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REVIEW ARTICLE

The Impact of Cannabis Decriminalization and Legalization on Road Safety Outcomes: A Systematic Review

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Introduction: There is substantial debate concerning the impact of cannabis decriminalization and legalization on road safety outcomes.

Methods: Seven databases were systematically searched: Embase, MEDLINE, and PsycINFO through Ovid as well as Web of Science Core Collection, SafetyLit, Criminal Justice Database (ProQuest), and Transport Research International Documentation (from inception to June 16, 2021). Eligible primary studies examined group-level cannabis decriminalization or legalization and a road safety outcome in any population.

Results: A total of 65 reports of 64 observational studies were eligible, including 39 that applied a quasi-experimental design. Studies examined recreational cannabis legalization (n=50), medical cannabis legalization (n=22), and cannabis decriminalization (n=5). All studies except 1 used data from the U. S. or Canada. Studies found mixed impacts of legalization on attitudes, beliefs, and self-reported driving under the influence. Medical legalization, recreational legalization, and decriminalization were associated with increases in positive cannabis tests among drivers. Few studies examined impacts on alcohol or other drug use, although findings suggested a decrease in positive alcohol tests among drivers associated with medical legalization. Medical legalization was associated with reductions in fatal motor-vehicle collisions, whereas recreational legalization was conversely associated with increases in fatal collisions.

Discussion: Increased cannabis positivity may reflect changes in cannabis use; however, it does not in itself indicate increased impaired driving. Subgroups impacted by medical and recreational legalization, respectively, likely explain opposing findings for fatal collisions. More research is needed concerning cannabis decriminalization; the impacts of decriminalization and legalization on nonfatal injuries, alcohol and other drugs; and the mechanisms by which legalization impacts road safety outcomes.

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INTRODUCTION

There has been a global shift toward cannabis decriminalization and legalization for medical and recreational purposes over the past several decades.[1] This shift reflects efforts to both align the law with societal values and practices and reduce the harms caused by the criminalization of cannabis.[2] Decriminalization, in which cannabis is not legal but is not considered a criminal

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offense (e.g., criminal sanctions may be replaced by civil sanctions such as fines or referral to drug rehabilitation), is estimated to have been implemented in >30 countries worldwide.[2] Medical cannabis (e.g., requiring a prescription or other evidence of medical need) is legal in many countries, including Canada, and in more than half of all states in the U.S.[3] Uruguay, Canada, and Malta are the only countries to have legalized recreational cannabis on a national scale (in 2013, 2018, and 2021, respectively),[4] and since 2012, 18 U.S. states and the District of Columbia have legalized recreational cannabis.[5]

There is substantial debate concerning the impact of cannabis decriminalization and medical and recreational legalization on potential harms, including drug-impaired driving and related outcomes (e.g., attitudes and beliefs, collisions, injuries).[6] Acute cannabis consumption is known to impair driving ability,[7] with meta-analyses estimating that cannabis impairment is associated with a low-moderate increase in collision risk.[8] However the precise economic and societal costs of cannabis-impaired driving are difficult to determine (e.g., because cannabis is frequently consumed with other legal and illegal substances,[9] and the conduct and reporting of drug testing vary across jurisdictions[10]).

The liberalization of cannabis policies may impact drug-impaired driving through different mechanisms, including attitudes, beliefs, and social norms concerning the safety of driving under the influence of cannabis (DUIC)[11]; the prevalence, frequency, and/or potency of cannabis consumed[12−16]; and the consumption of other drugs (e.g., alcohol, opioids), which may be either substitutes or complements to cannabis use.[13,15,17] However, assessing the causal impact of cannabis policies on road safety outcomes is challenging owing to a number of factors, including differential policy implementation (e.g., retail sales, home growing) and cointerventions such as cannabis per se driving limits.[18] Jurisdictions that liberalize cannabis policies may also differ from other jurisdictions in terms of time-varying factors, including regulations (e.g., seatbelt laws, graduated licensing, senior licensing, distracted driver laws, speed limits),[15] spillover effects from neighboring jurisdictions with legalization,[19] and patterns of substance use[20,21] and motor-vehicle safety[22] over time.

These and other jurisdiction-specific policy, legal, and demographic differences and/or residual biases from methodologic challenges in policy impact evaluation may explain the variability of findings in the literature. However, there is no comprehensive synthesis of the relevant evidence to date. Therefore, a systematic review of the impact of cannabis decriminalization and legalization on road safety outcomes was conducted to inform cannabis-related policy and interventions for the prevention of drug-impaired driving as well as to identify gaps and limitations in the current literature.

METHODS

A systematic review was conducted and reported in accordance with the PRISMA statement.[23] The protocol was submitted to the international prospective register of systematic reviews on June 15, 2021, before the completion of preliminary searches (CRD42021261243).[24]

Search Strategy

Seven databases were systematically searched from inception to June 16, 2021: Embase, MEDLINE, and PsycINFO through Ovid as well as the Web of Science Core Collection, SafetyLit, Criminal Justice Database (ProQuest), and Transport Research International Documentation databases. Search terms included subject headings and text words for *cannabis, policies*, and *road safety outcomes*. No limits were placed on language or date of publication. The search strategies (Appendix 1, available online) were peer reviewed by a librarian in accordance with the peer review of electronic search strategies statement.[25] Additional gray literature searches were conducted of relevant conference proceedings and preprint repositories to identify any relevant unpublished literature. The reference lists of included reports were also searched for additional eligible publications.

Study Selection

Search results were downloaded and deduplicated in EndNote X9.[26] Unique references were transferred to Distiller SR, a systematic review software (Evidence Partners, Ottawa, Canada). Title/abstracts were screened in duplicate by 2 independent reviewers. Reports (including conference proceedings and abstracts) were included if they (1) contained primary data from an experimental, quasi-experimental, or observational study, with or without an external control group; (2) examined group-level cannabis decriminalization, legalization (medical or recreational), or a relevant policy dimension (e.g., retail sales); (3) reported at least 1 road safety outcome (e.g., attitudes concerning DUIC, biochemical measures of cannabis among drivers, traffic-related mortality) in any population; and (4) included a relevant comparator (e.g., pre-exposure for within-group comparisons or unexposed group [s] for between-group comparisons) (Appendix 2, available online). The full text was retrieved for any reference considered potentially eligible by either reviewer. Full texts were likewise screened in duplicate (Appendix 3, available online), with any reference meeting the inclusion criteria included in the review. In the event that a conference abstract or other brief report overlapped entirely with a full-text report, only the full text was included. Non-English language reports were subject to the same selection process.

Risk of Bias

Risk of bias of included studies was assessed independently by 2 reviewers using the Risk Of Bias In Non-randomized Studies−of Interventions tool.[27] Bias was assessed to be low (comparable with a well-performed randomized trial), moderate (good nonrandomized study), serious (important problems), critical (too problematic to contribute useful evidence), or no information in 7 domains: confounding, selection of participants, classification of interventions, deviations from intended interventions, missing data, measurement error, and reporting.

Data Synthesis

Data, including publication, policy, and population characteristics; study methodology; and road safety outcomes, were extracted by 1 reviewer and validated by the second reviewer. Given substantial heterogeneity between studies, a narrative synthesis of the findings was conducted.

RESULTS

A total of 6,402 records were identified through database searches (Figure 1). After duplicates (*n*=2,665) were removed, 3,737 records remained for title/abstract screening. Of these, 143 records were considered potentially eligible and were retrieved for full-text review. An additional 10 reports identified from gray literature and citation searches were also assessed for eligibility. A total of 65 reports of 64 studies satisfied the criteria for inclusion.

Included reports (Table 1[15,19,24,28−91]) were published between 2013 and 2021, with more than half (*n*=35) published in 2019 or later. Most were peer reviewed (*n*=45), with the remaining being organizational reports (*n*=13), dissertations (*n*=3), conference abstracts (*n*=2), or working papers (*n*=2), and all were in English language. All studies were observational, including 39 studies that applied quasi-experimental designs (e.g., difference-in-differences, interrupted time series). Apart from a single study conducted using data from Uruguay,[68] studies used data from the U.S. only (*n*=59), Canada only (*n*=2), or both (*n*=2). Included studies examined cannabis decriminalization (*n*=5), medical cannabis legalization and/or retail sales (*n*=22), and recreational cannabis legalization and/or retail sales (*n*=50).

The overall risk of bias of included reports was assessed to be moderate (*n*=19; moderate or low risk of bias in all the 7 domains) or serious (*n*=46; serious risk of bias in at least 1 domain) using the Risk Of Bias In Non-randomized Studies−of Interventions tool (Appendix 4, available online).[27] Studies were assessed to be at either moderate (*n*=26) or serious (*n*=39) risk of confounding depending on the extent to which they addressed potential confounding (e.g., owing to time-varying factors). Risk of bias in the measurement of outcomes was assessed to be low (*n*=21), moderate (*n*=19), serious (*n*=23), or no information (*n*=2), with the most common sources of potential measurement bias related to drug-testing practices and self-reported outcomes. Selection of participants into the study was assessed to be low (*n*=32), moderate (*n*=7), or serious (*n*=26), often owing to selection that was potentially related to the policy and outcomes of interest. Given the absence of routine protocol registration for nonexperimental studies, most included studies were assessed to be at moderate risk of bias for selection of the reported results (*n*=60) if they clearly defined their outcome measurements and

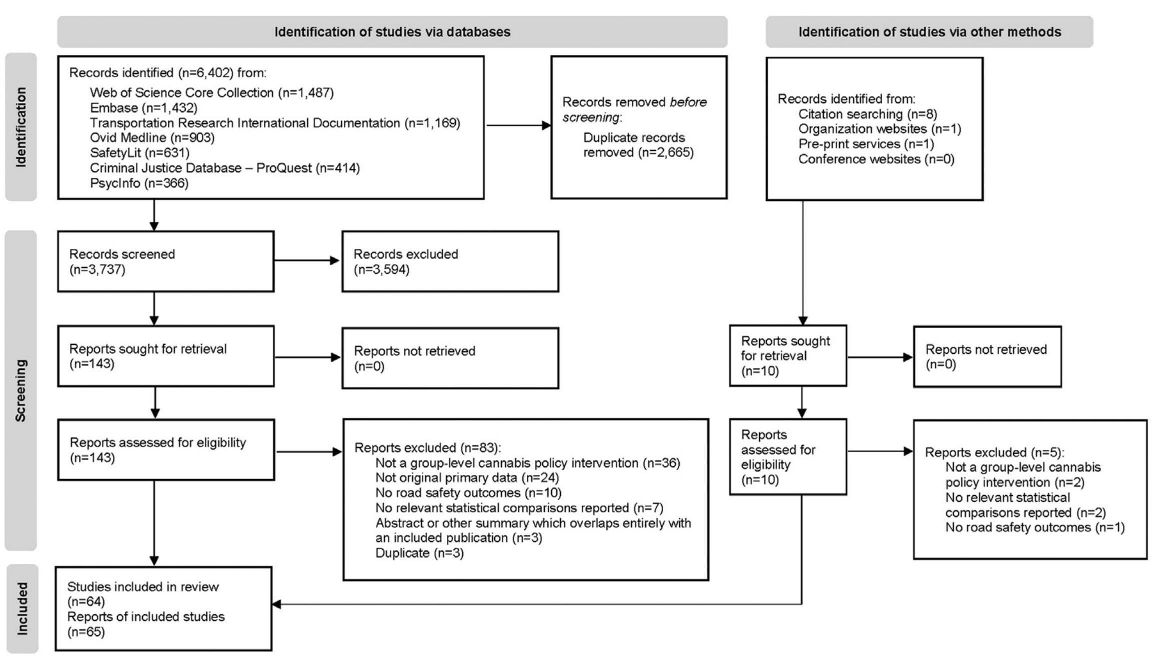

Figure 1. Flow diagram of study selection.
Source: This figure was adapted from Page et al.[23]

Table 1. Characteristics of Included Studies Examining the Impact of Cannabis Policies on Road Safety Outcomes

First author (year)	Study design	Policy intervention (s)	Road safety outcome(s)	Outcome data source(s)	Overall risk of bias[a]
Adams (2017)[28]	Quasi-experimental	Medical cannabis legalization	Proportion of drivers, drivers and front seat passengers, or backseat passengers wearing a seatbelt	National Occupant Protection Use Survey (NHTSA)	Serious
Anderson (2013)[15]	Quasi-experimental	Medical cannabis legalization	MVC fatalities per 100,000 population; fatalities per 100,000 population resulting from collisions in which (1) at least 1 driver had BAC >0, (2) at least 1 driver had BAC ≥0.1, (3) or all drivers had BAC=0	FARS (NHTSA)	Moderate
Aydelotte (2017)[29]	Quasi-experimental	Recreational cannabis legalization	MVC fatalities per billion vehicle miles traveled	FARS (NHTSA)	Moderate
Aydelotte (2019)[30]	Quasi-experimental	Recreational cannabis legalization, recreational cannabis retail sales	MVC fatalities per billion vehicle miles traveled	FARS (NHTSA)	Moderate
Banta-Green (2016)[31]	Quasi-experimental	Recreational cannabis legalization	Proportion of drivers suspected of DUI or involved in serious collisions who test positive for THC	Toxicology laboratory, dispatch, and officer activity logs (Washington State Patrol)	Serious
Bartos (2020)[32]	Quasi-experimental	Medical cannabis legalization	Annual MVC fatalities	FARS (NHTSA)	Moderate
Benedetti (2021)[33]	Cross-sectional survey	Medical cannabis legalization; recreational cannabis legalization	Proportion of respondents who (1) self-reported driving within 1 hour of cannabis use at least once in the last year, (2) said that driving within 1 hour of cannabis use is somewhat or completely acceptable, and (3) somewhat or strongly supported a per se cannabis law	Traffic Safety Culture Index survey (AAA Foundation for Traffic Safety)	Serious
Benedetti (2021)[34]	Cross-sectional survey	Medical cannabis legalization; recreational cannabis legalization	Proportion of respondents who self-reported driving within 1 hour of cannabis use at least once in the last year	Traffic Safety Culture Index survey (AAA Foundation for Traffic Safety)	Serious
Berg (2018)[35]	Cross-sectional survey	Medical cannabis retail sales; recreational cannabis retail sales	Proportion of respondents who self-reported DUIC at least once in the past 30 days	Cross-sectional survey	Serious
Calvert (2020)[36]	Quasi-experimental	Medical cannabis legalization; recreational cannabis legalization; recreational cannabis retail sales	Fatal MVCs and fatal pedestrian-involved MVCs per month per 100,000 population	FARS (NHTSA)	Moderate
Chamlin (2021)[37]	Quasi-experimental	Recreational cannabis legalization	Number of fatal MVCs per month that involved alcohol	FARS (NHTSA)	Serious
Chung (2019)[38]	Quasi-experimental	Recreational cannabis retail sales	Proportion of patients admitted for MVC-related traumatic injuries who tested positive for THC or other drugs	Hospital trauma registries (Traumabase, Digital Innovations, Inc.)	Serious
Cook (2020)[39]	Quasi-experimental	Cannabis decriminalization; medical cannabis legalization	Fatal MVCs per capita; fatal MVCs per capita with BAC ≥0.08	FARS (NHTSA)	Moderate

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Table 1. Characteristics of Included Studies Examining the Impact of Cannabis Policies on Road Safety Outcomes (*continued*)

First author (year)	Study design	Policy intervention (s)	Road safety outcome(s)	Outcome data source(s)	Overall risk of bias[a]
Couper (2014)[40]	Cohort	Recreational cannabis legalization	Proportion of suspected impaired drivers testing positive for THC or 11-nor-9-carboxy-THC	Blood toxicology results submitted by law enforcement officers (Washington State)	Serious
Cuttler (2018)[41]	Cross-sectional survey	Recreational cannabis retail sales	Proportion of respondents who self-reported (1) whether they believed that cannabis impairs their ability to drive safely, (2) whether they drive within 1 hour of using cannabis, and (3) whether they had ever been in an accident or received a ticket while DUIC	Cross-sectional survey	Serious
Delling (2019)[42]	Cohort	Recreational cannabis legalization; recreational cannabis retail sales	Medical diagnosis of MVC at hospital admission	Healthcare Cost and Utilization Project inpatient databases	Serious
Eichelberger (2016)[43]	Cross-sectional survey	Recreational cannabis legalization	Proportion of respondents who: (1) agreed that driving after using cannabis is a problem; (2) self-reported having driven within 2 hours of using cannabis in the past year; or (3) self-reported having driven within 2 hours of using alcohol in the past year	Cross-sectional survey from Opinion America Group, LLC	Serious
Eichelberger (2019)[44]	Cross-sectional survey	Recreational cannabis retail sales	Proportion of drivers who tested positive for THC, tested positive for alcohol or both, self-reported the likelihood of cannabis impairing driving, and the risk of being arrested for cannabis-impaired driving	Roadside surveys (NHTSA; Insurance Institute for Highway Safety)	Serious
Farmer (2021)[45]	Quasi-experimental	Recreational cannabis legalization; recreational cannabis retail sales	MVCs with injuries per quarter; MVCs with fatalities per quarter	State-maintained databases	Moderate
Fedorova (2021)[46]	Cohort	Recreational cannabis legalization	Self-reported DUIC in the past 90 days	Cannabis, Health, and Young Adults study	Serious
Fink (2020)[47]	Quasi-experimental	Medical cannabis legalization	Self-reported DUIC in the past 12 months; self-reported DUI of alcohol in the past 12 months	National Longitudinal Alcohol Epidemiologic Survey (1991–1992); National Epidemiologic Survey on Alcohol and Related Conditions (2001–2002); NESARC-III (2012–2013)	Serious
Fowles (2021)[48]	Quasi-experimental	Recreational cannabis legalization	MVC fatalities per vehicle miles traveled	FARS (NHTSA)	Serious
Goodman (2020)[49]	Cross-sectional survey	Recreational cannabis legalization	Proportion of respondents who reported having ever driven within 2 hours of using cannabis	International Cannabis Policy study (wave 1)	Serious
Grigorian (2019)[50]	Cohort	Recreational cannabis legalization	Proportion of THC–positive patients with trauma whose mechanism of injury is MVC or motorcycle accident	Hospital trauma registry	Serious

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Table 1. Characteristics of Included Studies Examining the Impact of Cannabis Policies on Road Safety Outcomes (*continued*)

First author (year)	Study design	Policy intervention (s)	Road safety outcome(s)	Outcome data source(s)	Overall risk of bias[a]
Guenzburger (2013)[51]	Quasi-experimental	Medical cannabis legalization	Proportion of drivers involved in fatal collisions who test positive for cannabinoids	FARS (NHTSA)	Serious
Hake (2019)[52]	Quasi-experimental	Recreational cannabis legalization	Proportion of drivers involved in fatal collisions who test positive for cannabinoids	FARS (NHTSA)	Serious
Hamzeie (2017)[53]	Quasi-experimental	Cannabis decriminalization; recreational cannabis legalization	Proportion of drivers involved in fatal collisions who test positive for any cannabis-related substance	FARS (NHTSA)	Serious
Hansen (2020)[54]	Quasi-experimental	Recreational cannabis legalization	Proportion of fatal MVCs that involve at least 1 driver who is (1) cannabis positive, (2) alcohol positive, or (3) neither; total MVC-related fatalities per billion vehicle miles traveled that involve at least 1 driver who is (1) cannabis positive, (2) alcohol positive, or (3) neither	FARS (NHTSA)	Moderate
Hao (2020)[55]	Quasi-experimental	Recreational cannabis legalization	DUI arrests per 10,000 population	Uniform Crime Reporting Program data	Serious
Highway Loss Data Institute (2017)[56]	Quasi-experimental	Recreational cannabis retail sales	MVC claims per insured vehicle years	Highway Loss Data Institute	Moderate
Highway Loss Data Institute (2018)[57]	Quasi-experimental	Recreational cannabis retail sales	MVC claims per insured vehicle years	Highway Loss Data Institute	Moderate
Jones (2019)[58]	Quasi-experimental	Medical cannabis legalization	Proportion of drivers evaluated at Level I trauma centers who (1) were THC positive or (2) had BAC exceeding the legal limit for their age (≥0.08 g/dL for drivers aged ≥21 years and any conclusive level [BAC >0g/dL] for drivers aged 16−20 years) or (3) THC positive with any detectable alcohol	Arizona State trauma registry	Serious
Kamer (2020)[59]	Quasi-experimental	Recreational cannabis retail sales	MVC fatalities per billion vehicle miles traveled	FARS (NHTSA)	Serious
Kim (2016)[60]	Quasi-experimental	Medical cannabis Retail Sales and/or Allowances for Home Cultivation	Proportion of fatally injured drivers who tested positive for opioids	FARS (NHTSA)	Serious
Lane (2019)[19]	Quasi-experimental	Recreational cannabis retail sales	MVC fatalities per million residents	Wide-Ranging Online Data for Epidemiologic Research web application (Centers for Disease Control and Prevention); RoadSafetyBC	Moderate
Lee (2018)[61]	Quasi-experimental	Cannabis decriminalization; medical cannabis retail sales; recreational cannabis retail sales	Proportion of drivers involved in fatal collisions who test positive for THC	FARS (NHTSA)	Serious

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Table 1. Characteristics of Included Studies Examining the Impact of Cannabis Policies on Road Safety Outcomes (*continued*)

First author (year)	Study design	Policy intervention (s)	Road safety outcome(s)	Outcome data source(s)	Overall risk of bias[a]
Lensch (2020)[62]	Cross-sectional survey	Recreational cannabis retail sales	Self-reported risky behaviors and attitudes toward cannabis-impaired driving	International Cannabis Policy study (Wave 1)	Serious
Leung (2021)[63]	Quasi-experimental	Medical cannabis legalization; recreational cannabis legalization	Number of MVC fatalities	FARS (NHTSA)	Moderate
Masten (2014)[64]	Quasi-experimental	Medical cannabis legalization	Proportion of drivers involved in fatal collisions who test positive for cannabinoids	FARS (NHTSA)	Serious
McGinty (2017)[65]	Cross-sectional survey	Recreational cannabis legalization	Proportion of respondents who agree that legalization increases MVCs	Cross-sectional survey	Serious
Miller (2018)[66]	Quasi-experimental	Recreational cannabis legalization; recreational cannabis retail sales	DUI arrest rate per 100,000 population; fatal MVCs involving at least 1 driver with BAC ≥0.08 or higher per 100,000 population	Uniform Crime Reports — Crime in the United States (Federal Bureau of Investigation); FARS (NHTSA)	Serious
Monfort (2018)[67]	Quasi-experimental	Recreational cannabis retail sales	MVCs per million passenger vehicle registrations	Insurance Institute for Highway Safety	Moderate
Nazif-Munoz (2020)[68]	Quasi-experimental	Recreational cannabis legalization	MVC fatalities among light motor vehicles drivers and motorcyclists	National Road Safety Agency of Uruguay and the Ministry of Transport and Public Works	Moderate
Notrica (2020)[69]	Quasi-experimental	Cannabis decriminalization or legalization	Age-adjusted MVC mortality per 100,000 population	FARS (NHTSA)	Moderate
Otto (2016)[70]	Cross-sectional survey	Medical cannabis legalization; recreational cannabis legalization	DUIC: behavior, intention, willingness, attitude; perceived norms (injunctive), perceived norms (descriptive)	Driving under the Influence of Cannabis Survey	Serious
Pollini (2015)[71]	Cross-sectional survey	Cannabis decriminalization	Proportion of cannabinoid-positive drivers among drug-tested weekend drivers and among drug-tested fatally injured drivers	Roadside surveys; FARS (NHTSA)	Serious
Ramirez (2016)[72]	Cross-sectional survey	Recreational cannabis retail sales	Proportion of drivers positive for THC, alcohol, other drugs only, or medications	Roadside surveys	Serious
Rotermann (2020)[73]	Cross-sectional survey	Recreational cannabis legalization	Proportion of respondents with a driver's license who reported having driven within 2 hours of cannabis use in the past 3 months; proportion of respondents who reported having been a passenger in a vehicle driven by someone who had consumed cannabis within 2 hours in the past 3 months	National Cannabis Survey	Serious
Salomonsen-Sautel (2014)[74]	Quasi-experimental	Medical cannabis retail sales	Proportion of drivers involved in fatal collisions who (1) test positive for cannabis or (2) have BAC ≥0.08	FARS (NHTSA)	Serious

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Table 1. Characteristics of Included Studies Examining the Impact of Cannabis Policies on Road Safety Outcomes (*continued*)

First author (year)	Study design	Policy intervention (s)	Road safety outcome(s)	Outcome data source(s)	Overall risk of bias[a]
Santaella (2017)[75]	Quasi-experimental	Medical cannabis retail sales	MVC fatalities per 100,000 population	FARS (NHTSA)	Moderate
Santaella-Tenorio (2017)[76]	Quasi-experimental	Medical cannabis legalization; medical cannabis retail sales	MVC fatalities per 100,000 population	FARS (NHTSA)	Moderate
Santaella-Tenorio (2020)[77]	Quasi-experimental	Recreational cannabis retail sales	MVC fatalities per billion vehicle miles traveled	FARS (NHTSA)	Moderate
Sevigny (2018)[78]	Quasi-experimental	Cannabis decriminalization; medical cannabis legalization, home cultivation, and retail sales; recreational cannabis legalization	Proportion of drivers involved in fatal MVCs who are THC positive	FARS (NHTSA)	Serious
Slater (2016)[79]	Cohort	Medical cannabis legalization	Proportion of drivers involved in fatal MVCs who are tested for drugs	FARS (NHTSA)	Serious
Steinemann (2018)[80]	Cohort	Medical cannabis legalization	Proportion of fatally injured drivers who are positive for (1) THC, (2) methamphetamine, or (3) alcohol	FARS (NHTSA); Hawaii State trauma registry	Serious
Tefft (2016)[81]	Cohort	Recreational cannabis legalization	Proportion of drivers involved in fatal MVCs who are THC positive	Washington State FARS (Washington Traffic Safety Commission)	Serious
Tefft (2020)[82]	Cohort	Recreational cannabis legalization	Proportion of drivers involved in fatal MVCs who are THC positive	Washington State FARS (Washington Traffic Safety Commission)	Serious
Temple (2020)[83]	Cohort	Recreational cannabis retail sales	MVC-related fatalities per month	FARS (NHTSA)	Serious
Vogler (2017)[84]	Quasi-experimental	Medical cannabis legalization; recreational cannabis legalization	MVC-related fatalities per 100,000 population (quarterly): (1) overall, (2) no alcohol but cannabis positive; proportion of vehicle fatalities involving drunk drivers (without evidence of cannabis); proportion of drivers testing positive for both alcohol and cannabis; proportion of drivers testing positive for cannabis	FARS (NHTSA)	Moderate
Wadsworth (2018)[85]	Cross-sectional survey	Recreational cannabis legalization; recreational cannabis retail sales	Among youth who had ever used cannabis: ever driven within 2 hours of use; all respondents: ever been a passenger of a driver who used cannabis within 2 hours, do you think driving a vehicle within 2 hours of using cannabis increases accident risk, how likely are drivers to get caught by the police	International Tobacco Control Policy Evaluation Project tobacco and youth e-cigarette survey (wave 1)	Serious
Windle (2021)[86]	Quasi-experimental	Recreational cannabis legalization; recreational cannabis retail sales	Fatal MVCs and MVC fatalities per 100,000 person-years	FARS (NHTSA)	Serious

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Table 1. Characteristics of Included Studies Examining the Impact of Cannabis Policies on Road Safety Outcomes (*continued*)

First author (year)	Study design	Policy intervention (s)	Road safety outcome(s)	Outcome data source(s)	Overall risk of bias[a]
Winstock (2021)[87]	Cross-sectional survey	Recreational cannabis legalization	Respondents were asked to respond to 3 measures related to a DUIC message: newness, believability, and potential to change behavior	Global Drug Survey 2019	Serious
Woo (2019)[88]	Quasi-experimental	Recreational cannabis legalization; recreational cannabis retail sales	Fatal MVCs per month; fatal MVCs per month in which drivers were THC positive	Washington State FARS (Washington Traffic Safety Commission); police accident report files	Serious
Woods-Fry (2019)[89]	Cross-sectional survey	Recreational cannabis legalization	Proportion of respondents who reported (1) having driven a motor vehicle within 2 hours of using cannabis in the past 12 months, (2) having driven a motor vehicle within 2 hours of using cannabis and alcohol in the past 12 months, or (3) agreement that cannabis does not affect one's driving as much as alcohol	Road Safety Monitor (Traffic Injury Research Foundation; Beer Canada; Desjardins)	Serious
Woods-Fry (2020)[90]	Cross-sectional survey	Recreational cannabis legalization	Proportion of respondents who reported (1) having driven a motor vehicle within 2 hours of using cannabis in the past 12 months, (2) having driven a motor vehicle within 2 hours of using cannabis and alcohol in the past 12 months, (3) agreement that cannabis does not affect one's driving as much as alcohol, or (4) concern about drugged drivers	Road Safety Monitor (Traffic Injury Research Foundation; Beer Canada; Desjardins)	Serious

BAC, blood alcohol concentration; DUI, driving under the influence; DUIC, driving under the influence of cannabis; FARS, Fatality Analysis Reporting System; MVC, motor-vehicle collision; NHTSA, National Highway Traffic Safety Administration; THC, tetrahydrocannabinol.
[a]Assessed using the Risk Of Bias In Non-randomized Studies—of Interventions tool (Appendix 4, available online).

analyses, and these were internally consistent across the methods and results of the report. Risk of bias owing to missing data was largely considered low (n=30) or no information (n=30), and assessed risk of bias because of classification of interventions and deviations from intended interventions were low for all reports.

Cannabis Decriminalization

Five studies examined cannabis decriminalization (Appendix 5, available online).[39,53,61,71,78] Four (all serious risk of bias) found increases in positive cannabis tests (referred to as cannabis positivity for a positive cannabis test in any bodily fluid in the remaining text) associated with decriminalization among drivers involved in fatal collisions (range of ORs: 1.10−1.67).[53,61,71,78] The fifth study (moderate risk of bias) found no difference in fatal motor-vehicle collisions (MVCs) (incidence rate ratio=1.02; 95% CI=0.95, 1.10) or fatal MVCs involving alcohol (incidence rate ratio=0.95; 95% CI=0.79, 1.15) associated with decriminalization in the U.S.[39]

Medical Cannabis Legalization

A total of 23 reports of 22 studies examined the impact of medical cannabis legalization or retail sales on road safety outcomes (Appendix 6, available online). Reported outcomes included self-reported attitudes, beliefs, and behaviors concerning driving under the influence; positive cannabis, alcohol, and other drug tests among drivers; seat belt use; and MVCs.

Self-reported attitudes, beliefs, and behaviors concerning driving under the influence. All studies that examined these outcomes (n=5) were assessed to be at serious risk of bias. Two studies found no difference in attitudes and beliefs concerning DUIC between residents of U.S. states with medical cannabis legalization and those without.[33,70] Three studies found an association between legalization and greater self-reported DUIC,[33,34,47] with 1 study noting that the finding was not consistent across all time periods and states,[47] whereas a fourth study found lower self-reported DUIC associated with retail sales.[35]

Positive cannabis, alcohol, and other drug tests among drivers and patients with trauma. Seven studies examined the association between medical legalization and/or retail sales and cannabis positivity. All studies found increases after medical legalization or retail sales in pooled states[78,84] or in at least 1 jurisdiction, including Arizona,[58] California,[51,64] Colorado,[74] Connecticut,[61] Hawaii,[51,64,80] and Washington.[51,64] One study found decreases in cannabis positivity after retail sales in Arizona and New Jersey, relative to decreases in states with cannabis prohibition.[61] In the study assessed to have the lowest risk of bias (moderate), Vogler[84] (2017) found a 5.5% increase in cannabis positivity among drivers involved in fatal collisions after medical legalization in 22 pooled states, although the estimate was imprecise.

Six studies examined alcohol positivity among drivers. Three studies (all serious risk of bias) did not find changes in alcohol positivity associated with medical legalization in Arizona[58] or Hawaii[80] nor associated with retail sales in Colorado.[74] However, 3 other studies (all moderate risk of bias) that used pooled data from U.S. states or cities found decreases in alcohol positivity associated with medical legalization (range= −6% to −28%).[15,39,84]

Two studies examined other drug positivity among fatally injured drivers. One study observed an increase in methamphetamine positivity before versus after medical legalization in Hawaii (4.8% vs 7.3%),[80] whereas another estimated a 21% decrease in the odds of opioid positivity (OR=0.79; 95% CI=0.61, 1.03) after retail sales/home cultivation in pooled U.S. states.[60] Finally, a single study compared state drug-testing rates, finding no differences by state legalization status or by driver survival or fault.[79]

Seatbelt use. One study found a reduction in seatbelt use among drivers of passenger vehicles, particularly male drivers between the ages of 25 and 69 years, in states with medical legalization versus those without.[28]

Motor-vehicle collisions. A total of 8 studies (all moderate risk of bias) examined the impact of medical cannabis legalization and/or retail sales on fatal MVCs or related mortality. All studies found reductions in fatal MVCs or related mortality associated with medical legalization and/or retail sales.[15,32,36,39,63,75,76,84] In pooled U.S. jurisdictions, reductions associated with legalization ranged from −3.5% to −9.3%.[15,36,39,63,76,84] Santaella-Tenorio et al.[76] (2017) found no association between medical retail sales and fatal MVCs, despite finding a reduction associated with medical legalization; however, CIs were wide. Calvert and Erickson[36] (2020) also examined pedestrian-involved fatal collisions specifically and found no conclusive immediate or continuing effects. In studies that reported subgroups by sex, 1 study found similar reductions in fatal collisions associated with medical legalization among males compared with that among females (−9% vs −11%),[39] whereas 2 other studies suggested greater reductions in fatalities among males than among females (−10.8% vs −6.9%,[15] −4.2% vs −2.5%[84]). Five studies also reported subgroups by age; however, categorical cut offs selected varied, and there was no clear pattern across studies that suggested effect measure modification by age group.[75,84]

Recreational Cannabis Legalization

A total of 50 included studies examined recreational cannabis legalization and/or retail sales (Appendix 7, available online). Reported road safety outcomes included self-reported attitudes, beliefs, and behaviors concerning driving under the influence; positive cannabis, alcohol, and other drug tests among drivers; and MVCs.

Self-reported attitudes, beliefs, and behaviors concerning driving under the influence. Several studies (all serious risk of bias) examined attitudes and beliefs concerning DUIC (n=11),[33,41,43,44,62,65,70,85,88,90,91] or self-reported DUIC (n=12)[33−35,41,43,46,49,62,73,85,90,91] or driving under the influence of alcohol (n=3).[43,90,91] For all outcomes, the estimated direction of effect was inconsistent across studies.

Positive cannabis, alcohol, and other drug tests among drivers and patients with trauma. Reported outcomes included positive cannabis (n=15), alcohol (n=5), or other drug (n=3) tests among drivers involved in fatal collisions or patients presenting with MVC-related trauma. Nine studies found an increase in cannabis positivity associated with recreational legalization or retail sales in Colorado[61]; Washington[40,44,61,72,81,82,88]; Colorado and Washington combined[53]; or Alaska, Colorado, Oregon, and Washington combined.[38,50,84] Five studies found no difference in Colorado[38,50,54] or Washington.[31,52,54] A single study found a decrease in Colorado and Washington.[78] There were 2 studies at the lowest risk of bias (moderate): Vogler (2017) found a pooled increase of 31.4% in MVC fatalities in which the driver was cannabis positive, and alcohol was not involved in Arkansas, Colorado, Oregon, and Washington compared with that in control states.[84] Hansen and colleagues[54] (2020) estimated that compared with MVC fatalities in synthetic controls, MVC fatalities in which at least 1 driver was cannabis positive increased by >60% after legalization in Colorado and Washington, with 45%−60% of the increase attributable to legalization, although state-specific estimates were imprecise.

Five studies examined alcohol positivity, with 1 study finding an increase before versus after recreational legalization in Colorado,[37] and 2 studies suggesting a decrease in alcohol positivity before versus after recreational retail sales in Washington.[44,72] The 2 studies at the lowest risk of bias (moderate) found no difference before and after legalization in Colorado or Washington compared with that in synthetic controls[54] or in 4 pooled states compared with that in control states.[84] Studies examining other drug positivity[38,40,72] or arrests for driving under the influence[55,66] were all assessed to be at serious risk of bias, and the estimated direction of effect was mixed across studies.

Motor-vehicle collisions. Twenty studies examined the impact of recreational cannabis legalization (n=13) and/or retail sales (n=13) on MVCs or related morbidity, mortality, or healthcare utilization. For Colorado, most studies found an increase in MVCs or related outcomes associated with recreational legalization[36,42,84] or retail sales,[19,36,42,56,57,67,77,83,86] with 2 studies finding no difference.[54,86] Among the studies assessed to be at the lowest risk of bias (moderate), fatal collisions or MVC fatalities were estimated to have increased from 3.6% to 5.9% after legalization[36,84] or by 0.4 fatalities per billion vehicle miles travelled[54]; after retail sales, MVCs were estimated to have increased from 2.5% to 13.9%[36,56,57,67] or by 0.83 and 1.46 fatalities per million residents or billion vehicle miles traveled, respectively.[19,77] For Washington, most studies found an increase in fatal collisions or MVC fatalities associated with recreational legalization[84,86,88] or retail sales.[19,56,57,67,77,83,86,88] Several studies suggested no difference[54] or were inconclusive[84,86] owing to wide CIs. Among the studies at the lowest risk of bias (moderate), fatal collisions or MVC fatalities were estimated to have increased from 1.4% to 3.6%[36,67,84] or by 0.7 fatalities per billion vehicle miles traveled after legalization[54]; estimates for retail sales ranged from −0.14% to 9.7%[36,56,57,67] or increased by 0.94 and 0.08 fatalities per million residents or billion vehicle miles traveled, respectively.[19,77] Two studies that combined data from Colorado and Washington estimated increases in MVC fatalities per billion vehicle miles traveled of 0.2 (95% CI= −0.4, 0.9) and 1.2 (95% CI= −0.6, 2.1) for recreational legalization and 1.8 (95% CI=0.4, 3.7) for retail sales.[29,30]

For Oregon, most studies likewise found an increase in MVCs related to recreational legalization[36,84,86] or retail sales,[56,67,83,86] although 2 studies found no difference[57] or were inconclusive owing to wide CIs.[36] Among the studies assessed to be at the lowest risk of bias (moderate), fatal collisions or MVC fatalities were estimated to have increased from 1.5% to 20.5% after legalization.[36,84] For retail sales, estimates ranged from 0.7% to 4.5%[36,56,57,67]; Lane and Hall[19] (2019) found that Oregon had an increase of 1.40 (95% CI=0.68, 2.12) in MVC fatalities per million residents associated with their neighbor Washington's legalization of retail sales, compared with a 0.85 (95% CI= −1.57, 3.26) increase associated with Oregon's own retail sales 15 months later. Several studies were suggestive of an increase in MVC fatalities in Alaska after recreational legalization[84,86] or retail sales[83,86]; however, the estimates were imprecise.

Among studies that pooled data from >2 U.S. states, most found point estimates suggesting an increase in MVCs or related outcomes associated with recreational legalization[36,45,69,84,86] or retail sales,[19,56,57,59,63,67,86] whereas 1 study was inconclusive for retail sales.[45] Among the studies at the lowest risk of bias (moderate), there was an estimated 1.4%–7.8% increase in MVC fatalities associated with legalization[45,63,84] and a 1.4%–6.0% increase in MVCs associated with retail sales.[45,56,57,67] One study using data from Uruguay found that recreational legalization was associated with a 52.4% increase (95% CI=11.6, 93.3) in light motor-vehicle drivers' fatality rate, but this was not observed for motorcyclists.[68]

DISCUSSION

In this systematic review of 64 observational studies that primarily used data from the U.S., there was mixed evidence regarding the impacts of medical and recreational cannabis legalization on attitudes, beliefs, and self-reported DUIC. However, reported outcomes, populations, and study designs varied widely across studies. Nevertheless, cannabis decriminalization, medical legalization, and recreational legalization were found to be associated with increases in cannabis positivity among drivers, although many studies examining this outcome were assessed to be at serious risk of bias because of potential confounding and measurement error. This systematic review also found an association between medical cannabis legalization and retail sales and reductions in fatal MVCs across studies. In contrast, recreational cannabis legalization and retail sales were associated with increases in fatal MVCs. Many studies that reported collisions and/or fatalities were quasi-experimental in design and were assessed to be at lower risk of bias than studies that examined other outcomes.

Increases in positive cannabis tests among drivers may reflect increases in the prevalence, frequency, and/or potency of cannabis use; however, the detection of cannabis does not in itself indicate driving impairment.[91] Unlike alcohol, for which blood alcohol concentration is a consistent indicator of the degree of impairment from alcohol, tetrahydrocannabinol passes quickly from the blood and into other organs where its metabolites can remain for extended periods.[91] Therefore, despite consistent evidence from meta-analyses indicating that acute cannabis use is associated with increased risk of MVCs,[8] it remains difficult to correlate specific biochemical levels of tetrahydrocannabinol with the degrees of driving impairment across individuals.[92]

Although all policies were associated with increases in cannabis positivity, medical legalization and retail sales were associated with reductions in fatal MVCs, whereas recreational legalization and retail sales were associated with increases in fatal MVCs. These opposing findings are likely owing to the subgroups primarily impacted by medical and recreational legalization, respectively. Individuals who use medical cannabis are older and in poorer health than those who use recreational cannabis,[93] and the most common reason for seeking medical cannabis certification is chronic pain.[94] The substitution of cannabis for alcohol[15,39,76,95] and/or opioids[95−97] among individuals who use medical cannabis may explain the observed reductions in fatal MVCs associated with medical legalization because cannabis is known to impair psychomotor skills and cognitive functions to a lesser degree than alcohol and opioids.[98] In this review, data were limited concerning alcohol and other drug positivity among drivers; however, the findings were suggestive of a decrease in alcohol positivity associated with medical legalization. Although the review was inconclusive regarding an association between recreational legalization and alcohol and other drug positivity among drivers, other studies have found no changes in alcohol use[99] or suggested that individuals who use recreational cannabis may use alcohol as a complement to cannabis.[100−102]

Overall, this review has a number of policy and research implications. First, there are few data available concerning the impact of cannabis decriminalization on road safety outcomes, despite this being the most common cannabis liberalization policy globally.[2] Second, cannabis policies may have opposing effects on road safety outcomes, depending on the population subgroups most impacted (e.g., medical versus recreational use). Third, the impact of cannabis decriminalization and legalization on road safety outcomes may be modified by a number of factors, including heterogeneity in policy, legal, and demographic characteristics between legalizing jurisdictions. Allowance of retail sales may be an important effect measure modifier owing to increased visibility, affordability, and access to cannabis compared with legalization alone.[16,103] This review did not find clear differences between legalization only and retail sales, although most studies selected either one exposure or the other, making direct comparisons difficult. Likewise, few studies considered other policy dimensions (e.g., home growing). Cointerventions such as per se cannabis limits or zero tolerance laws may also modify the effect of cannabis policies on road safety outcomes; however, their effectiveness in deterring DUIC is unclear.[104,105] Previous studies have also suggested that the impact of cannabis policies is likely to differ between population subgroups.[16] Few studies in this review reported results by sex or age group, although 2 studies suggested that the impact of legalization on MVC-related outcomes may be greater among males.[15,84] Finally, future research should consider quasi-experimental designs (e.g., difference-in-differences), which were typically assessed to have a lower risk of bias than other observational study designs in this review. Likewise, outcomes that were not self-reported nor depended on drug-testing rates/reporting (e.g., fatal MVCs) were the least likely to be subject to measurement error. Future work should consider methodologic solutions for underreported and/or frequently mismeasured outcomes (e.g., nonfatal injuries, drug testing) to advance the understanding of the impact of cannabis policies on road safety outcomes.

LIMITATIONS

First, few conclusions could be drawn concerning the impact of cannabis decriminalization on road safety outcomes because there were few studies available. Second, data were limited concerning nonfatal injuries from MVCs; the impact of legalization on MVC fatalities may or may not have direct correspondence to nonfatal injuries. Third, the assessed risk of bias for all included studies was moderate or serious (because no study could be considered at low risk of bias given the potential for confounding). However, this was considered when drawing conclusions. Fourth, the overall findings may not apply to specific jurisdictions, given the heterogeneity between policy, legal, and demographic characteristics. Finally, nearly all the available data were from the U.S., which limits the generalizability of the findings to other jurisdictions globally. Likewise, more than half of the included studies used data from the U.S. Fatality Analysis Reporting System; this database includes data on collisions that occurred on public roadways and resulted in at least 1 death within 30 days.[106] Although the incidence of fatal collisions is likely to be accurately reported, there are known limitations regarding the drug-testing data in this database[10] that were considered during the risk of bias assessment for studies reporting these outcomes.

CONCLUSIONS

This systematic review found that medical cannabis legalization was associated with reductions in fatal

MVCs, whereas recreational cannabis legalization was associated with increases in fatal MVCs. There was also evidence that cannabis decriminalization, medical legalization, and recreational legalization may be associated with increases in cannabis positivity among drivers. There were mixed impacts of medical and recreational legalization on attitudes, beliefs, and self-reported DUIC. Evidence was limited concerning the impact of medical and recreational legalization on nonfatal injuries and road safety outcomes related to alcohol and other drugs, although the findings were suggestive that medical cannabis legalization may decrease alcohol positivity among drivers. More research is needed concerning the impact of cannabis decriminalization on road safety outcomes and the mechanisms by which legalization impacts road safety outcomes.

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