

## Evaluating the public health impacts of legalizing recreational cannabis use in the USA

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## **Abstract**

### **Background and aims**

Since 2012 four US states have legalized the retail sale of cannabis for recreational use by adults and more are likely to follow. This report aimed to (1) briefly describe the regulatory regimes so far implemented; (2) outline their plausible effects on cannabis use and cannabis-related harm; and (3) suggest what research is needed to evaluate the public health impact of these policy changes.

### **Method**

We reviewed the drug policy literature to identify: (1) plausible effects of legalizing adult recreational use on cannabis price and availability; (2) factors that may increase or limit these effects; (3) pointers from studies of the effects of legalizing medical cannabis use; and (4) indicators of cannabis use and cannabis-related harm that can be monitored to assess the effects of these policy changes.

### **Results**

Legalization of recreational use will probably increase use in the long run but the magnitude and timing of any increase is uncertain. It will be critical to monitor: cannabis use in household and high school surveys; cannabis sales; the number of cannabis plants legally produced; and the THC content of cannabis. Indicators of cannabis-related harms that should be monitored include: car crash fatalities and injuries; emergency department presentations; presentations to addiction treatment services; and the prevalence of regular cannabis use among young people in mental health services and the criminal justice system.

### **Conclusions**

Plausible effects of legalizing recreational cannabis use in the USA include substantially reducing the price of cannabis and increasing heavy use and some types of cannabis-related harm among existing users. In the longer term it may also increase the number of new users.

## Introduction

Since 2012 four US states (Alaska, Colorado, Oregon and Washington State) have legislated to allow the sale of cannabis for recreational use by adults over the age of 21 and Washington State legalized growing cannabis for personal use and gifting to friends [1,2]. More states will vote on similar proposals in 2016 and Vermont is considering legalization [3].

In this paper we discuss the probable effects of legalization on cannabis prices, social acceptability of cannabis use and availability and, in turn, their likely effects on cannabis use among current users and nonusers. We adopt a public health approach in which we assume that the population level adverse health effects of cannabis (see box 1 for a summary of these) will be related to: the number of users, the quantity and potency of the cannabis that they use, the frequency of their use, the contexts in which they use (e.g. when driving), and the ways in which cannabis legalization affects the use of alcohol, tobacco and the opioids.

We first briefly describe the regulatory regimes in Colorado and Washington State and then outline some mechanisms by which this form of legalization may increase cannabis use. We then outline ways in which the cannabis market, cannabis use and cannabis-related harm can be monitored in 'early adopter' states to evaluate the effects of legalization policies on cannabis use and cannabis-related harm. These results may inform the design of regulations in other US and nation states that follow the examples of Colorado and Washington. We do not attempt to undertake any analyses in this paper because there is insufficient data for the task. Our aim is to outline the analyses that will need to be done when sufficient data have accumulated to permit evaluations of the public health effects of these policies.

## Legalization as implemented in Colorado and Washington

Colorado and Washington commenced legal sales in January and July 2014 respectively [4-6]. Oregon allowed sales for recreational use from medical marijuana dispensaries starting in October 2015 [7,8]; Alaska lawmakers published policy guidelines in November 2015, began accepting licence applications in February 2016, and expect to begin issuing cultivating and testing licences in June and retail and product manufacturing licences in September 2016 [9,10]. (See table 1 for summary of provisions).

In Colorado and Washington adults over the age of 21 can purchase up to 28.5 g from a single retailer [6,11,12]. Regulations differ in who is licensed to supply cannabis; in both states cannabis products are taxed on their sale price (at different rates) but at levels that will reduce legal prices to well below black market prices [4,11,12]. Drug-impaired driving is prohibited in both states [13].

Colorado and Washington have implemented regulatory systems similar to those used to regulate alcohol [14], namely, state licensing of commercial entities that retail cannabis for profit [11]. Commercialization of sales and more efficient cannabis production and distribution are the likely long term outcomes of a for profit industry in the US economic and political system. Under the US Constitution those who sell legal commodities have commercial freedom of speech to advertise and promote the use of their products [15]. The same may not be true in other countries that choose to legalize cannabis (e.g. Canada) where governments may be able to regulate cannabis sales in ways that minimize adverse effects on public health [16,17].

## **How may legalization of recreational use increase cannabis use?**

The major mechanism through which legalization is likely to increase recreational cannabis use is by substantially reducing the price of cannabis. The reasons for the reduction in price are explained in more detail below. Legalization will have other effects that may increase use, namely, it will be easier and safer to obtain a regular supply of a commodity which it is lawful to purchase and consume. Users will no longer have to obtain cannabis from the black market or grow it themselves. Criminal penalties will no longer be a deterrent to cannabis use which will also be more socially acceptable. These social costs of cannabis use will decline along with its price [18] but price is the variable whose effects on alcohol and tobacco have been the most thoroughly studied so we focus on the effects of legalization on price.

### **Probable Effects of Legalization on Cannabis Price**

There are several reasons why the price of cannabis in a legal market will fall well below black market prices [18,19]. First, the price of legal cannabis need not include a black market premium to cover the risks of arrest or drug market violence.

Second, legal production will be more efficient because it will no longer be clandestine and so growers will be able to increase the scale of production to reduce unit prices and pass these savings on to consumers. In jurisdictions where regulators allow licensees to be involved in production, processing, wholesale and retail sales, as they now are in Colorado, the efficiency of production is likely to be maximized and costs reduced more rapidly than in settings where

regulatory systems result in larger numbers of small scale enterprises at each step in the process from growing to sale [19].

Third, the proposed tax regimes based on sales price will fail to keep cannabis prices at black market prices [19]. They may indeed provide incentives to increase the THC content of cannabis because this will enable producers and sellers to effectively reduce the tax rate and increase their profits [15]. A tax based on THC content has been recommended as one way to remove this incentive [3] but this suggestion has not so far been adopted by any state that has legalized cannabis.

Data from commercial companies that aggregate consumer reports of cannabis prices show that cannabis prices in states that have legalized medical or recreational use are 10% below the national average and up to 20% lower than the prices paid in states that have not legalized medical or recreational use [20]. It is uncertain how much further these prices will fall and how soon because the number of retail outlets may be limited. Initially, state governments have restricted the numbers of licenced producers and retailers to make regulation easier. This effectively grants licensees an oligopoly on cannabis sales that reduces their need to compete on price. Some states also allow local governments to ban retail outlets in their jurisdictions, thereby restricting retail outlets to larger cities [16], as had occurred in Colorado. The fear that the Federal government will enforce federal laws against drug trafficking may also provide a brake on the large scale outdoor commercial cultivation of cannabis that would most rapidly reduce prices [3].

## Plausible Effects of Legalization on Cannabis Use

The use of alcohol and tobacco generally increases as their price falls and use generally decreases when their price increases [21-23]. There is more limited evidence that the same is true of the relationship between cannabis use and cannabis price [24]. This suggests that legalizing recreational cannabis sales will also increase cannabis use by reducing price. It is uncertain by how much [25] because we cannot predict either how low cannabis prices will go, or how much users may increase their consumption in response to large reductions in price [18,19].

If the effects of lower prices on alcohol consumption [26] apply to cannabis use then lower cannabis prices are most likely to increase frequency of use among current users [18] who will be able to buy more of their drug of choice for the same price. In surveys of US high school students, only 18% of current users say they will use more cannabis if it is (or becomes) legal [27] but we do not know how accurately these users can predict the effects of lower cannabis prices on their own use.

It is less certain whether, and if so, how much, a decline in cannabis prices may increase the number of new cannabis users. The Monitoring the Future Surveys of US high school seniors report that only 10% of those who have not used cannabis say that they will do so if it is legal [27] but again we do not know how accurately non-users can predict their future use in a legal market where cannabis use is common among their peers.

We can get some pointers to possible effects of cannabis legalization on cannabis use from studies of the effects of medical marijuana laws (MML) in some US states on cannabis use.

These studies have a major limitation, namely, that the liberality of medical marijuana regulations varies widely between states. This means that simple comparisons of rates of cannabis use in states that have and have not legalized medical marijuana will under-estimate the effects of more liberal MMLs and overestimate the impact of more tightly regulated MMLs [28].

## **The Effects of Medical Marijuana Laws**

### **Effects on Adolescent Cannabis Use**

A reasonable concern is that medical cannabis laws will increase adolescent cannabis use by making the drug more available and sending the message that cannabis use is not risky [29].

Researchers have evaluated these concerns by comparing trends in cannabis use in surveys of adolescents in states that have and have not legalized medical cannabis use [30]. These surveys were not primarily designed for this evaluation task. They were designed to provide samples that were representative of the US high school population generally rather than of the high school populations of individual states. Comparisons have had to be made between the populations of groups of states that have legalized and not legalized medical marijuana, often by averaging data over two survey years to produce stable estimates. These analyses do not take into account large differences between the states regarding the conditions under which medical use of cannabis is allowed [28].

Comparisons of adolescent cannabis use in household and school-based surveys have generally not found differences between states with and without MMLs (e.g. [31-38]). The largest study [39] of trends in adolescent cannabis use in Monitoring the Future Surveys between 1991 and 2014 compared trends in past 30 day cannabis use in the 21 states that had

legalized MM use with those in the 27 mainland US states which had not. The analysis controlled for social, economic and demographic differences between these states and schools. States which passed MMLs had higher rates of 30 day cannabis use before these laws were passed (15.9% vs 13.3%) than states that had not, indicating that states with higher rates of cannabis use were more likely to allow medical use. There was no increase, however, in adolescent cannabis use after the passage of MMLs (16.3% pre to 15.5% post).

Similar results emerged from comparisons of trends in cannabis use among young people aged 12 to 20 in states with and without MMLs in the US National Household Survey of Drug Use [40]. The proportion of young people who reported using cannabis in the year after MMLs were passed marginally increased between 2004 and 2012 but there was no increase in cannabis use in the past 30 days, or in daily use, among these young people.

### **Effects on Adult Cannabis Use**

Household survey data suggests that cannabis use may have increased among cannabis users over the age of 21 years after the passage of MMLs between 2004 and 2012 [40]. There were no differences in rates of *initiation* of cannabis use among adults between MML and non MML states. Adults in MML states, however, reported: higher rates of cannabis use in the past 30 days (an increase of 1.32%); higher rates of daily cannabis use (an increase of 0.58%); and higher rates of cannabis abuse/dependence (an increase of 10%) than adults in states that did not have MMLs. Surveys also indicate that the prevalence of cannabis dependence increased in the US population between 1991-1992 and 2001-2002 [41] and

again between 2001-2002 and 2012-2013 [39]. No breakdown has been provided, however, on whether these increases were greater in states that did and did not have MMLs.

One study has examined the possible effects of MMLs on treatment seeking for cannabis use disorders. Chu [42] compared the number of persons seeking first time treatment for cannabis problems between 1992 and 2011 in states with and without MMLs. After MMLs were passed, there was a 15-21% increase in new treatment episodes for primary cannabis use problems in persons who had not been referred by the criminal justice system.

### **Effects on Cannabis Related Harm**

Evaluations of the effects of MMLs on cannabis-related motor vehicle fatalities have been mixed. Some studies [43] have found an increase in the percentage of cannabis-impaired drivers in fatal crashes in states with MMLs but interpretation is complicated by the fact that testing for cannabis use was less common before MMLs were enacted and more common thereafter.

Anderson et al [44] examined the role of alcohol in car crashes between 1990 and 2010 in US states that did and did not have MMLs. They found an 8-11 per cent greater decrease in total traffic fatalities and in fatalities with a BAC > 0.08% in states with MMLs. They argued (using data on self-reported alcohol use and beer sales) that this effect was explained by young males substituting cannabis for alcohol because cannabis was cheaper in MML states.

A comparison of trends in fatal motor vehicle crashes in Colorado and 34 states without MMLs between 1994 and 2011 produced results that were inconsistent with those of Anderson et al [45]. These authors found a larger increase in cannabis positive fatalities in Colorado after 2009 than in the 34 states without MMLs. They also found no change in alcohol-related motor vehicle fatalities in Colorado or the 34 states without MMLs. The analyses of longer time series on traffic fatalities in more US states will be required to clarify these conflicting findings.

### **Effects on Other Types of Drug-related Harm**

A number of studies have examined trends in alcohol-related harm to see if cannabis is a substitute for alcohol among young men in states with MMLs [46]. Wen et al's analysis of National Household Survey data on alcohol use in states with MMLs [40] found more binge drinking, and more concurrent use of alcohol and cannabis, among adults over 21 years in states with MMLs.

Anderson et al reported steeper declines in suicides among males aged 20 to 30 in US states that legalized MM than in those that had not [47]. This finding was not supported by another analysis that controlled for differences between states [48] or the failure to find an association between suicide rates and the number of MM patients in US states between 2004 and 2010.

[49]

Lower rates of opioid overdose deaths have been reported in states with MMLs than those without such laws and the difference in OD death rates increased over time [50]. This finding has been interpreted as evidence that the use of cannabis for pain relief reduces the number of fatal opioid overdoses. However, a correlation between time series data on opioid overdose deaths and state MMLs is weak evidence for a causal relationship [51]. Better evidence is needed, e.g. individual level data showing that cannabis and opioid use have changed in the ways required for a causal relationship, and that the association at state level is not explained by other differences between states that have and have not passed MMLs [52].

## **Evaluating the Effects of Legalizing Recreational Cannabis Use**

### **Effects on Cannabis Use among Youth**

Any increase in cannabis use among youth after legalization will probably be preceded by reductions in the perceived risks, and increases in the social acceptability, of using cannabis. This pattern was observed with increased cannabis use in the Monitoring the Future Surveys in the USA in the 1970s and the converse was observed during the 1980s, when increased perceptions of risk and declining social acceptability were followed by a decline in cannabis use [53,54]. The Monitoring the Future data will provide a useful baseline against which to evaluate any effects of legalization on these attitudes.

Another leading indicator of future increases in youth cannabis use will be an increased frequency of use among youth who already use cannabis, or are at higher risk of doing so. This could be detected in surveys of youth in high schools who are counselled for conduct or school problems, youth in the juvenile justice system, and youth seeking treatment for anxiety, depression and psychosis.

### **Effects on Cannabis Use in Adults**

A number of cannabis-related harms may be expected to increase if adults who already use cannabis do so more frequently. These include: convictions for cannabis-impaired driving; car crash fatalities and injuries involving cannabis-intoxicated drivers; and emergency department (ED) attendances for the adverse effects of ingesting cannabis products with higher than usual THC content.

We may or may not expect to see more adults seeking professional help for problems related to their cannabis use, for reasons outlined below. An earlier indication of increased cannabis problems in adults may be provided by survey data in which non-users are asked whether they have expressed concerns to a family member, or a friend about their cannabis use.

Cannabis users can also be asked whether a family member has expressed concern about their cannabis use. Similar questions have been used to track population trends in problem alcohol use [55].

If the ADAM system of monitoring drugs used by arrestees [56] had not been discontinued, researchers could have used these data to monitor trends in the amount of THC consumed by groups of heavy cannabis users. In its absence, the next best option may be to monitor THC levels in the Fatality Analysis Reporting System [57,58].

Population levels of cannabis use may potentially be assessed via the analysis of cannabis metabolites in waste water. Regular sampling and analysis of cannabinoid metabolites in waste water may be able to establish whether the total amount of cannabis used in the population is stable or increasing, without telling us about the number of users [59]. This will require the solution of analytical challenges in estimating THC and its metabolites in waste water.

## **Possible Effects of Legalization on Indicators of Cannabis-related Harm**

### **Acute Adverse Effects**

Greater access to cheaper and more potent cannabis is likely to increase presentations to emergency departments (ED). Monte et al [60] have reported increases in cannabis-related ED presentations in Boulder, Colorado after the legalization of cannabis. These included increased numbers (from a low base rate) of: childhood poisonings from the accidental ingestion of edible cannabis products packaged like confectionary; cannabis intoxication in adults marked by unpleasant psychological reactions; a severe vomiting syndrome in heavy users of very potent cannabis products; and severe burns among users who attempted to

extract THC from cannabis oils using butane. With the exception of the burns, these adverse effects occurred in users of edible cannabis products.

Studies of cannabis-related ED presentations should also assess the prevalence of rarer, more serious cardiovascular outcomes, such as, myocardial infarctions, acute coronary syndromes and strokes in young adults. Case series and case-control studies have reported these outcomes in young adults smoking potent forms of cannabis in France [61-64] and in a number of EU states [65].

### **Effects on Treatment Seeking**

As noted above, there are indications of increased rates of cannabis dependence symptoms in epidemiological surveys and more adults are voluntarily seeking treatment since the legalization of medical cannabis use. It is less certain how the legalization of recreational cannabis use may affect treatment seeking. Treatment seeking could be delayed, for example, if the fact that cannabis is legal and cheap reduces social pressure from families and friends to seek treatment. Any increase in the number of problem cannabis users who seek treatment voluntarily could be offset by a decline in the number of *adult* cannabis users who are legally coerced into treatment, as has happened in Colorado [66]. Adolescents with cannabis use problems will still be coerced into treatment, and these numbers may well increase, if courts refer more adolescents to treatment.

Useful information on these issues can be collected from US national treatment data [67].

These national data could be supplemented by information from surveys [68] of new cannabis treatment entrants that ask them about: their reasons for seeking treatment; the type and amounts of cannabis that they use; their usual routes of administration; and where they have obtained their cannabis (to assess the extent to which the black market is still being used by the heaviest cannabis users).

### **Effects on Other Health Outcomes**

It will be important to assess the contributions that alcohol- and cannabis-impaired driving make to motor vehicle accidents. This research will need to assess to what extent cannabis is a substitute for alcohol in young men, the population group at greatest risk of alcohol and cannabis abuse and MVAs. Such evaluations should also examine possible effects of cannabis legalization on rates of other types of alcohol related harm such as suicides and assaults.

It will also be important to monitor any effects that cannabis legalization may have on tobacco smoking among adolescents and young adults. In past decades when tobacco smoking rates among youth in the USA were higher, a “gateway” hypothesis was proposed to explain a common pathway from early tobacco and alcohol use to an increased chance of later cannabis use. With the decline in youth tobacco use, evidence has emerged of a possible “reverse gateway effect” in which the initiation of cannabis smoking increases the later uptake of tobacco smoking [69].

It will also be important to assess the social distribution of any adverse effects of cannabis legalization. A common argument in favour of cannabis legalization is that it will eliminate the discriminatory imposition of criminal penalties for cannabis use on minority users [23]. It will therefore be important to assess the effects of legalization on these minority groups, e.g. are these groups over-represented among heavy cannabis users who seek treatment? Have racial inequalities in drug arrests been reduced by cannabis legalization [70]?

### **The Need for Better Evaluation Designs**

Ideally evaluations of the public health impact of cannabis legalization need to use stronger designs than the ecological studies assessing differences between states in time series data on health outcomes such as car crash fatalities, suicides or opioid overdose deaths. The results of these types of studies are open to many competing explanations. Assessing the plausibility of these explanations requires more detailed data on individuals' use of cannabis and other drugs and individual level data on the relationships between cannabis and other drug use and these kinds of harm within states. Federal agencies may need to increase the state sample sizes in national household and school surveys to enable valid and statistically powerful comparisons between cannabis use and cannabis-related outcomes in states that have adopted different cannabis policies.

In principle, the emerging variability among US state cannabis laws, and the variations in the timing of these changes, will allow researchers to assess whether any effects on cannabis use and cannabis-related harm found in the early adopter states are replicated in states that are later adopters. The challenge for researchers will be to realize this opportunity. When

politicians introduce new legislation they generally do not give a high priority to doing so in a way that will enable researchers to conduct valid controlled evaluations of natural policy experiments, despite Donald Campbell's argument over 50 years ago that we should treat all reforms as experiments [71]. Delays in obtaining research funding may make it difficult to obtain baseline data on patterns of cannabis use. Funding agencies may need to find flexible ways of contracting researchers to evaluate the effects of these policy changes.

### **Research Benefits of Cannabis Legalization**

In principle, cannabis legalization will also make it possible to monitor how much cannabis is sold because sales data will be a by-product of regulation. Measures of the THC and CBD content of cannabis products could also be required by the regulatory authorities as a condition of licensing. These data would allow us to estimate the amount of THC consumed by heavy users and per capita THC consumption.

Waste water monitoring of cannabis metabolites could potentially be a cheaper way to estimate the community's cannabis consumption [59], if challenges in the quantification of THC and its metabolites in waste water can be addressed [72]. This would potentially enable waste water analyses to assess the size of the black market from the gap between legal sales of THC and the total amount of THC consumed in the population.

Cannabis legalization will also make it easier to research the health effects of recreational cannabis use. It will be easier, for example, to study representative samples of adult users and address questions that have been difficult to answer under prohibition, namely: what doses of THC and CBD do regular cannabis users typically obtain? To what extent do they titrate their

doses of THC when using more potent cannabis products? Does the ability to titrate dose vary with the route of administration?

If the conflict between US Federal and State cannabis laws can be resolved, it will also be easier to study the therapeutic benefits of cannabis and cannabinoids. Legalization will reduce the distorting effects of cannabis prohibition and reduce the strategic use of medical cannabis laws as a stepping stone to legalization of recreational use [73].

## **Conclusions**

The legalization of recreational cannabis use in the USA is a large scale public health experiment whose outcomes may be unclear for a decade. The legalization of medical cannabis use has so far not produced marked increases in cannabis use among youth but it does seem to have increased cannabis use and cannabis-related problems among adult users. The modest impact of medical cannabis laws to date cannot be used to predict that the same will be true of cannabis outcomes in states that legalize retail sales to adults. The latter is a much more radical policy change. Given our experience with alcohol, legalization is likely to substantially reduce the price of cannabis, increase heavy use, and increase some types of cannabis-related harm, among existing users. In the longer term it may also increase the number of new users.

The creation of legal cannabis markets for recreational use in the USA is at an early stage of implementation so it is too soon to assess whether it has increased cannabis use and cannabis-related harm. Future evaluations will need to look for the following types of evidence: more

favourable attitudes towards cannabis use among young people; increased frequency of use among at risk youth (e.g. those who seek help for cannabis use and mental health problems and those in the criminal justice system); increased use and cannabis-related problems (car crashes, ED attendances for cannabis-related problems; increased treatment seeking for cannabis use problems; and treatment for mental disorders) and cannabis use among adult cannabis users. An evaluation of this policy change should also assess how increases in cannabis use affect alcohol and tobacco use and other drug-related harm among youth and young adults. These results should ideally inform the design of any policy changes that are intended to reduce cannabis-related harm after legalization.

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## References

- 1 US GAO. State marijuana legalization: DOJ [Department of Justice] should document its approach to monitoring the effects of legalization. US GAO Report to Congressional Requestors. Washington, DC: US Government Accountability Office; 2015. Available at: <http://www.gao.gov/assets/680/674464.pdf>; <http://www.webcitation.org/6fuxvgE5x> (accessed 11 March 2016).
- 2 Garvey T, Yeh BT. State legalization of recreational marijuana: selected legal issues. Washington, DC: Congressional Research Office; 2014. Available at: <https://fas.org/sgp/crs/misc/R43034.pdf>; <http://www.webcitation.org/6fyNkKli4> (accessed 13 March 2016)

- 3 Caulkins J, Kilmer B, Kleiman M, MacCoun R, Midgette G, Oglesby P, *et al.* Considering marijuana legalization: insights for Vermont and other jurisdictions. Santa Monica: RAND Corporation; 2015. Available at: [http://www.rand.org/pubs/research\\_reports/RR864.html](http://www.rand.org/pubs/research_reports/RR864.html); <http://www.webcitation.org/6fSNvLCx7> (accessed 10 April 2015).
- 4 Hudak J. Colorado's rollout of legal marijuana is succeeding: a report on the state's implementation of legalization. Washington, DC: Brookings Institution and the Washington Office on Latin America (WOLA); 2014. Available at: <http://www.brookings.edu/~media/research/files/papers/2014/07/colorado-marijuana-legalization-succeeding/cepmmjcov2.pdf>; <http://www.webcitation.org/6fSNS4BRf> (accessed 11 November 2015).
- 5 Washington State Liquor Control Board. I-502 Implementation (Frequently asked questions about implementing Initiative 502); 2015. Available at: [http://www.liq.wa.gov/mj2015/faqs\\_i-502](http://www.liq.wa.gov/mj2015/faqs_i-502); <http://www.webcitation.org/6fSQLfdYb> (accessed 21 February 2016).
- 6 Colorado Department of Public Health and Environment. Retail marijuana; 2013. Available at: <https://www.colorado.gov/pacific/cdphe/retail-marijuana>; <http://www.webcitation.org/6fSNG7jr5> (accessed 21 February 2016).
- 7 Oregon Health Authority Medical Marijuana Dispensary Program. Frequently asked questions: early recreational marijuana sales. Portland: State of Oregon, 2015. Available at: <http://www.oregon.gov/oha/mmj/Pages/faq.aspx#earlysales>; <http://www.webcitation.org/6fSOBETwx> (accessed 11 November 2015).

- 8      Sebens S. Oregon governor OKs early sales of recreational-use marijuana. New York: Thomson Reuters, 2015. July 29. Available at:  
<http://www.reuters.com/article/2015/07/30/us-usa-marijuana-oregon-idUSKCN0Q404520150730#UJ71VuldzK5VI939.99>;  
<http://www.webcitation.org/6fSOZV1J4> (accessed 21 February 2016).
- 9      Alcohol and Marijuana Control Office. Marijuana Initiative FAQs: Marijuana establishment licence questions. Anchorage, AK: State of Alaska, 2016. Available at:  
<https://www.commerce.alaska.gov/web/amco/MarijuanaInitiativeFAQs.aspx>;  
<http://www.webcitation.org/6fhNZsLaW> (accessed 2 March 2016).
- 10     Quinn S. Alaska allows recreational marijuana as legalization campaign spreads. New York: Thomson Reuters, 2015. February 24. Available at:  
<http://www.reuters.com/article/2015/02/24/us-usa-alaska-marijuana-idUSKBN0LS0ZH20150224>; <http://www.webcitation.org/6fSOJNZaA> (accessed 21 February 2016).
- 11     Wallach PA. Washington's marijuana legalization grows knowledge, not just pot. Washington, DC: Brookings Institution and the Washington Office on Latin America (WOLA); 2014. Available at: <http://www.brookings.edu/research/reports/2014/08/25-washington-marijuana-legalization-knowledge-experiment-wallach>;  
<http://www.webcitation.org/6fSOu1xPz> (accessed 11 November 2015).
- 12     Washington State Department of Revenue. Marijuana: taxes due on recreational marijuana; 2014. Available at:  
<http://dor.wa.gov/Content/FindTaxesAndRates/marijuana/Default.aspx>;  
<http://www.webcitation.org/6fSP69EmN> (accessed 27 November 2014).

- 13 Pardo B. Cannabis policy reforms in the Americas: a comparative analysis of Colorado, Washington, and Uruguay. *Int J Drug Policy* 2014; 25: 727-35.
- 14 Wallach PA, Hudak J. Legal marijuana: comparing Washington and Colorado. Washington, DC: Brookings Institution; 2014. Available at: <http://www.brookings.edu/blogs/fixgov/posts/2014/07/08-washington-colorado-legal-marijuana-comparison-wallach-hudak>; <http://www.webcitation.org/6fSP0VyBA> (accessed 10 February 2015).
- 15 Room R. Legalizing a market for cannabis for pleasure: Colorado, Washington, Uruguay and beyond. *Addiction* 2014; 109: 345-51.
- 16 Subritzky T, Pettigrew S, Lenton S. Issues in the implementation and evolution of the commercial recreational cannabis market in Colorado. *Int J Drug Policy* 2015; December 15: 10.1016/j.drugpo.2015.12.001.
- 17 Rehm J, Fischer B. Cannabis legalization with strict regulation, the overall superior policy option for public health. *Clin Pharmacol Ther* 2015; 97: 541-4.
- 18 Caulkins JP, Hawken A, Kilmer B, Kleiman M. *Marijuana legalization: what everyone needs to know*. New York: Oxford University Press; 2012.
- 19 Kilmer B, Caulkins JP, Pacula RL, MacCoun RL, Reuter PH. Altered state? Assessing how marijuana legalization in California could influence marijuana consumption and public budgets. Santa Monica, CA: RAND Drug Policy Research Center; 2010. Available at: [http://www.rand.org/content/dam/rand/pubs/occasional\\_papers/2010/RAND\\_OP315.pdf](http://www.rand.org/content/dam/rand/pubs/occasional_papers/2010/RAND_OP315.pdf); <http://www.webcitation.org/6fSO4BEC0> (accessed 4 July 2014).

- 20 Swanson A, Gamio L. How the price of pot differs in 50 states and 8 major cities, 2015. February 19, 2016. Available at:  
<https://www.washingtonpost.com/news/wonk/wp/2015/06/22/how-the-price-of-pot-differs-in-50-states-and-8-major-cities/>; <http://www.webcitation.org/6fSOgfi4V>  
(accessed 21 February 2016).
- 21 Babor T, Caetano R, Casswell S, Edwards G, Giesbrecht N, Graham K, *et al.* *Alcohol: no ordinary commodity: research and public policy*. 2nd ed. Oxford: Oxford University Press; 2010.
- 22 Chaloupka FJ, Warner KE. The economics of smoking. In: Newhouse JP, Cuyler AJ, editors. *The handbook of health economics*. New York: Elsevier; 2000, pp. 1539-627.
- 23 Pacula RL, Kilmer B, Wagenaar AC, Chaloupka FJ, Caulkins JP. Developing public health regulations for marijuana: lessons from alcohol and tobacco. *Am J Public Health* 2014; 104: 1021-8.
- 24 Pacula R. Examining the impact of marijuana legalization on marijuana consumption: insights from the economics literature. RAND working paper. Santa Monica, CA: RAND Corporation; 2010. Available at:  
[http://www.rand.org/pubs/working\\_papers/WR770.html](http://www.rand.org/pubs/working_papers/WR770.html);  
<http://www.webcitation.org/6fhEZK7tL> (accessed 2 March 2016).
- 25 Hall WD, Pacula RL. *Cannabis use and dependence: public health and public policy*. Reissue of first (2003) ed. Cambridge, UK: Cambridge University Press; 2010.
- 26 Wagenaar AC, Salois MJ, Komro KA. Effects of beverage alcohol price and tax levels on drinking: a meta-analysis of 1003 estimates from 112 studies. *Addiction* 2009; 104: 179-90.

- 27 Palamar JJ, Ompad DC, Petkova E. Correlates of intentions to use cannabis among US high school seniors in the case of cannabis legalization. *Int J Drug Policy* 2014; 25: 424-35.
- 28 Pacula RL, Powell D, Heaton P, Sevigny EL. Assessing the effects of medical marijuana laws on marijuana use: the devil is in the details. *J Policy Anal Manage* 2015; 34: 7-31.
- 29 Hall W, Morley K. Possible causes and consequences of reduced perceptions of the risks of using cannabis. *Clin Toxicol* 2015; 53: 141-2.
- 30 Maxwell JC, Mendelson B. What do we know now about the impact of the laws related to marijuana? *J Addict Med* 2016; 10: 3-12.
- 31 Cerda M, Wall M, Keyes KM, Galea S, Hasin D. Medical marijuana laws in 50 states: investigating the relationship between state legalization of medical marijuana and marijuana use, abuse and dependence. *Drug Alcohol Depend* 2012; 120: 22-7.
- 32 Lynne-Landsman SD, Livingston MD, Wagenaar AC. Effects of state medical marijuana laws on adolescent marijuana use. *Am J Public Health* 2013; 103: 1500-6.
- 33 Ammerman S, Ryan S, Adelman WP. The impact of marijuana policies on youth: clinical, research, and legal update. *Pediatrics* 2015; 135: e769-85.
- 34 Wall MM, Poh E, Cerda M, Keyes KM, Galea S, Hasin DS. Adolescent marijuana use from 2002 to 2008: higher in states with medical marijuana laws, cause still unclear. *Ann Epidemiol* 2011; 21: 714-6.
- 35 Harper S, Strumpf EC, Kaufman JS. Do medical marijuana laws increase marijuana use? Replication study and extension. *Ann Epidemiol* 2012; 22: 207-12.

- 36 Wall MM, Poh E, Cerda M, Keyes KM, Galea S, Hasin DS. Commentary on Harper S, Strumpf EC, Kaufman JS. Do medical marijuana laws increase marijuana use? Replication study and extension. *Ann Epidemiol* 2012; 22: 536-7.
- 37 Choo EK, Benz M, Zaller N, Warren O, Rising KL, McConnell KJ. The impact of state medical marijuana legislation on adolescent marijuana use. *J Adolesc Health* 2014; 55: 160-6.
- 38 Schuermeyer J, Salomonsen-Sautel S, Price RK, Balan S, Thurstone C, Min SJ, *et al.* Temporal trends in marijuana attitudes, availability and use in Colorado compared to non-medical marijuana states: 2003-11. *Drug Alcohol Depend* 2014; 140: 145-55.
- 39 Hasin DS, Wall M, Keyes KM, Cerdá M, Schulenberg J, O'Malley PM, *et al.* Medical marijuana laws and adolescent marijuana use in the USA from 1991 to 2014: results from annual, repeated cross-sectional surveys. *Lancet Psychiatry* 2015; 2: 601-8.
- 40 Wen H, Hockenberry JM, Cummings JR. The effect of medical marijuana laws on adolescent and adult use of marijuana, alcohol, and other substances. *J Health Econ* 2015; 42: 64-80.
- 41 Compton WM, Grant BF, Colliver JD, Glantz MD, Stinson FS. Prevalence of marijuana use disorders in the United States: 1991-1992 and 2001-2002. *JAMA* 2004; 291: 2114-21.
- 42 Chu YW. The effects of medical marijuana laws on illegal marijuana use. *J Health Econ* 2014; 38: 43-61.
- 43 Masten SV, Guenzburger GV. Changes in driver cannabinoid prevalence in 12 U.S. states after implementing medical marijuana laws. *J Safety Res* 2014; 50: 35-52.

- 44 Anderson DM, Hansen B, Rees DI. Medical marijuana laws, traffic fatalities, and alcohol consumption. *J Law Econ* 2013; 56: 333-69.
- 45 Salomonsen-Sautel S, Min SJ, Sakai JT, Thurstone C, Hopfer C. Trends in fatal motor vehicle crashes before and after marijuana commercialization in Colorado. *Drug Alcohol Depend* 2014; 140: 137-44.
- 46 Anderson DM, Rees DI. The legalization of recreational marijuana: how likely is the worst-case scenario? *J Policy Anal Manage* 2014; 33: 221-32.
- 47 Anderson DM, Rees DI, Sabia JJ. Medical marijuana laws and suicides by gender and age. *Am J Public Health* 2014; 104: 2369-76.
- 48 Grucza RA, Hur M, Agrawal A, Krauss MJ, Plunk AD, Cavazos-Rehg PA, *et al.* A reexamination of medical marijuana policies in relation to suicide risk. *Drug Alcohol Depend* 2015; 152: 68-72.
- 49 Rylander M, Valdez C, Nussbaum AM. Does the legalization of medical marijuana increase completed suicide? *Am J Drug Alcohol Abuse* 2014; 40: 269-73.
- 50 Bachhuber MA, Saloner B, Cunningham CO, Barry CL. Medical cannabis laws and opioid analgesic overdose mortality in the United States, 1999-2010. *JAMA Intern Med* 2014; 174: 1668-73.
- 51 Finney JW, Humphreys K, Harris AH. What ecologic analyses cannot tell us about medical marijuana legalization and opioid pain medication mortality. *JAMA Intern Med* 2015; 175: 655-6.
- 52 Hayes MJ, Brown MS. Legalization of medical marijuana and incidence of opioid mortality. *JAMA Intern Med* 2014; 174: 1673-4.

- 53 Johnston LD, O'Malley PM, Bachman JG. *National survey results on drug use from the Monitoring the Future Study, 1975-1993. College students and young adults.* Rockville, MD: National Institute on Drug Abuse; 1994.
- 54 Johnston LD, O'Malley PM, Bachman JG. *National survey results on drug use from the Monitoring the Future Study, 1975-1993. Secondary school students.* Rockville, MD: National Institute on Drug Abuse; 1994.
- 55 Room R, Greenfield T, Weisner C. "People who might have liked you to drink less": changing responses to drinking by U. S. family members and friends, 1979-1990. *Contemp Drug Probl* 1991; 18: 573-95.
- 56 US National Institute of Justice. NIJ's drugs and crime research: arrestee drug abuse monitoring programs. Washington, DC: USA.gov, 2014. June 18. Available at: <http://www.nij.gov/topics/drugs/markets/adam/pages/welcome.aspx>; <http://www.webcitation.org/6fSOnNIUv> (accessed 19 February 2016).
- 57 Berning A, Smither D. Understanding the limitations of drug test information, reporting, and testing practices in fatal crashes. Traffic Safety Facts Research Notes/Impaired Driving. Washington, DC: National Highway Traffic Safety Administration; 2014. Available at: <http://www-nrd.nhtsa.dot.gov/Pubs/812072.pdf>; <http://www.webcitation.org/6fyIHTcpf> (accessed 19 February 2016).
- 58 Compton RP, Berning A. Drug and alcohol crash risk. Washington, DC: National Highway Traffic Safety Administration, 2015. Available at: [http://www.nhtsa.gov/staticfiles/nti/pdf/812117-Drug\\_and\\_Alcohol\\_Crash\\_Risk.pdf](http://www.nhtsa.gov/staticfiles/nti/pdf/812117-Drug_and_Alcohol_Crash_Risk.pdf); <http://www.webcitation.org/6fSNnuhL4> (accessed 19 February 2016).

- 59 Daughton CG. Illicit drugs: contaminants in the environment and utility in forensic epidemiology. *Rev Environ Contam Toxicol* 2011; 210: 59-110.
- 60 Monte AA, Zane RD, Heard KJ. The implications of marijuana legalization in Colorado. *JAMA* 2015; 313: 241-2.
- 61 Jouanjus E, Lapeyre-Mestre M, Micallef J. Cannabis use: signal of increasing risk of serious cardiovascular disorders. *J Am Heart Assoc* 2014; 3: e000638.
- 62 Jouanjus E, Leymarie F, Tubery M, Lapeyre-Mestre M. Cannabis-related hospitalizations: unexpected serious events identified through hospital databases. *Br J Clin Pharmacol* 2011; 71: 758-65.
- 63 Wolff V, Armspach JP, Lauer V, Rouyer O, Ducros A, Marescaux C, *et al.* Ischaemic strokes with reversible vasoconstriction and without thunderclap headache: a variant of the reversible cerebral vasoconstriction syndrome? *Cerebrovasc Dis* 2015; 39: 31-8.
- 64 Wolff V, Lauer V, Rouyer O, Sellal F, Meyer N, Raul JS, *et al.* Cannabis use, ischemic stroke, and multifocal intracranial vasoconstriction: a prospective study in 48 consecutive young patients. *Stroke* 2011; 42: 1778-80.
- 65 Dines AM, Wood DM, Yates C, Heyerdahl F, Hovda KE, Giraudon I, *et al.* Acute recreational drug and new psychoactive substance toxicity in Europe: 12 months data collection from the European Drug Emergencies Network (Euro-DEN). *Clin Toxicol (Phila)* 2015; 53: 893-900.

- 66 Davis JM, Mendelson B, Berkes JJ, Suleta K, Corsi KF, Booth RE. Public health effects of medical marijuana legalization in Colorado. *Am J Prev Med* 2016; 50: 373-9.
- 67 SAMHSA. 2013 N-SSATS - Data on substance abuse treatment facilities. Rockville, Maryland: Substance and Mental Health Services Administration; 2015. Available at: [http://www.dasis.samhsa.gov/webt/state\\_data/US13.pdf](http://www.dasis.samhsa.gov/webt/state_data/US13.pdf); <http://www.webcitation.org/6fyISV05E> (accessed 19 February 2016).
- 68 SAMHSA. N-SSATS Quick statistics state profiles. Rockville, MD: Substance Abuse and Mental Health Services Administration, Center for Behavioral Health Statistics and Quality, 2015. Available at: <http://www.dasis.samhsa.gov/webt/newmapv1.htm>; <http://www.webcitation.org/6fSORFZdk> (accessed 19 February 2016).
- 69 Becker J, Schaub MP, Gmel G, Haug S. Cannabis use and other predictors of the onset of daily cigarette use in young men: what matters most? Results from a longitudinal study. *BMC Public Health* 2015; 15: 1-10.
- 70 Males M, Buchen L. Reforming marijuana laws: which approach best reduces the harms of criminalization? A five state analysis. San Francisco, CA: Centre on Juvenile and Criminal Justice; 2014. Available at: [http://www.cjcj.org/uploads/cjcj/documents/cjcj\\_marijuana\\_reform\\_comparison.pdf](http://www.cjcj.org/uploads/cjcj/documents/cjcj_marijuana_reform_comparison.pdf); <http://www.webcitation.org/6fuya425f> (accessed 11 March 2016).
- 71 Campbell DT. Reforms as experiments. *Am Psychol* 1969; 24: 409-29.
- 72 van Nuijs AL, Castiglioni S, Tarcomnicu I, Postigo C, de Alda ML, Neels H, *et al.* Illicit drug consumption estimations derived from wastewater analysis: a critical review. *Sci Total Environ* 2011; 409: 3564-77.

73 Hall WD. U.S. policy responses to calls for the medical use of cannabis. *Yale J Biol Med* 2015; 88: 257-64.

74 Hall WD, Degenhardt L. Adverse health effects of non-medical cannabis use. *Lancet* 2009; 374: 1383-91.

Accepted Article

Table 1: Cannabis legalization provisions in four US states that have legalized cannabis

	<b>Alaska</b>	<b>Colorado</b>	<b>Oregon</b>	<b>Washington</b>
Passed	2014	2012	2014	2012
Legal sales	2016	2014	2016	2014
Legal age	21 years	21 years	21 years	21 years
Legal Quantity	28.5 g	28.5 g	28.5 g	28.5 g
Regulator	Alcohol and Marijuana Control Office	Marijuana Enforcement Division, Dept of Revenue	Oregon Liquor Control Commission	State Liquor and Cannabis Board
Tax regime	\$50 state excise per 28.5 g	15% state excise included in sale price	Tax free until 2016 from dispensaries. Then 25% on nonmedical sales	Retailer pays excise of 37%
Licensing	Cultivators, retailers, manufacturers, testing facilities	Cultivators, retailers, manufacturers, testing facilities	Producers, processors, wholesalers, retailers	Producer, Processor, and retailer
Medical Marijuana	Allowed from age 18; until legal sales medical users can cultivate but not sell	Allowed from age 18; taxed at lower rate	Allowed from age 18. Purchases at retail stores not subject to sales tax	Allowed from age 18; personal cultivation allowed for medical users
Personal cultivation	Allowed & untaxed; six plants (up to 3 mature plants)	Allowed at age 21 and untaxed (six plant total)	Allowed; up to four plants	Not allowed

Drug-affected driving	Prohibited	Prohibited	Prohibited	Prohibited
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Box 1: Adverse effects of chronic recreational cannabis smoking identified in epidemiological studies (Source: Hall and Degenhardt, 2009 [74])

#### Most probable adverse effects

- a cannabis dependence syndrome (in around 1 in 10 users);
- chronic bronchitis and impaired respiratory function in regular smokers;
- psychotic symptoms and disorders in heavy users, especially those with a history of psychotic symptoms or a family history of these disorders;
- impaired educational attainment among adolescents who use regularly;
- subtle cognitive impairment in those who use daily for a decade or more.

#### Possible adverse effects

- respiratory cancers;
- behaviour disorders in children whose mothers used cannabis while pregnant;
- depressive disorders, mania, and suicide;
- increased likelihood of using other illicit drugs in adolescents.