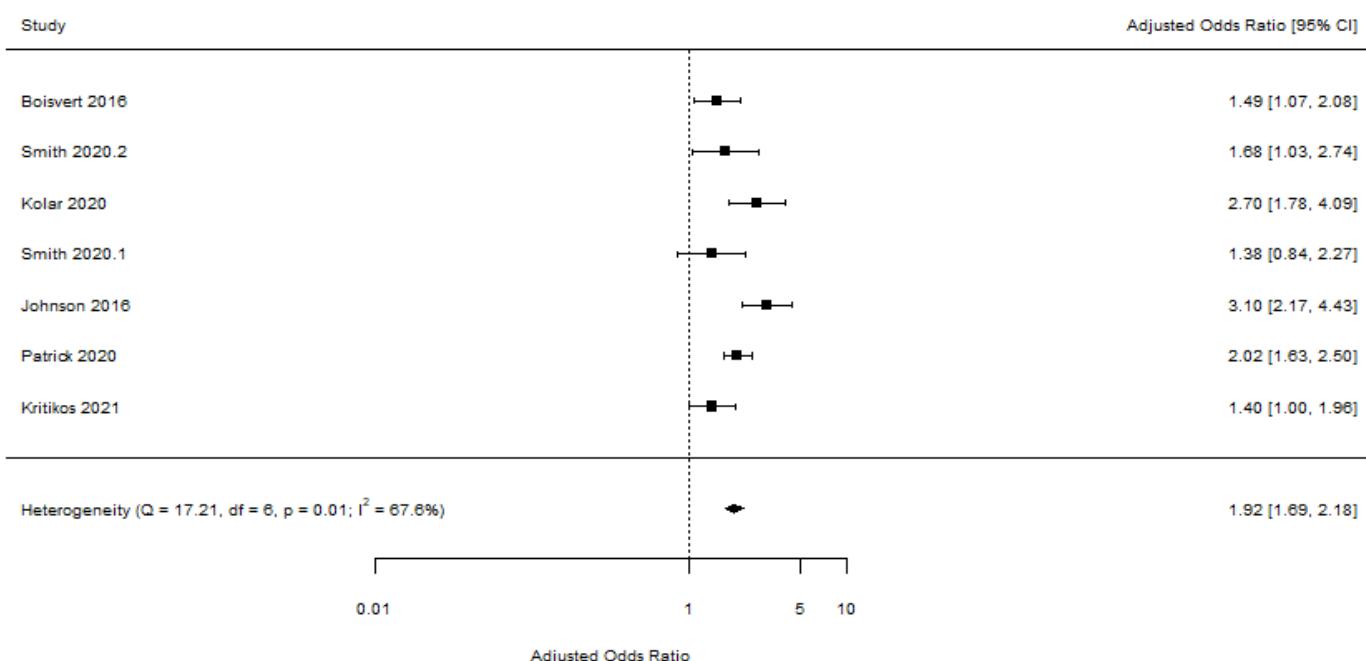
Supplemental Figure B.3. Funnel plot of trim-and-fill-analysis results
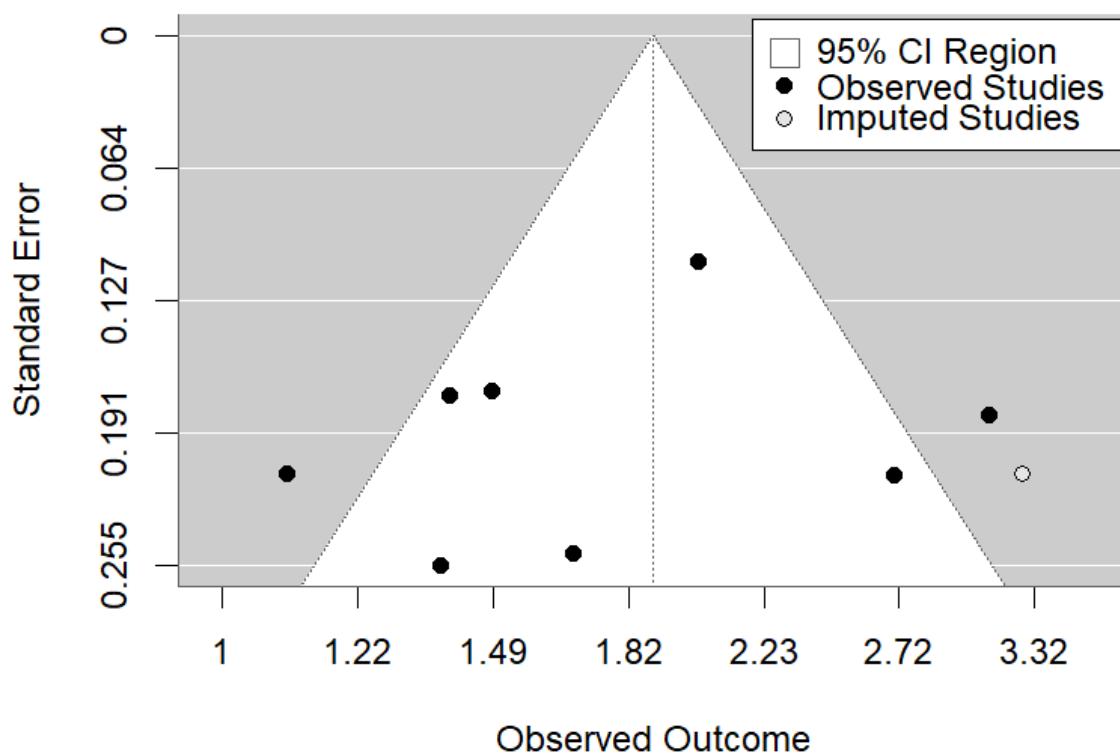
Supplemental Figure B.4. Trim-and-fill-analysis results

Study	Adjusted Odds Ratio [95% CI]
Ball 2023	1.10 [0.73, 1.66]
Boisvert 2016	1.49 [1.07, 2.08]
Smith 2020.2	1.68 [1.03, 2.74]
Kolar 2020	2.70 [1.78, 4.09]
Smith 2020.1	1.38 [0.84, 2.27]
Johnson 2016	3.10 [2.17, 4.43]
Patrick 2020	2.02 [1.63, 2.50]
Kritikos 2021	1.40 [1.00, 1.96]
Filled 1	3.26 [2.15, 4.92]
Heterogeneity (Q = 30.46, df = 8, p = 0.00; I^2 = 76.4%)	1.89 [1.47, 2.43]

Adjusted Odds Ratio
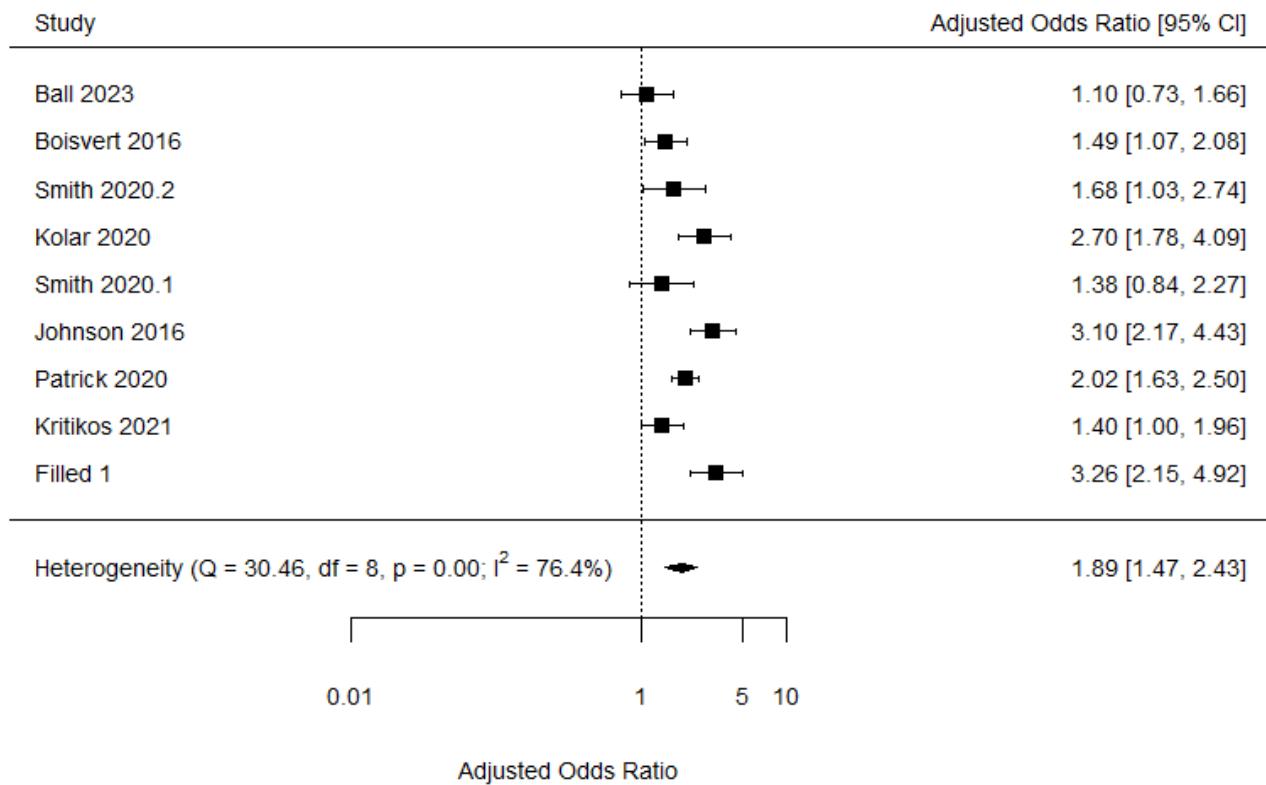
Supplemental Figure C. Meta-Analysis Results of Age on Current Cannabis Vaping, Adjusted Odds of Older Age (Grade 10/ Age 15) (Ref: Younger (Grade 8-9/ Age 14)), among Adolescents who Currently Use Cannabis (Past Year)
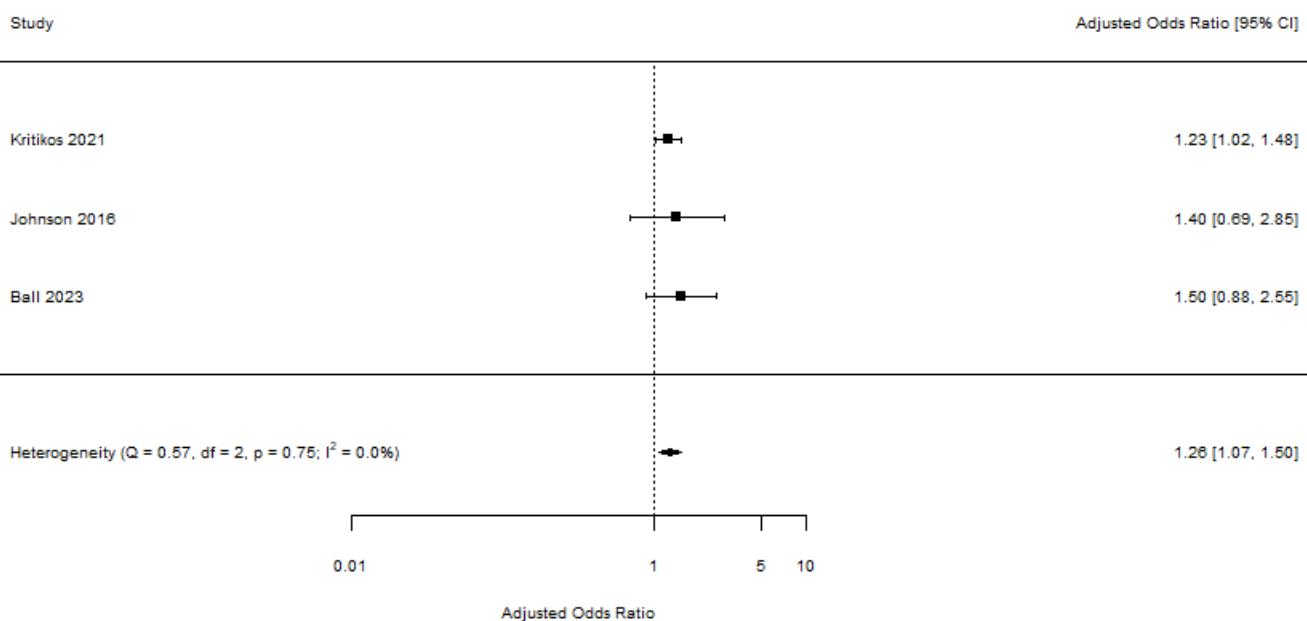
Supplemental Figure D. Meta-Analysis Results of Ethnicity on Current Cannabis Vaping, Adjusted Odds of Non-Hispanic Black (Ref: Non-Hispanic White), among Adolescents who Currently Use Cannabis (Past Year)

Study	Adjusted Odds Ratio [95% CI]
Kritikos 2021	0.68 [0.30, 1.52]
Boisvert 2020	0.67 [0.27, 1.65]
Patrick 2020	0.50 [0.31, 0.80]
Johnson 2016	0.50 [0.20, 1.22]
Heterogeneity (Q = 0.65, df = 3, p = 0.89; I^2 = 0.0%)	0.55 [0.39, 0.77]

Adjusted Odds Ratio
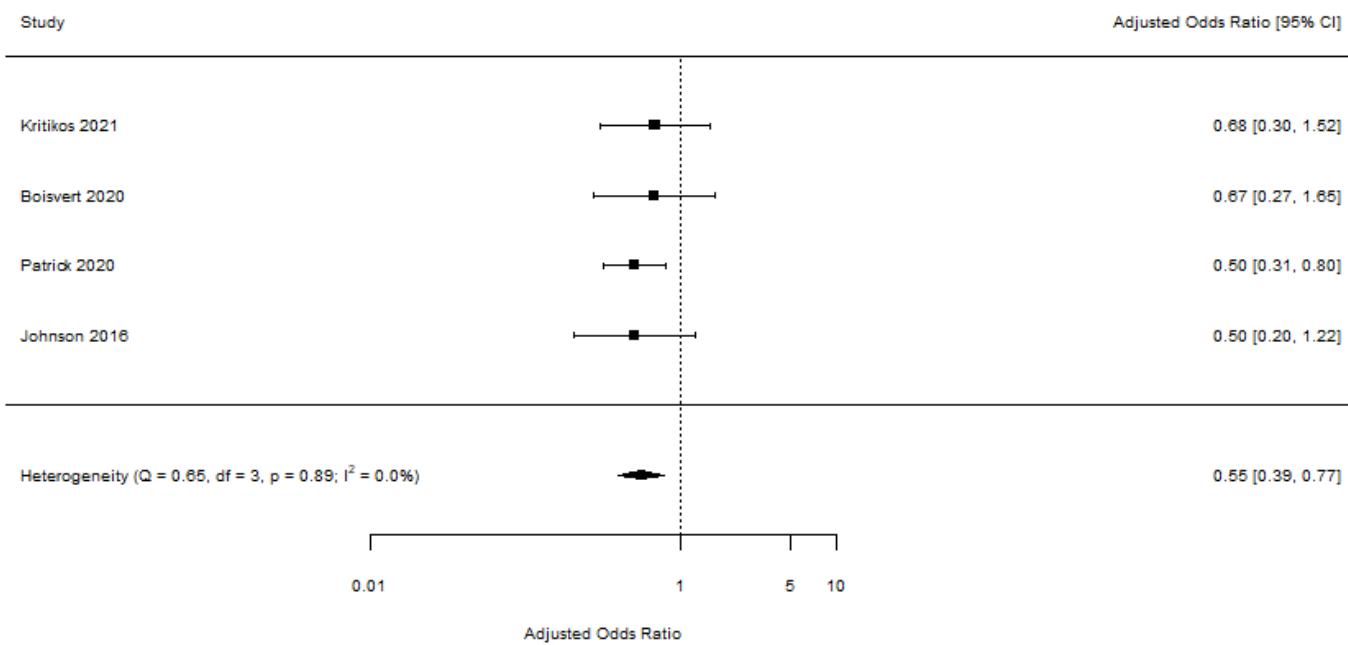
Supplemental Figure E. Meta-Analysis Results of Ethnicity on Current Cannabis Vaping, Adjusted Odds of Non-Hispanic Black (Ref: Non-Hispanic White), among General Adolescent Population

| Study	Adjusted Odds Ratio [95% CI]
Dai 2020	0.60 [0.33, 1.10]
Parks 2022	0.78 [0.45, 1.36]
Mattingly 2024	1.06 [0.75, 1.49]
Maynard 2023	0.77 [0.31, 1.89]
Heterogeneity (Q = 2.97, df = 3, p = 0.40; I^2 = 20.7%)	0.85 [0.63, 1.15]

Adjusted Odds Ratio
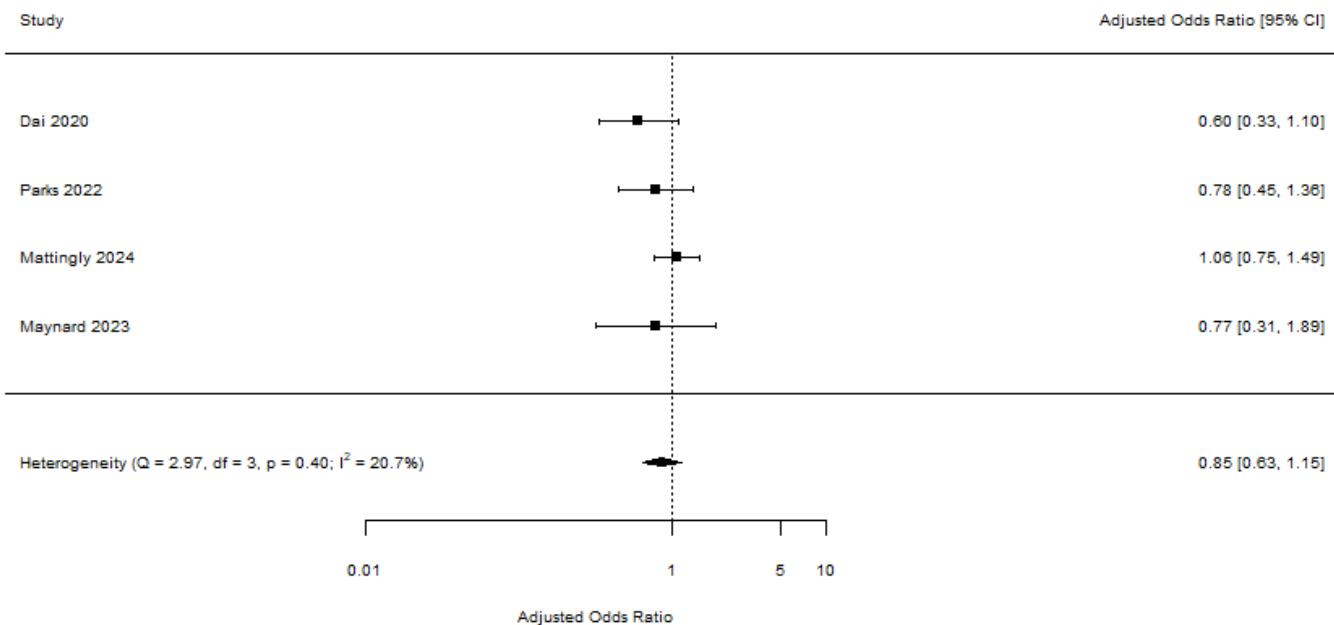
Supplemental Figure F. Meta-Analysis Results of Ethnicity on Current Cannabis Vaping, Adjusted Odds of Asians (Ref: Non-Hispanic White), among Adolescents who Currently Use Cannabis (Past Year)

| Study	Adjusted Odds Ratio [95% CI]
Ball 2023	0.10 [0.06, 0.17]
Boisvert 2020	0.24 [0.11, 0.53]
Patrick 2020	1.22 [0.83, 1.79]
Johnson 2016	2.60 [1.00, 6.78]
Heterogeneity (Q = 67.87, df = 3, p = 0.00; I^2 = 95.5%)	0.52 [0.12, 2.20]

Adjusted Odds Ratio
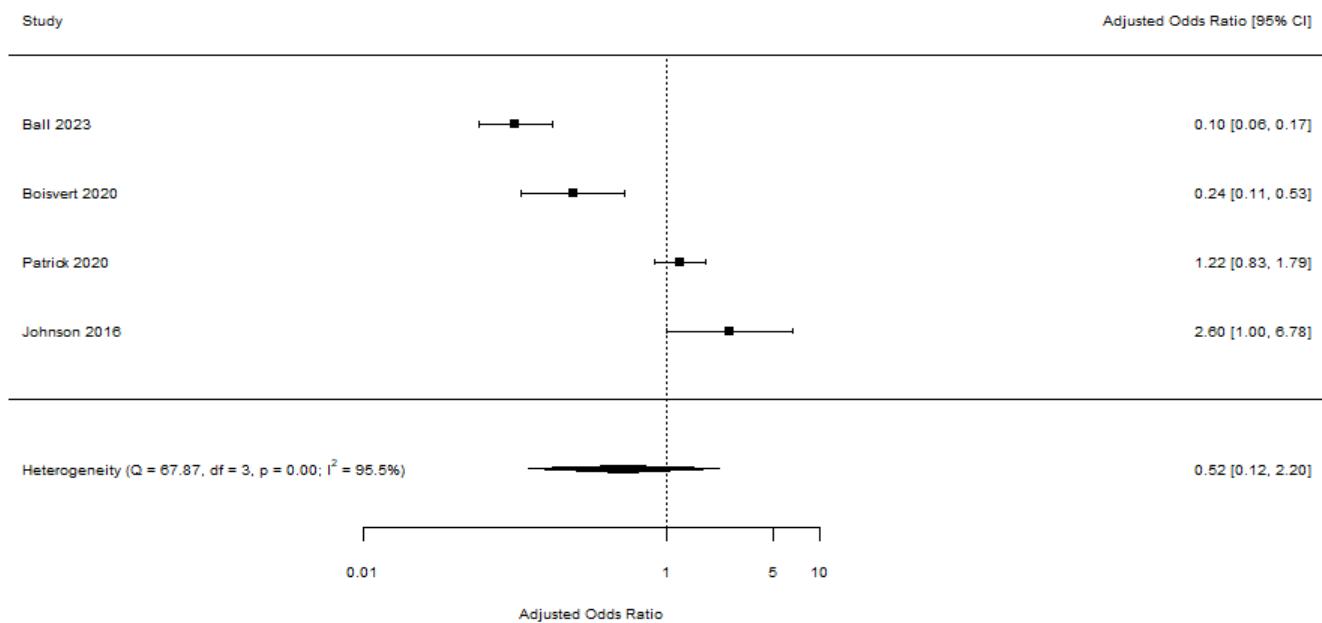
Supplemental Figure G. Meta-Analysis Results of Ethnicity on Current Cannabis Vaping, Adjusted Odds of Hispanic (Ref: Non-Hispanic White), among People who Currently Use Cannabis (Past Year)
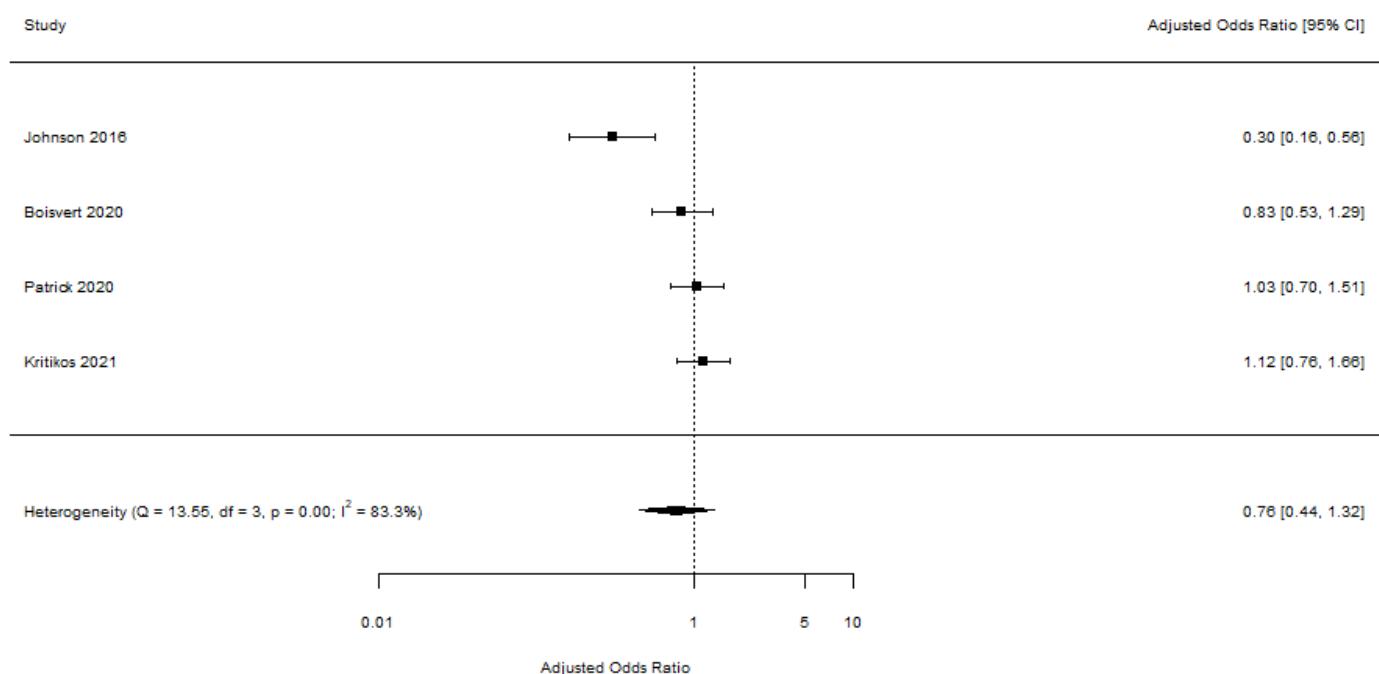
Supplemental Figure H. Meta-Analysis Results of Ethnicity on Current Cannabis Vaping, Adjusted Odds of Hispanic (Non-Hispanic White), among General Population
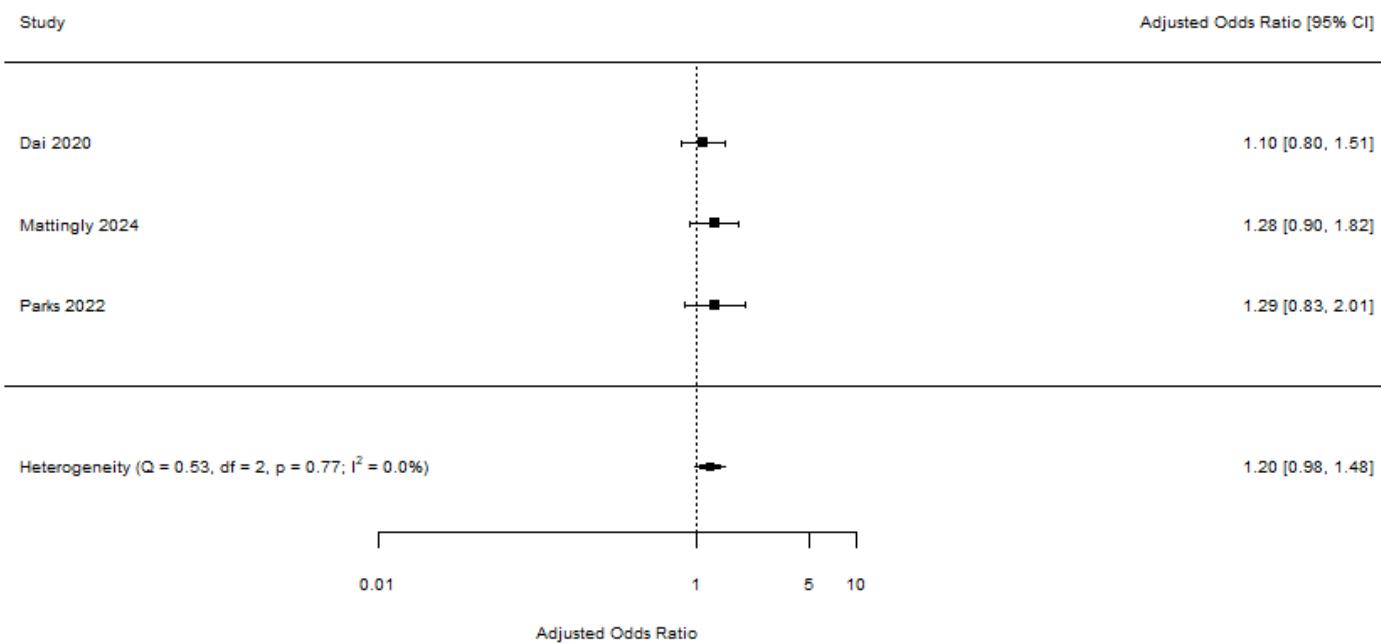
Supplemental Figure I. Meta-Analysis Results of Tobacco Use on Current Cannabis Vaping, Adjusted Odds of Current Cigarettes Use (Ref: No Current Use), among Adolescents who Currently Use Cannabis (Past Year)

Supplemental Figure I.1. Meta-analysis results
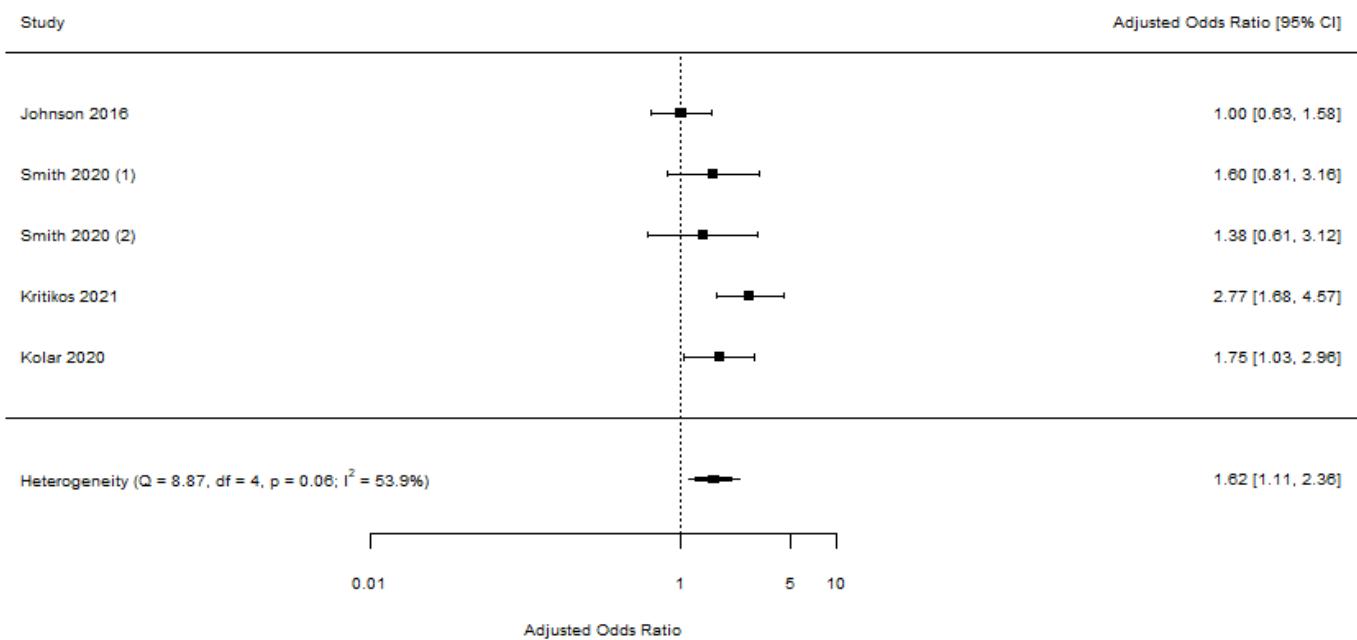
Supplemental Figure I.2. Sensitivity analysis results
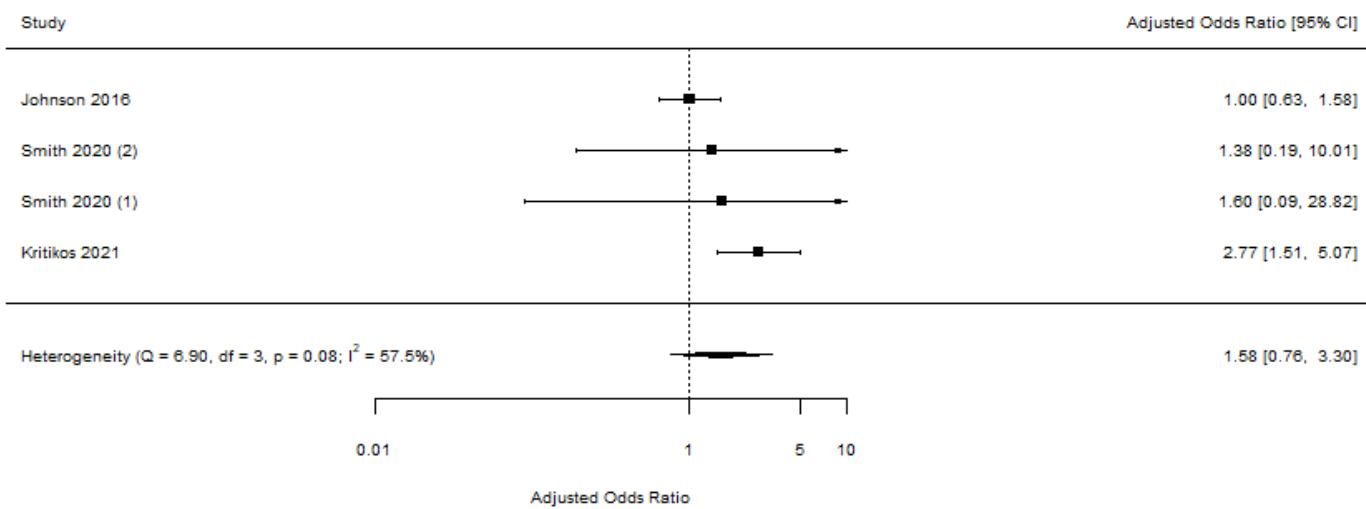
Supplemental Figure I.3. Funnel plot of trim-and-fill-analysis results
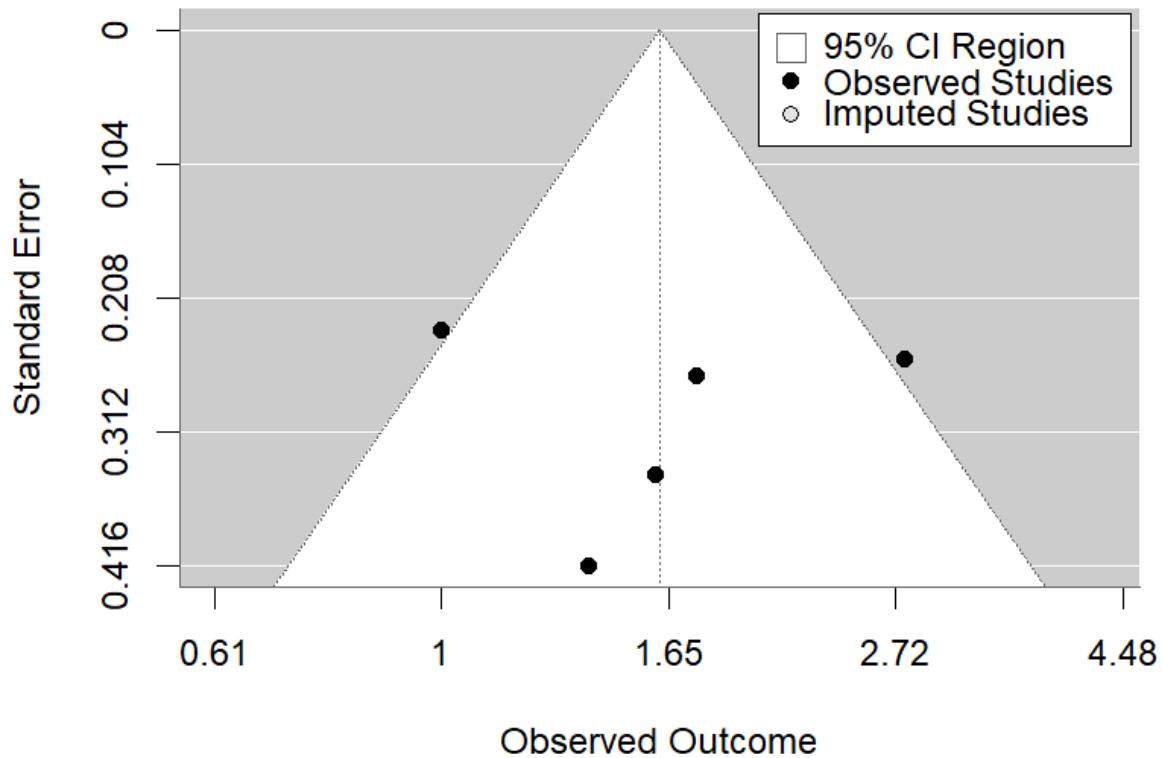
Supplemental Figure J. Meta-Analysis Results of Alcohol Use on Current Cannabis Vaping, Adjusted Odds of Current Alcohol Use (Ref: No Current Use), among Adolescents who Currently Use Cannabis (Past Year)


| Study	Adjusted Odds Ratio [95% CI]
Kolar 2020	1.70 [0.72, 4.02]
Johnson 2016	1.80 [1.15, 2.82]
Kritikos 2021	4.80 [2.88, 8.00]
Heterogeneity (Q = 9.06, df = 2, p = 0.01; I^2 = 76.1%)	2.52 [1.27, 5.01]

Adjusted Odds Ratio
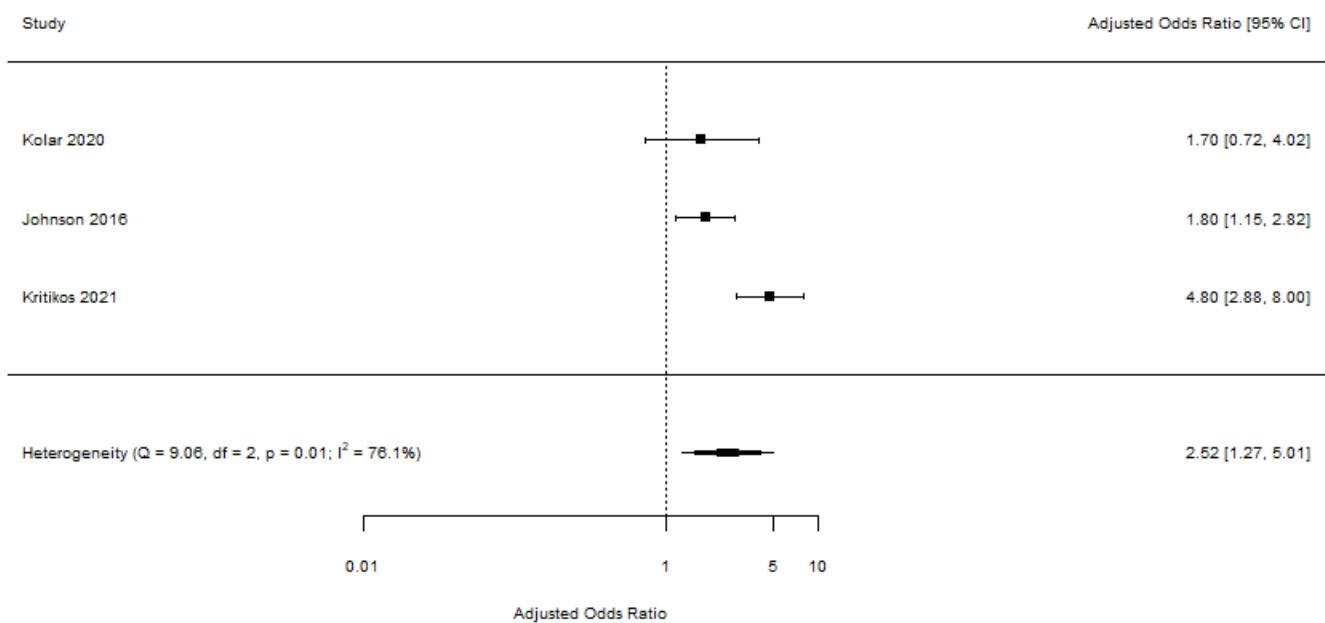
Supplemental Figure K. Meta-Analysis Results of Sex on Lifetime Ever Cannabis Vaping, Adjusted Odds of Male (Ref: Female), among General Adolescent Population

Supplemental Figure K.1. Meta-analysis results

Study	Adjusted Odds Ratio [95% CI]
Boccio 2022b	0.75 [0.58, 0.96]
Kowitt 2019	1.33 [0.87, 2.04]
Peters 2018	1.27 [1.01, 1.59]
Taleb 2020	0.76 [0.64, 0.90]
Morean 2015	2.05 [1.48, 2.84]
Eggers 2017	1.13 [0.90, 1.42]
Heterogeneity (Q = 40.69, df = 5, p = 0.00; I^2 = 88.6%)	1.12 [0.83, 1.52]

Adjusted Odds Ratio
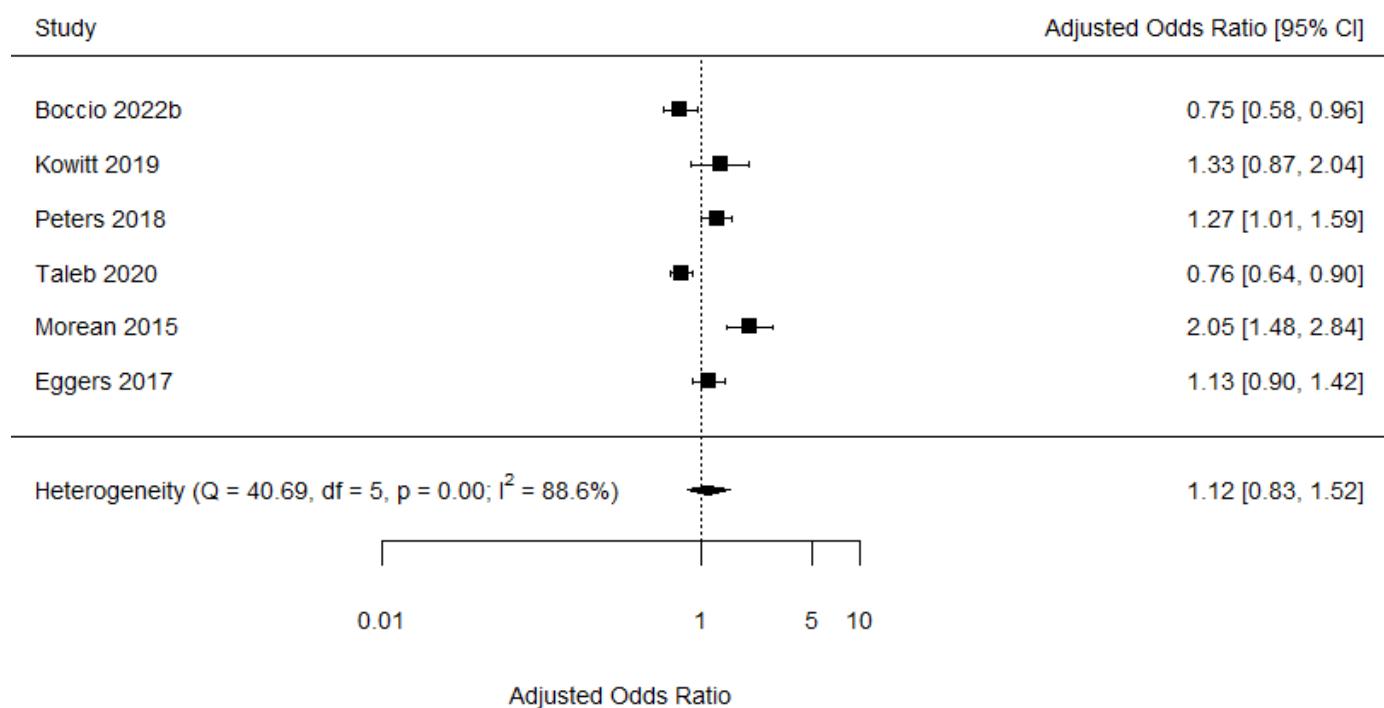
Supplemental Figure K.2 Trim-and-fill-analysis results

Study	Adjusted Odds Ratio [95% CI]
Eggers 2017	1.13 [0.90, 1.42]
Morean 2015	2.05 [1.48, 2.84]
Taleb 2020	0.76 [0.64, 0.90]
Filled 1	0.48 [0.35, 0.67]
Peters 2018	1.27 [1.01, 1.59]
Kowitt 2019	1.33 [0.87, 2.04]
Boccio 2022b	0.75 [0.58, 0.96]
Heterogeneity (Q = 58.46, df = 6, p = 0.00; I^2 = 92.0%)	1.00 [0.71, 1.42]

Adjusted Odds Ratio
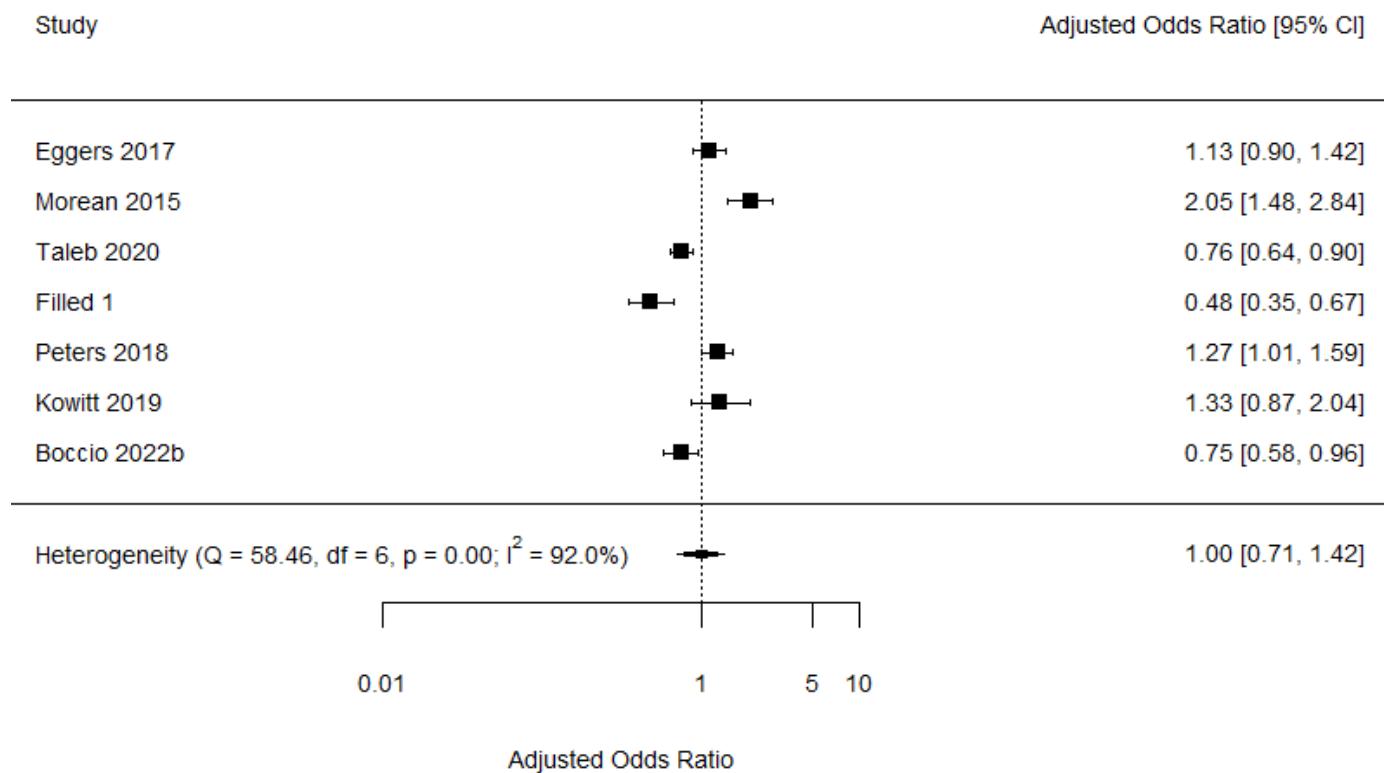
Supplemental Figure L. Meta-Analysis Results of Ethnicity on Lifetime Ever Cannabis Vaping, Adjusted Odds of Non-Hispanic Black (Ref: Non-Hispanic White), among General Adolescent Population

Study	Adjusted Odds Ratio [95% CI]
Eggers 2017	0.92 [0.66, 1.28]
Kowitt 2019	0.51 [0.22, 1.17]
Boccio 2022	0.87 [0.58, 1.31]
Taleb 2020	1.42 [1.05, 1.93]
Peters 2018	1.93 [1.15, 3.23]
Heterogeneity (Q = 12.84, df = 4, p = 0.01; I^2 = 72.1%)	1.08 [0.75, 1.56]

Adjusted Odds Ratio
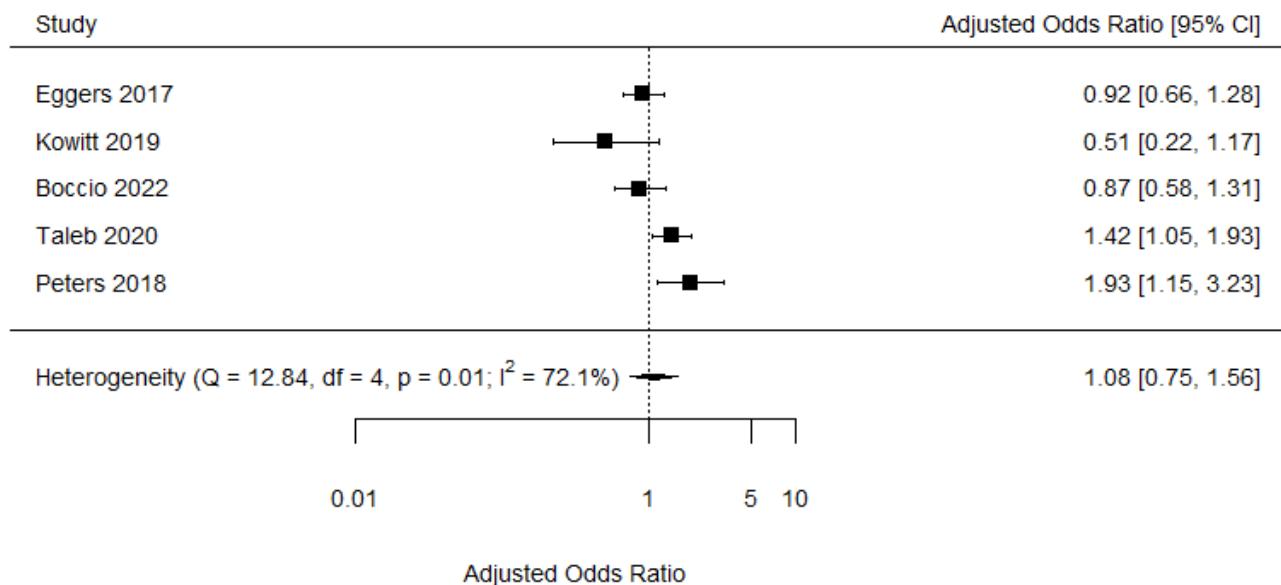
Supplemental Figure M. Meta-Analysis Results of Ethnicity on Lifetime Ever Cannabis Vaping, Adjusted Odds of Hispanic (Ref: Non-Hispanic White), among General Adolescent Population

Study	Adjusted Odds Ratio [95% CI]
Kowitt 2019	1.03 [0.77, 1.37]
Boccio 2022	1.16 [0.85, 1.58]
Eggers 2017	0.98 [0.76, 1.27]
Taleb 2020	2.30 [1.89, 2.79]
Peters 2018	2.73 [1.94, 3.85]
Heterogeneity (Q = 49.51, df = 4, p = 0.00; I^2 = 91.8%)	1.49 [0.98, 2.27]

Adjusted Odds Ratio
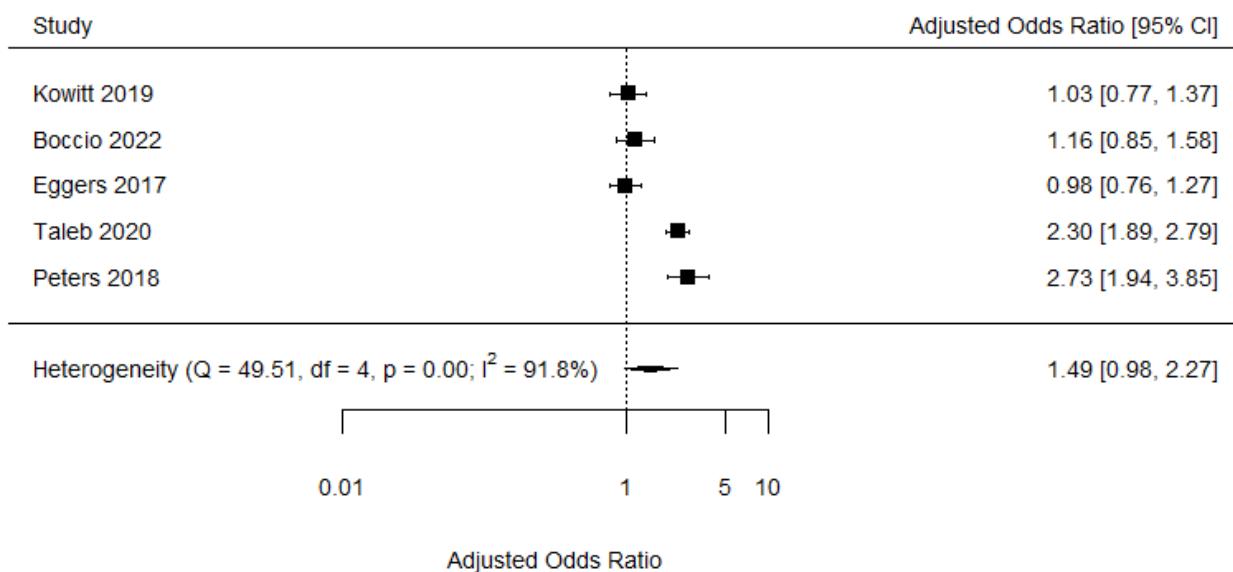
Supplemental Figure N. Meta-Analysis Results of Ethnicity on Lifetime Ever Cannabis Vaping, Adjusted Odds of Other Ethnicities (Ref: Non-Hispanic White), among General Adolescent Population

Study	Adjusted Odds Ratio [95% CI]
Kowitt 2019	1.38 [0.72, 2.64]
Boccio 2022	1.19 [0.77, 1.83]
Peters 2018	1.89 [1.19, 3.01]
Taleb 2020	1.03 [0.77, 1.38]
Eggers 2017	0.83 [0.54, 1.28]
Heterogeneity (Q = 7.43, df = 4, p = 0.11; I^2 = 47.8%)	1.18 [0.90, 1.54]

Adjusted Odds Ratio