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Chapter

Evidence of Health Effects Associated with Marijuana Use: A Comprehensive Public Health Review

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Abstract

Starting in 2014, Colorado Department of Public Health was designated to monitor the emerging science and medical information relevant to the health effects associated with marijuana use. After years of conducting an ongoing systematic review of scientific literature, we have established 139 evidence statements within 11 health topics. Our mission is to translate the science into meaningful public health statements and recommendations to inform and educate the general public, health-care providers, and everyone in-between on the health effects associated with marijuana use. This chapter summarizes evidence from all of our health topics; ranging from respiratory effects of marijuana to cognitive and academic effects of marijuana use on adolescents and young adults.

Keywords: tetrahydrocannabinol, marijuana use, health effects, public health, systematic review

1. Introduction

In 2014 recreational, adult-use of cannabis (interchangeably referred to as marijuana) was established in the state of Colorado. At this time the Colorado Department of Public Health and Environment (CDPHE) was given statutory responsibility in Colorado Revised Statute (C.R.S.) 25-1.5-110, to; “monitor changes ... in the emerging science and medical information relevant to the health effects associated with marijuana use.” and “appoint a panel of health care professionals with expertise in, but not limited to, neuroscience, epidemiology, toxicology, cannabis physiology, and cannabis quality control to further direct policy.” Based on this charge, CDPHE appointed a 14-member committee titled the Retail Marijuana Public Health Advisory Committee (RMPHAC) to review scientific literature on the health effects of marijuana.

Under the same statute mentioned previously, the RMPHAC is directed to “... establish criteria for studies to be reviewed, reviewing studies and other data, and making recommendations, as appropriate, for policies intended to protect consumers of marijuana or marijuana products and the general public.” To implement this

charge, the RMPHAC meets four or five times a year to review the scientific literature currently available on health effects of marijuana use, evaluate findings without bias, openly discuss the science and apply expert opinion, come to consensus on the science, translate the science into public health messages, make policy-related recommendations, recommend surveillance activities, and identify and address gaps in the science important to public health. All this information is compiled and detailed in a report every two years for the Colorado State Board of Health, the Colorado Department of Revenue, and the Colorado General Assembly, titled “Monitoring Health Concerns Related to Marijuana in Colorado” [1].

Since 2014, and prior to this publication, the RMPHAC has come together on a quarterly basis, held discussions concerning hundreds of articles, and developed over one hundred evidence statements within eleven health topics. As more scientific evidence regarding cannabis health effects are published, this committee continues to build upon existing evidence statements or will construct new statements when appropriate. This chapter will detail the review methods used by the RMPHAC to develop evidence statements about the health effects associated with marijuana use, describe the findings from all eleven health topics, and report the public health statements, recommendations, and research gaps used to inform public health policy in the State of Colorado.

2. Systematic review development and process

The first step in the process of investigating the health effects from marijuana use was to develop and implement an unbiased, transparent, and complete process for evaluating scientific literature and data on marijuana use and health outcomes. To ensure this, the RMPHAC and CDPHE technical staff developed a twelve step review process guided by the established preferred reporting items for systematic reviews and meta-analyses (PRISMA) framework [2]. These twelve steps are followed for each review and are as follows:

1. Conduct a broad search of current peer-reviewed publications quarterly. Relevant articles cited in reviews or other primary studies are also included.
2. Review relevant full-text articles identified in the search.
3. Rate the findings: each finding in the articles is rated as a high-, medium-, or low-quality finding based on strengths and limitations of the methods. Evaluation of the strengths and limitations was based on criteria in the grading of recommendations assessment, development and evaluation (GRADE) system, a well-accepted method for evaluating the quality of scientific evidence [3].
4. Group related findings: each finding is categorized based on population, exposure, and outcome (health effect), to answer specific questions.
5. Weigh the evidence: draft evidence statements that summarize the quantity and quality of evidence answering a specific question.
6. Translate the evidence: draft public health statement that translate the evidence statement into language at an 11th grade reading level.

7. Synthesize the evidence: draft public health recommendations (e.g., for education or monitoring) based on important information identified through the review process.
8. Identify research gaps: draft statements to articulate the research gaps identified during the review process.
9. Present to committee: findings, evidence statements, public health statements, public health recommendations, and research gaps are publicly presented to the RMPHAC for review and revision during open public meetings.
10. Public comment: during the open public meetings, interested stakeholders and members of the public are invited to provide comments relevant to the topics presented.
11. Reach consensus: committee members come to consensus on findings, evidence statement, public health statement, public health recommendations, and research gaps.
12. Adopt summary statements: committee votes to officially accept findings, evidence statements, public health statements, public health recommendations, and research gaps.

All review methods were approved by the RMPHAC, including the terms used to conduct the ongoing broad search of peer-reviewed publications for relevant literature. Medline is the priority research database used to obtain articles for review. Embase, the biomedical database, and gray literature were secondarily reviewed when references in included articles were not included in Medline searches. Studies of marijuana use in humans were the primary focus of the review, with animal studies included for only specific topics with limited human research. All identified peer-reviewed literature on a given topic was reviewed, regardless of positive or negative findings or quality of the methods utilized. For the ongoing broad Medline search, medical subject heading (MeSH) terms were used and is as follows; “Cannabis”[Mesh] OR Marijuana “Smoking”[Mesh] OR “Marijuana Abuse”[Mesh] OR cannabis OR marijuana OR marihuana OR hash oil OR hashish. In 2014, when this review was established, specific searches were conducted using the appropriate MeSH terms for each topic area.

Once relevant literature is obtained, each finding is rated high, medium, or low quality based on the strengths and limitations of the methods which is determined by criteria in the GRADE system. The GRADE system is a well-established method for systematic literature review and has been used by the Cochrane Collaboration, British Medical Journal, American College of Physicians, World Health Organization, and many others [3]. Findings rated high quality are defined as “We are very confident that the true effect lies close to that of the estimate of the effect outlined in the study.” These are well-designed and well-controlled studies with few limitations. Due to the fact that most studies included in our review are observational epidemiology studies, receiving a high quality rating does not necessarily imply causation. It simply implies that an observed association persists between an exposure and effect in an appropriately-sized study population after adjusting for appropriate confounders. Medium quality findings are defined as

“we are moderately confident in the effect estimate outlined in the study. The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.” For observational epidemiology studies this implies the finding of an observed association may be limited by a small study population or insufficient adjustment for important confounders. Low quality findings are defined as “our confidence in the effect estimate outlined in the study is limited. The true effect may be substantially different from the estimate of the effect.” For observational epidemiology studies this implies the finding of an observed association with an interpretation that is significantly restricted by study limitations.

Findings from relevant literature are usually grouped based on outcome or the health effect in question. However, in some situations findings are further subdivided based on factors such as: age range of the exposed population, special subject circumstances such as pregnancy or breastfeeding, level or method of marijuana use, time period since last use of marijuana, amount of marijuana used, and THC concentration. Standardized definitions of level of marijuana use (daily, weekly, etc.) and age groups (child, adolescent, young adult, etc.) were established to help facilitate grouping of findings. Once findings are grouped appropriately, the evidence is drafted into evidence statements that summarize the quality and quantity of scientific evidence supporting an association between marijuana use and a health outcome.

3. Systematic review findings

In order to make our review findings easily interpretable we used a standardized rating system to classify evidence statements. These statements are also constructed to accurately portray the quality and quantity of all findings used to support the particular health outcome. Evidence statements all use standardized language from one of the following six classifications:

- Substantial evidence—indicates robust scientific findings that support an association between marijuana use and the outcome.
- Moderate evidence—indicates scientific findings that support an association, but these findings have some limitations.
- Limited evidence—indicates modest scientific findings that support an association, but these findings have significant limitations.
- Mixed evidence—indicates both supporting and opposing scientific findings for an association, with neither direction dominating.
- Insufficient evidence—indicates the outcome has not been sufficiently studied to conclude whether or not there is an association between marijuana use and the outcome.
- Body of research failing to show an association—indicates the topic has been researched without evidence of an association; is further classified as a limited, moderate, or substantial body of research.

In the following sections evidence statements will be discussed according to health topic and statements with enough findings to receive a substantial or moderate rating are displayed in tables. All statements, regardless of evidence level, are drafted by CDPHE technical staff, revised based on committee review and feedback from technical advisors and public stakeholders. Statements in their final form are approved by a vote of the committee.

3.1 Marijuana use among adolescents and young adults

The RMPHAC has reviewed the relationships between adolescent and young adult marijuana use on various areas of concern; including cognitive abilities, academic performance, mental health, and future substance use, displayed in **Table 1**. Specifically regarding cognitive and academic abilities, weekly marijuana use by adolescents is associated with deficits for at least twenty-eight days after last use. Weekly use among adolescents is also associated with failure to graduate from high school or complete a college degree. Information on how marijuana use affects short-term and long-term IQ is currently insufficient and limited, respectively. As with many of our statements that reflect long-term marijuana use, the paucity of long-term studies is a research gap that will hopefully improve due to the changing legal landscape of cannabis throughout the United States.

Adolescents and young adults who use marijuana are more likely to experience psychotic symptoms in adulthood (such as hallucinations, paranoia, and delusional beliefs), future psychotic disorders (such as schizophrenia), and suicidal thoughts or attempting suicide, when compared to adolescents and young adults who do not use marijuana. Additionally, those using marijuana with higher tetrahydrocannabinol (THC) concentration (>10% THC) are more likely than non-users to continue using and to develop future mental health symptoms and disorders. How marijuana use during adolescence affects symptoms or a diagnosis of anxiety in adulthood currently stands at a mixed evidence level, with fourteen articles contributing to this rating. Only one of which received a high quality rating and also reported mixed findings relevant to this evidence statement on anxiety [64]. Results from their main analysis did show an association with adolescent cannabis use and adulthood anxiety, however, results from a monozygotic-only co-twin control analysis reported no association [64].

Evidence shows that adolescents who use marijuana can develop cannabis use disorder, along with marijuana use being associated with developing use disorder for tobacco, alcohol, and other drugs. On a more positive note, evidence shows that adolescents who receive treatment for cannabis use disorder can decrease their use and dependence. Additionally, those who quit using marijuana have lower risks of adverse cognitive and mental health outcomes than those who continue to use.

3.2 Marijuana use and cancer

To assess how marijuana use may or may not be associated with cancer, the RMPHAC reviewed health effects of the chemicals released in marijuana smoke and vapor and evaluated how different rates of marijuana use relate to cancer. Strong evidence shows marijuana smoke contains many of the same cancer-causing chemicals found in tobacco smoke [109]. There is also substantial evidence that daily or near-daily marijuana smoking is associated with pre-malignant lesions in the airway.

	Substantial evidence	Moderate evidence
Benefits of quitting	Treatment for cannabis use disorder can reduce use and dependence [4–10]	Quitting or decreasing marijuana use lowers the risk of adverse mental health outcomes [11–14]
Cognitive and academic effects	Weekly, or more frequent, use is associated with a lower rate of graduating high school [15–23]	Weekly, or more frequent, use is associated with a lower rate of attaining a college degree (among those who start a degree program) [19, 24–29]
		Weekly, or more frequent, use is associated with ongoing cognitive and academic impairment for at least 28 days after last use [30–35]
Mental health	Daily or near daily use is associated with future psychotic disorders like schizophrenia [36–43]	Marijuana use is associated with suicidal thoughts or attempting suicide [22, 44–63]
	Use is associated with future psychotic symptoms (likelihood increases with more frequent use) [14, 40, 42, 64–80]	
Substance use, abuse, and addiction	Those who use marijuana can develop cannabis use disorder (addiction) [81–87]	Marijuana use is associated with future use and use disorder for alcohol [15, 20, 88–92]
	Marijuana use is associated with future use and use disorder for marijuana, tobacco and other drugs [13, 15, 20, 22, 25, 28, 79, 84, 87–105]	
High THC (%) concentration		Using marijuana with higher THC concentration (>10% THC) is associated with continued use [38, 106–108]
		Use of marijuana with higher THC concentration (>10% THC) is associated with future mental health symptoms and disorders [38, 78, 107]

Table 1.
Marijuana use among adolescents and young adults.

However, there is conflicting research for whether or not marijuana smoking is associated with lung cancer. As shown by the moderate evidence statement in **Table 2**, the body of research reviewed has failed to show an association between smoking less than the equivalent of one joint per day for 10 years and lung cancer.

Apart from the respiratory system, most of our statements are not in **Table 2** due to the limited evidence available concerning cancers of the bladder, prostate, head and neck. These limited statements all suggest these forms of cancer might not have any association with marijuana use. However, there is evidence that marijuana use among adult males may be associated with nonseminoma testicular cancer. High quality research on non-respiratory tract cancers related to marijuana use remains a research gap identified by the RMPHAC.

	Substantial evidence	Moderate evidence
Cancer and precancerous lesions	Daily or near daily use is associated with pre-cancerous lesions in airway [110–112]	Smoking less than the equivalent of one joint per day for 10 years is not associated with lung cancer [113–118]
Chemicals in MJ smoke or vapor	Marijuana smoke contains many of the same cancer causing chemicals as tobacco smoke [109, 119–122]	
Genitourinary Cancer		Use among adult males is associated with increased risk of nonseminoma testicular cancer [123–127]

Table 2.
Marijuana use and cancer.

Substantial evidence	Moderate evidence
	Marijuana users/consumers younger than 55 years of age are at an increased risk of stroke [128–145]

Table 3.
Marijuana use and cardiovascular effects.

3.3 Marijuana use and cardiovascular effects

Related to cardiovascular health effects, how marijuana use associates with myocardial infarction, stroke, and death from cardiovascular causes were reviewed. Evidence shows that marijuana use or consumption in those under the age of fifty-five years are at an increased risk of ischemic stroke, as shown in **Table 3**. However, currently there is only limited scientific evidence to support our statements on myocardial infarction and death related to a cardiovascular event.

3.4 Marijuana dose and drug interactions

An important metric to understand is how THC blood levels compare from various marijuana methods of use and the numerous concentrations of THC in available products on the retail marijuana market. For example, there is substantial evidence that smoking more than 10 mg THC (or 10–20% of a 1 g marijuana joint) produces a blood THC level near or above 5 ng/mL within 10 min. As we see the THC concentration of marijuana products increase, we can expect this association to remain strong. One important finding in **Table 4** is that it can take up to four hours after consuming an edible marijuana product to reach the peak THC blood concentration and feel the full effects. Another method of use, vaporized THC, shows moderate evidence of producing a similar blood THC level to smoking the same amount.

Within this topic the RMPHAC reviewed effects of secondhand marijuana smoke, drug-drug interactions involving marijuana, and relationships between marijuana and opioid use. There is credible evidence of clinically important drug-drug interactions between marijuana and multiple medications, including some anti-seizure medications and a common blood-thinner, warfarin. Data about potential interactions are

	Substantial evidence	Moderate evidence
THC blood levels resulting from different exposures	It takes up to four hours after ingesting marijuana (edible products) to reach peak blood THC levels [146–151]	Ingesting (edible products) more than 15 mg THC may produce a blood THC level above 5 ng/mL [148, 152–154]
	Smoking more than 10 mg THC produces a blood THC level near or above 5 ng/mL within 10 min [152, 155–159]	Inhaling vaporized THC produces a blood THC level similar to smoking the same dose [149, 159, 160]
Secondhand exposure	Typical secondhand marijuana smoke exposure is unlikely to cause a positive drug screen by urine or blood [161–169]	

Table 4.
Marijuana dose and drug interactions.

lacking for many drugs at this time and are likely to evolve substantially in the coming years. Other than our statement about secondhand marijuana smoke exposure being unlikely to cause a positive drug screen, our statements in this topic area are all based on limited evidence. Health effects resulting from secondhand marijuana smoke exposure is an area lacking in research. There is also conflicting evidence for whether or not marijuana use is associated with a decrease in opioid use among chronic pain patients or individuals with a history of problem drug use.

3.5 Marijuana use and driving

As with any psychoactive substance it is imperative to know how marijuana affects a person’s ability to drive and the crash risks associated with use. To fully comprehend how marijuana causes driving impairment we must also understand the pharmacokinetics of THC in the human body to know how long these affects will persist after last use. **Table 5** displays all driving related statements that have evidence to provide a substantial or moderate rated statement. Current research shows substantial evidence that recent marijuana use by a driver increases the risk of a motor vehicle crash. In addition, using alcohol and marijuana together increases impairment and the risk of a motor vehicle crash more than using either substance alone.

The RMPHAC also set out to determine how various patterns of marijuana use affect driving. People that consume marijuana less-than-weekly are likely to experience impaired driving after using marijuana containing ten milligrams or more of THC. This statement holds true for smoking or consuming edible marijuana products. Research on driving impairment for those that consume more frequently than weekly is currently lacking in scientific literature. Due to this our evidence statement on crash risk for different levels of use (less-than-weekly compared to more frequent use) has received an insufficient rating at this time.

Articles measuring THC blood levels were also assessed to evaluate for any correlation to driving impairment, crash risk, and to develop statements informing consumers the amount of time to wait prior to driving. There is substantial evidence, including a randomized clinical trial [202], which has displayed meaningful driving impairment with a whole blood THC of 2–5 ng/mL. Additionally, moderate evidence points to a positive relationship between THC blood level and motor vehicle crash risk. In order for marijuana consumers to allow impairment to resolve, less-than-weekly consumers should wait at least six hours after smoking or

	Substantial evidence	Moderate evidence
Combined marijuana and alcohol use	Combined use of marijuana and alcohol increases crash risk more than either substance alone [170–181]	
Impairment and crash risk	Recent marijuana use/consumption by a driver increases the risk of a motor vehicle crash [170–172, 174, 182–188]	Higher THC blood level increases the risk of a motor vehicle crash [173, 178, 180, 189]
	Smoking more than 10 mg THC can lead to driving impairment [147, 155, 157, 177, 190–200]	Blood THC levels of impaired drivers are higher now than they were in the past [201]
	Orally ingesting more than 10 mg THC can lead driving impairment [146, 147, 153, 155]	
	Increased risk of driving impairment at blood THC as low as 2–5 ng/mL [155, 185, 190, 202–206]	
Time to wait before driving	Waiting at least 6 after smoking less than 18 mg allows driving impairment to resolve or nearly resolve [155, 190, 207]	Waiting at least 6 h after smoking about 35 mg allows driving impairment to resolve or nearly resolve [157, 192, 196]
	Waiting at least 8 h after orally ingesting less than 18 mg allows driving impairment to resolve or nearly resolve [147, 153, 155, 208]	

Table 5.
Marijuana use and driving.

eight hours after eating or drinking marijuana products. When consuming larger amounts of THC or for people that consume more frequently, evidence is currently insufficient to determine the safe amount of time for impairment to wear off. Evidence is also showing that blood THC levels of marijuana-impaired drivers are higher now than in the past, likely resulting from the increasing THC concentration of available marijuana products.

3.6 Marijuana use and gastrointestinal or reproductive effects

The RMPHAC reviewed how marijuana use may affect gastrointestinal disease, particularly cyclic vomiting, and infertility or abnormal reproductive function. Displayed in **Table 6**, evidence shows that long-time, daily or near daily marijuana use is associated with cyclic vomiting, also called cannabinoid hyperemesis syndrome (CHS). A majority of evidence supporting this statement is from case reports or case series of identified CHS patients, however, many review articles detail diagnostic criteria, treatment options, and the physiology behind marijuana use and CHS presentation [220]. Regarding reproductive function, there is limited research showing marijuana use is associated with male infertility or abnormal function, however, the research is conflicting for women.

3.7 Marijuana use and injury

The RMPHAC reviewed workplace, recreational and other non-driving injuries, burns from hash-oil extraction or failed electronic smoking devices, and physical

	Substantial evidence	Moderate evidence
Cyclic vomiting		Cyclic vomiting can occur with long-time, daily or near daily marijuana use/consumption (cannabinoid hyperemesis syndrome) [209–219]

Table 6.
Marijuana use and gastrointestinal and reproductive effects.

	Substantial evidence	Moderate evidence
Physical dating violence		Young adult women who use marijuana are unlikely to perpetrate physical dating violence [221–226]

Table 7.
Marijuana use and injury.

dating violence. Evidence shows mixed results for marijuana use affecting the risk of workplace injury, recreational injury, and other types of non-driving-related injury. There have been many reports of severe burns resulting from home-extraction of butane hash oil leading to explosions, and cases of electronic smoking devices exploding, leading to trauma and burns.

Concerning dating violence, **Table 7** shows our only statement reaching moderate or substantial levels of evidence is that young adult women who use marijuana are unlikely to perpetrate physical dating violence against their dating partners. Otherwise, evidence does show that young adults who use marijuana are unlikely to commit or be victims of physical dating violence, however evidence is limited at this time. Evidence for adolescent boys that use marijuana has mixed findings for physical dating violence perpetration and limited evidence for victimization, with evidence for adolescent girls being the opposite (**Table 7**).

3.8 Marijuana use and neurological, cognitive, and mental health effects

Similar to statements in our adolescent and young adult section, it is imperative to understand how marijuana could impact neurological, cognitive, and mental health in adult marijuana consumers. This section also explores how marijuana consumption relates to marijuana abuse and addiction among adult consumers. While our review on cognitive effects includes decision making, executive function, memory impairment, and lasting cognitive effects, strong evidence has been found only for memory impairment, as shown in **Table 8**. We have found substantial evidence that daily or near daily adult marijuana consumers are more likely than non-users to have memory impairments for at least seven days after last use. Evidence is mixed for whether or not these memory impairments or other cognitive effects last for at least twenty-eight days after last use, among the same population of adult consumers.

As with all psychoactive substances, mental health effects in adult marijuana consumers must be examined. An important acute effect of THC with substantial evidence is psychotic symptoms, such as hallucinations, paranoia, and delusional beliefs during intoxication, and these symptoms are worse with higher doses. Additionally, daily or near daily marijuana use is associated with developing a psychotic disorder such as schizophrenia. As detailed in our report focusing on the increasing concentration of THC in products available, there is increased public health concern as these

	Substantial evidence	Moderate evidence
Cognitive effects	Daily or near daily use is associated with impaired memory for at least 7 days [30, 227–235]	
Mental health effects	Use is associated with acute psychotic symptoms during intoxication, which are worse with higher doses [236–243]	
	Daily or near daily use is associated with future psychotic disorders like schizophrenia [38, 42, 107, 244–246]	Use of marijuana with THC concentration > 10% is associated with future psychotic disorders like schizophrenia [38, 107, 247]
Substance use, abuse and addiction	Those who use marijuana can develop cannabis use disorder (addiction) [82, 85, 86, 93, 248–252]	
	Treatment for cannabis use disorder can reduce use and dependence [4, 6, 8, 9, 253–257]	
	Those using daily or near daily can experience withdrawal symptoms when abstaining [11, 258–270]	

Table 8.
Marijuana use and neurological, cognitive, mental health effects.

products may lead to higher potential for adverse health effects in consumers [1]. This concern is substantiated by available research enabling us to provide a moderate rated statement showing association between higher concentration THC products and future psychotic disorders in adult marijuana consumers.

Finally, evidence shows marijuana consumers can experience withdrawal symptoms when abstaining and become addicted to marijuana or develop cannabis use disorder. However, as with adolescents, treatment for cannabis use disorder can reduce use and dependence in adult consumers. Many associations within this section lack high quality evidence or research currently exhibits mixed findings, such as marijuana use being associated with anxiety, depression, or bipolar disorder (**Table 8**).

3.9 Marijuana use during pregnancy and/or breastfeeding

Table 9 details our evidence concerning marijuana use during pregnancy and breastfeeding. Biological evidence shows THC passes through the placenta to the fetus and is present in the breast milk of women who use marijuana. Scientific evidence shows the fetus absorbs and metabolizes THC passed through the placenta and THC metabolites are found in the meconium or first stool passed by the newborn after birth. Additionally, infants who drink breast milk containing THC absorb and metabolize the THC. These statements show how important it is to understand how marijuana use during pregnancy and/or breastfeeding can affect the offspring or impact delivery of the offspring.

Specifically regarding exposed offspring, the RMPHAC reviews potential effects starting at birth and later in childhood or adolescence. Marijuana use during pregnancy has shown to not be associated with birth defects in general, but limited evidence of an association with an increased risk of heart defects, stillbirth, and decreased growth in offspring. Stronger evidence was found for effects that are seen

	Substantial evidence	Moderate evidence
Effects on exposed offspring		Prenatal marijuana exposure is associated with reduced cognitive function, academic ability, and IQ scores in childhood [271–280]
		Prenatal marijuana exposure is associated with attention problems in childhood [273, 281–285]
Birth defects		Prenatal marijuana use is not associated with birth defects [286–292]
Preterm delivery or abnormal birth weight		Maternal use during pregnancy is associated with infants being born small for gestational age (birth weight less than 10th percentile for gestational age) [286, 287, 289, 292–305]
Biological evidence concerning marijuana use during pregnancy and breastfeeding		
	THC is passed through the placenta of women who use marijuana, the fetus absorbs and metabolizes the THC, and THC metabolites are found in the meconium [306–310].	
	THC is present in the breast milk of women who use marijuana. Infants who drink breast milk containing THC absorb and metabolize the THC [311–316].	

Table 9.
Marijuana use during pregnancy and/or breastfeeding.

in offspring years after birth if a child’s mother used marijuana while pregnant. These include impaired cognitive function and academic ability, lower IQ scores, and attention problems in childhood.

3.10 Marijuana use and respiratory effects

While consumers have a variety of marijuana products to choose from, smoking marijuana flower remains the most common method of use and thus respiratory effects must be evaluated [317]. The RMPHAC reviews respiratory diseases such as chronic obstructive pulmonary disorder (COPD), chronic bronchitis and asthma, respiratory infections, lung function relative to smoked marijuana. The committee has also reviewed potential health effects of vaporized marijuana as those products have emerged on the legal market. Displayed in **Table 10**, strong evidence shows an association between daily or near-daily marijuana use and chronic bronchitis, including chronic cough, sputum production, and wheezing. Weaker evidence shows daily or near-daily marijuana use may be associated with bullous lung disease leading to pneumothorax in individuals younger than forty years of age. Additionally, limited evidence does show frequent smokers who switch from marijuana smoking to marijuana vaporizing may have fewer respiratory symptoms and improved pulmonary function. Finally, a notable effect of acute marijuana smoking is a short-term improvement in lung airflow, though evidence contributing to this statement is dated (**Table 10**).

3.11 Unintentional marijuana exposure in children

As marijuana becomes more accessible to the public, we must consider unintentional exposures in homes with children and how packaging can affect these. Strong evidence was found, shown in **Table 11**, that more unintentional exposures of children occur in states with increased legal access to marijuana, and exposures can lead

	Substantial evidence	Moderate evidence
Smoked marijuana	Use is associated with chronic bronchitis with cough, wheezing and mucus [318–327]	
	Acute use is associated with short-term lung airflow improvement [328–330]	

Table 10.
Marijuana use and respiratory effects.

Substantial evidence	Moderate evidence
Legal marijuana access increases unintentional marijuana exposures in children [331–341]	Child-resistant packaging reduces unintentional pediatric poisonings [342–344]

Table 11.
Unintentional marijuana exposure in children.

to significant clinical effects requiring medical attention and even hospitalization. However, evidence does show that child-resistant packaging reduces unintentional pediatric marijuana poisonings (**Table 11**).

4. Public health statements and recommendations

Once evidence statements have been drafted and approved by the RMPHAC, the next step (number 6 from our systematic review process) is to translate the evidence into public health statements. These are designed to accurately reflect the evidence statements using language the public can understand. The committee also wanted to ensure these statements conveyed the volume and quality of research related to the outcome and allowed the statement to stand on its own without context. Similar to our evidence statements, these use standardized language to represent the strength of relationship and use the phrase “associated with” to represent epidemiologic associations that do not imply causation. As of the date of this book’s publication CDPHE has seventy-four public health statements corresponding to all our evidence statements rated moderate or substantial.

In a similar manner, public health statements are subsequently drafted into public health recommendations. These are synthesized in order to inform the development of evidence-based prevention and education campaigns performed by CDPHE. Furthermore, recommendations are separated by data quality issues, surveillance, and education. Our recommendations share common themes to those put forth by the National Academies of Sciences, Engineering, and Medicine’s review of health effects associated with cannabis and cannabinoids [345].

Data quality issues are defined as recommendations to improve current data collection deficiencies at the clinical or governmental level that prevent full analysis of public health outcomes related to marijuana use. It is especially important to improve data quality by systematically collecting information on the frequency, amount, THC content, and method of marijuana use in both public health surveillance and medical care settings. Clinicians should routinely screen for marijuana use during hospitalizations, especially among pregnant or adolescent patients.

Public health surveillance recommendations are based on improving capacity to detect an acute public health danger (e.g., real time emergency department

surveillance to detect poisonings from contaminated product); the ability to characterize chronic public health dangers to support policy and other intervention decisions; or the ability to generate epidemiologic data to contribute to planning and evaluating population level interventions. Questions regarding marijuana use should be continued on population-based surveys such as the Behavioral Risk Factor Surveillance System, the Healthy Kids Colorado Survey, and Pregnancy Risk Assessment Monitoring System. Additionally, methods should be expanded to collect more detailed information, such as quantity and methods of use, THC content of products used, and adverse effects experienced.

Education recommendations are included to ensure evidence-based information on potential health effects of marijuana use is provided to the appropriate target audiences. Public education is especially important related to the effects of use during pregnancy, adolescent use, driving after use, increasing THC concentration of products, and unsafe storage around children. Education for health care providers should also be emphasized on the need for marijuana use screening, the known health effects of use, and encouraging more open dialog between providers and patients.

5. Research gaps

In addition to public health recommendations, important research gaps related to the population-based health effects of marijuana use were identified during the literature review process. These research gaps are based on common limitations of existing research or issues important to public education or policymaking. Research gaps particularly important to public health and safety include the need for: (1) research on the effects of marijuana use on pregnant women and their offspring, including while breastfeeding; (2) research on marijuana and marijuana products that contain THC concentrations consistent with products currently available in legalized markets; (3) research on health effects among individuals who have used marijuana frequently for a long period of time; (4) research on driving impairment among people who use marijuana more than weekly and may have developed tolerance; (5) research to better characterize the pharmacokinetics/pharmacodynamics, potential drug interactions, health effects, and impairment related to non-smoking methods of marijuana use such as edible products and vaporizing; and (6) research to better describe the risk of adverse health effects due to contamination of the marijuana product by fungi, mold, solvents, additives, heavy metals, and pesticides.

Other research gaps identify areas that need improvement in new research moving forward. Such as studies using better and more standardized indicators of marijuana use, including frequency, THC content, and route of exposure, including populations that use marijuana daily or near daily, and stratifying groups by age and gender. Finally one step to provide strong evidence would be research data on a community based cohort to study both beneficial and adverse health effects of marijuana consumption. Identifying these research gaps provides researchers and funding sources with an important framework to prioritize areas of research related to marijuana use and public health.

6. Conclusion

Since 2014, when CDPHE was designated to monitor the emerging science and medical information relevant to the health effects associated with marijuana use, the

RMPHAC and CDPHE technical staff have conducted an ongoing systematic review of scientific literature to establish over one hundred evidence statements with eleven health topics. Our mission is to translate the science into meaningful public health statements and recommendations to inform and educate the general public, healthcare providers, and everyone in-between on the health effects associated with marijuana use.

First, the committee established a strict process to ensure a thorough and unbiased review, set up quarterly meetings to enable open discussions on a continuous basis, and come to consensus on the science and how to present this information to the public. After establishing our process, evidence from scientific research is constantly reviewed and added when appropriate to form a comprehensive review of marijuana health effects across eleven health topic. Strong evidence statements from all health topics were displayed in tables and key findings were detailed in subsections to provide an overview of effects associated with marijuana use across many different populations and health topics. Additional details were described on how these evidence statements are used to inform public health policy in the State of Colorado through public health recommendations and research gaps.

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Conflict of interest


“The authors declare no conflict of interest.”

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