HHS Public Access

Author manuscript

Am J Prev Med. Author manuscript; available in PMC 2017 March 01.

Published in final edited form as:

Am J Prev Med. 2016 March ; 50(3): 373–379. doi:10.1016/j.amepre.2015.06.034.

Public Health Effects of Medical Marijuana Legalization in Colorado

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Abstract

Introduction—The public health consequences of the legalization of marijuana, whether for medical or recreational purposes, are little understood. Despite this, numerous states are considering medical or recreational legalization. In the context of abrupt changes marijuana policy in 2009 in Colorado, the authors sought to investigate corresponding changes in marijuana-related public health indicators.

Methods—This observational, ecologic study used an interrupted time-series analysis to identify changes in public health indicators potentially related to broad policy changes that occurred in 2009. This was records-based research from the state of Colorado and Denver metropolitan area. Data were collected to examine frequency and trends of marijuana-related outcomes in hospital discharges and poison center calls between time periods before and after 2009 and adjusted for population. Analyses were conducted in 2014.

Results—Hospital discharges coded as marijuana-dependent increased 1% per month (95% CI=0.8, 1.1, $p<0.001$) from 2007 to 2013. A change in trend was detected in poison center calls mentioning marijuana ($p<0.01$). After 2009, poison center calls increased 0.8% per month (95% CI=0.2, 1.4, $p<0.01$). Poison center calls also increased 56% (95% CI=49%, 63%, $p<0.001$) in the period following the policy change. Further, there was one hospital discharge coded as dependent for every 3,159 (95% CI=2,465, 3,853, $p<0.001$) medical marijuana registrant applications.

Conclusions—The abrupt nature of these changes suggests public health effects related to broad policy changes associated with marijuana. This report may be used to assist in policy decisions regarding the short-term public health effects of marijuana legalization.

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No financial disclosures were reported by the authors of this paper.

Introduction

The debate around medical and recreational marijuana has recently taken on new vigor with the enactment of legalization for recreational use in Colorado and Washington (2012), and more recently in Oregon and Alaska (2014). Twenty-three states and the District of Columbia have legalized medical marijuana, and it is presumed that more states will follow this example. At the time of this writing, Ohio and Pennsylvania had pending medical marijuana legislation. Information on the public health impact of medical legalization is still developing and further analyses of medical legalization may be informative to various bodies considering legalization. In 2000, Colorado voters supported a state constitutional amendment (Amendment 20) to legalize marijuana for medical use by a margin of 54% to 46%. Amendment 20 provided for the creation of a medical marijuana registry. To obtain a registry card and thus legal access to medical marijuana, patients must be diagnosed with a "debilitating condition" in the context of a "bona fide" relationship with a physician who "maintains, in good standing, a license to practice medicine."[1] Debilitating conditions approved by the Colorado Department of Public Health and Environment (CDPHE) and included in Amendment 20 are: cancer, glaucoma, HIV or AIDS, cachexia, severe pain, severe nausea, seizures, muscle spasms, and any other condition approved by CDPHE.[1]

Despite legalization, registered users did not increase substantially over the next several years.[2] The broad policy changes in 2009, however, appear to have led to an exceptionally rapid expansion in medical marijuana access. In October 2009, the Department of Justice issued the Ogden Memorandum that instructed federal prosecutors to not focus federal resources on "individuals whose actions are in clear and unambiguous compliance with existing state laws providing for the medical use of marijuana".[3] On the state level, in July 2009, the Colorado Board of Health rejected a limitation on the caregiver patient limit after nearly 12 hours of testimony from medical marijuana advocates, essentially allowing caregivers to act as licensed business entities with an unlimited number of patients. These decisions allowed for large medical marijuana centers and the creation of dispensaries. These changes led to a rapid rise in the number of medical marijuana applications. In January 2009, there were 495 applications per month. By October, there were 4,751 applications per month and CDPHE could no longer process the applications within the required 35 days. As a result, applicants were assumed to have a valid registration without the application being processed. By December, there were 10,155 applications per month. Further, between 2006 and 2008 there were no known dispensaries in Colorado, but by spring of 2009 more than 250 dispensaries had been established and by mid-2010 there were more than 900 dispensaries identified by law enforcement agencies.[4] This increase in the number of medical dispensaries, as well as the creation of recreational dispensaries in Colorado, raises the question of the public health impact of increased marijuana availability. These increases may have dampened the perceived risk of marijuana use in Colorado.[2] Attitudinal shifts, including changes in the perceived risk of a substance, have been an important factor in determining health-related outcomes regarding substance use. Similar levels of risk perception regarding marijuana use have been found between heavy and light users, and similar levels of risk perception were shown to exist between marijuana users who reported negative social and academic consequences of use and those who had not.[5,6]

Although a direct link between the enactment of medical marijuana laws and an increase in marijuana consumption has been debated, increased availability can play into the perceptions of the riskiness of casual use, and thus affect related public health concerns.[7]

Given the abruptly changing marijuana regulatory environment in Colorado, the state is in a unique position to conduct research on medical marijuana where much can be gained by examining the before and after effects of policy changes around 2009. This report seeks to examine potential public health consequences of increased dispensaries and medical card holders and the likely increase in corresponding marijuana consumption in Colorado and the Denver metropolitan area.

Methods

Data Sources

Various sources of public health data were obtained from collaborators to assess trends over time regarding marijuana use. Counts of medical marijuana registration (MMR) license applicants were obtained from CDPHE in a publicly available data set.[8] CDPHE maintains a confidential registry of all who applied for and were entitled to receive a registry identification card. Hospital discharge counts coded as ICD-9-CM 305.2 “cannabis abuse” and counts coded as ICD-9-CM 304.3 “cannabis dependence” were obtained from CDPHE as well. Counts of poison center calls mentioning marijuana were obtained from the Rocky Mountain Poison and Drug Center. Mentions are included in the poison center analysis along with other substances. Counts of marijuana treatment entries were obtained from the Drug/Alcohol Coordinated Data System, maintained by the Office of Behavioral Health. Finally, counts of adult arrests were obtained from the Data Analysis Unit of the Denver Police Department.

The denominator for this analysis was population estimated by the 2000 and 2010 Census. The analyses varied in geographic coverage; MMR applications, hospital discharges, and poison center calls were statewide-based counts, whereas treatment admissions and marijuana-related arrests were available for the Denver metropolitan area. The population at risk specific to geographic region was used as discussed below. Monthly time periods were available for all, except arrest analyses where data available were annual.

Statistical Analysis

To analyze effects related to broad policy changes, an interrupted time-series analysis was utilized with July 2009 used as a transition point, owing to the aforementioned policy events. The analyses explored changes in trends around July 2009 and changes in means between time periods before and after July 2009. More specifically, the analyses utilized an interaction term by time period, with time centered at July 2009 to test the change in the slope of the trends before and after 2009. The time period for a pre–post difference in means analyses was defined in the same manner. A reduced pre–post model was developed that dropped the interaction term when there were no significant changes in trends. Arrest data were centered at 2009 and analyzed similarly. As described above, substantial growth in

MMR applicants did not begin until 2009 and few registrant records exist prior to 2009. Consequently, the MMR analysis in this section concentrates on 2009–2013.

The authors also utilized monthly MMR applications as an ecologic exposure variable of marijuana over the 2009–2013 time period in analyses of hospital discharges. This gives an estimate of a population level of marijuana exposure. It is analogous to population-level exposures examined in prescription drug misuse based studies that have capitalized on the analysis of counts of dispensed prescriptions.[9–12] Monthly application numbers were used as the exposure variable in linear models of monthly hospital ICD9-coded discharges for dependence and for abuse.

As these analyses utilized time-series data, they could be in violation of the assumption of independence through serial correlations. The authors tested for the presence of serial correlations using the Durbin–Watson statistic in analyses utilizing linear models (MMR applicants over time, and MMR applicants versus hospital discharges). Where the Durbin Watson statistic suggested autocorrelated data, an AR1 structure was utilized. Owing to the count data used in other analyses over time (hospital discharges, poison center calls, treatment entries, and arrests) a negative binomial population rate modeling strategy was utilized. The negative binomial model incorporates an additional parameter to calculate SEs in the instance of overdispersion common in Poisson regression and has been utilized in highly similar analyses that suggest it is robust to serial correlations as well.[12] Further, the logged population at risk was utilized as the offset variable, correcting analyses for population growth. Population was linearized assuming a constant growth rate over the time interval from 2000 to 2010 and extrapolated through 2013. Follow-up linear models of MMR applications per population by month were conducted to evaluate confounding effects of population growth in the MMR application analysis. For ease of interpretation, and given lack of evidence of population confounding, results for the MMR application analysis are presented unadjusted for population. R, version 3.0.1, the nlme, lmtest, and MASS packages were utilized. All figures display predicted values (lines) over actual count data (points). Analyses were conducted in 2014.

Results

Appendix Figure 1 shows the number of new MMR patient applications over time. The total number of applications increased almost sixfold from December 2009 through January 2014 (43,769 to 247,905). Appendix Table 1 shows that over time there has been a steady increase in applications since 2009 and on average an additional 4,205 (95% CI=4,007, 4,403, $p<0.001$) applications were received per month.

Figure 1A highlights an increasing trend in monthly increments of marijuana-related hospital discharges. The mean values before and after July 2009 were different, where Table 1 displays a nearly 44% increase (95% CI=35.2%, 52.3%, $p<0.001$) in “abuse”-coded discharges, and a 57% increase (95% CI=43.4%, 72.0%, $p<0.001$) in “dependence”-coded discharges. From 2007 through 2013, there was an increase over time as well. Marijuana-related hospital discharges increased 0.8% (abuse) (95% CI=0.7%, 0.9%, $p<0.001$) and 1% (dependence) (95% CI=0.8%, 1.1%, $p<0.001$) per month, on average (Figure 1A and Table

1). Notably, the interaction term in the analysis of hospital discharges was not significant, indicating there was no change in trend corresponding with the 2009 data point.

Figure 1B depicts statewide marijuana-related calls to the Rocky Mountain Poison and Drug Center from 2004 through 2013. Marijuana exposure calls ranked either third or fourth behind calls related to alcohol, cocaine, and methamphetamine prior to 2009, but after 2009 marijuana calls ranked second to alcohol (data not shown). The 107 marijuana calls in 2010, 98 calls in 2011, 130 calls in 2012, and 136 calls in 2013 were 98.1%, 81.5%, 141%, and 152% increases, respectively, over the 54 calls in 2009. Table 1 highlights a nearly 56% increase in mean values between time periods (95% CI=49.0%, 62.8%, $p<0.001$), and an increasing trend starting in 2009 ($p<0.001$).

An association was detected between MMR applications and both hospital discharges coded for abuse and dependence (Figure 2C and D). On average, every 742 (95% CI=629, 857, $p<0.001$) applications were associated with one hospital discharge coded as abuse, and 3,159 (95% CI=2,465, 3,853, $p<0.001$) applications were associated with one hospital discharge for dependence.

Figure 3E graphically highlights monthly marijuana-related treatment admissions in the Denver metropolitan area. Marijuana treatment admissions increased from 2,694 in 2005 to a high of 3,295 in 2008 (by 22%) and remained at about that level in 2009 with 3,289 admissions. In 2011, marijuana admissions declined by 10.6% to 2,887 and there was a decreasing trend after 2009. Additionally, Table 1 highlights monthly trends in marijuana treatment admissions over time, where significant decreases of 0.7% per month in treatment entries after 2009 were found (95% CI= −0.9%, −0.5%, $p<0.001$). Further, the interaction term was significant ($p<0.001$), suggesting an abrupt change in marijuana treatment entrants where entries were increasing prior to policy change and decreasing afterwards. The mean values between time periods were not different. Adult arrests were relatively constant over time prior to 2009 and decreased afterward. These are displayed graphically in Figure 3F and highlighted in Table 1. The change in trend was significant ($p<0.001$), and arrests were decreasing 26% per year post 2009 (95% CI= −31.1%, − 20.3%, $p<0.001$).

Discussion

This paper presented changes in marijuana-related policy and public health outcomes over the time period of the study. The increases in MMR applicants and decreases in trends of marijuana-related arrests may be a direct result of policy changes. When taken with changes suggesting a decrease in the perceived risk of marijuana,[2,5,6] these factors may mark increased use and increased acceptance of marijuana over this time period, and be important components of deleterious public health outcomes. In addition to an increase in prevalence of marijuana use over this timeframe[2,6] and increases in marijuana-related fatal motor vehicle crashes previously reported,[13] this study identified increases in hospital discharges, poison center calls, and decreases in treatment entries and arrests in this time period. These concomitant occurrences suggest important effects that may be related to policy changes.

This analysis identified increases in hospital discharges over time that could be indicative of broad regulatory effects. However, there was no strong indication that the 2009 timepoint, in particular, marked these changes over time. The interaction term was not significant and therefore suggests these increases had been occurring regardless of 2009 policy changes. However, it is also important to note the linear relationship between MMR applications and hospital discharges. Albeit an imperfect exposure measure, the number of registrants allows an estimate of population based marijuana consumption, and is highly similar to exposure estimates based from counts of dispensed prescriptions used in other work.[9–12] The authors detected one dependence related discharge for every 3,159 applications and one discharge regarding abuse for every 743 applicants. There are limitations to this analysis, however; specifically, individual-level exposures are unknown and individuals likely diverted marijuana to those without licenses. Further, a contextual reference is necessary to weigh these findings appropriately from an ecologic perspective.

A tax-based comparison with alcohol and hospital discharges compared with discharges for marijuana will allow a population assessment of the relative dangers between the two substances based on the quantity spent. Although it is likely more individuals consumed alcohol than marijuana, in 2012, alcohol-related hospital discharges were approximately fivefold higher (623.2 vs 122.2 per 100,000; Colorado Drug and Alcohol Coordinated Data System), emergency department visits where alcohol was a component were 5.6 times higher (984.6 vs 176.2 per 100,000; CDPHE, Colorado Hospital Association Discharge Data Program), and treatment for alcohol dependence entries in 2012 were nearly two times higher (5,631 vs 2,845; Colorado Drug and Alcohol Coordinated Data System).

The authors detected changes in poison center calls that may be affected by the 2009 time point, after which increases were seen. Poison center call data can be considered as sentinel indicators of deleterious drug-related events because they are sensitive to exposures that do not result in an emergency department visit. However, they are also strongly predictive of emergency department visits due to prescription drug abuse[14] and of deaths due to methadone exposures.[15] The change detected in poison center calls suggests increased marijuana use that may result in a deleterious public health effects post policy change and may be predictive of emergency department visits mentioning marijuana. Further, recent reports have identified unique risks with edible marijuana products where dosage confusion and individual pharmacokinetics may lead to detrimental effects.[16] Given the utility of poison center data, they could be useful in evaluating regulatory changes that would address edibles in particular.

Nationally, in 2009 there were 4.5 million drug-related visits to the emergency department, and more than half of the visits were attributed to drug misuse or abuse that involved pharmaceuticals.[17] Marijuana use frequently occurs concurrently with prescription drug misuse,[18,19] alcohol,[20] tobacco,[21] prescription stimulants,[22] and in other polydrug scenarios.[23] It is possible that the incidence of marijuana-related hospital discharges and poison center calls can be attributed to polydrug use. Given the rates of prescription drug misuse and marijuana use, future investigations should explore polydrug exposures of marijuana and prescription medications.

Additionally, drug abuse treatment admissions and arrests for marijuana decreased post policy change. Decreases in arrests may be intuitive, but perhaps decreases in treatment admissions are reflective of a more accepting public opinion of marijuana use, and individuals who may have sought treatment prior to 2009 are less inclined to do so now. On the other hand, this decrease could be indicative of a decrease in arrests and corresponding decreases in mandated treatment. Frequently, nonviolent drug offenders are given the option of drug court where mandated treatment is ubiquitous. The relation of arrests and treatment entries could be important, as a report by Kelly et al.[24] in 2005 noted that judicial mandates could provide increased opportunity for needed drug treatment for offenders. Given the dramatic decreases reported regarding treatment entry, investigations identifying marijuana abuse behavior that is no longer captured through the justice system are warranted. These investigations will likely inform on public health consequences stemming from a new and potential sizable population needing treatment.

Limitations

Important limitations of this work need to be considered before broad interpretations are made. All presented data are ecologic in nature, where precise individual-level exposures are unknown.

Conclusions

The abrupt change in treatment entrants, arrests, and changes in poison center calls suggests an important role of policy change. Public health interventions, such as educational campaigns, could be utilized to mitigate negative outcomes. This report, owing to the unique effects over time, can be used as a guide to some of the short-term effects that may be related to marijuana policy changes in other states.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The funding source for this research was: NIH/National Institute on Drug Abuse, 5R01DA031816-04, Booth, Robert (Principal Investigator), August 1, 2011 through May 31, 2016.

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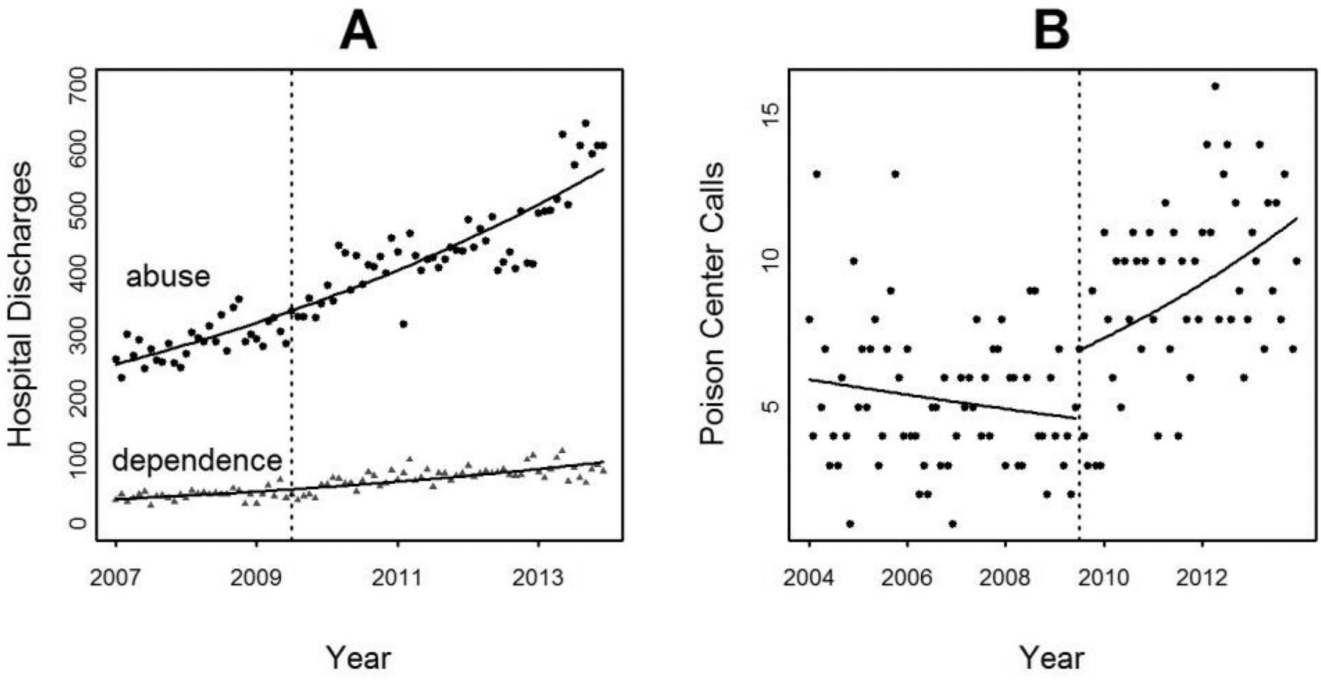

Figure 1.

Panel A depicts monthly hospital discharges coded as abuse and dependence over time. Panel B depicts monthly calls to the Rocky Mountain Poison and Drug Center over time. The dotted line corresponds to July 2009.

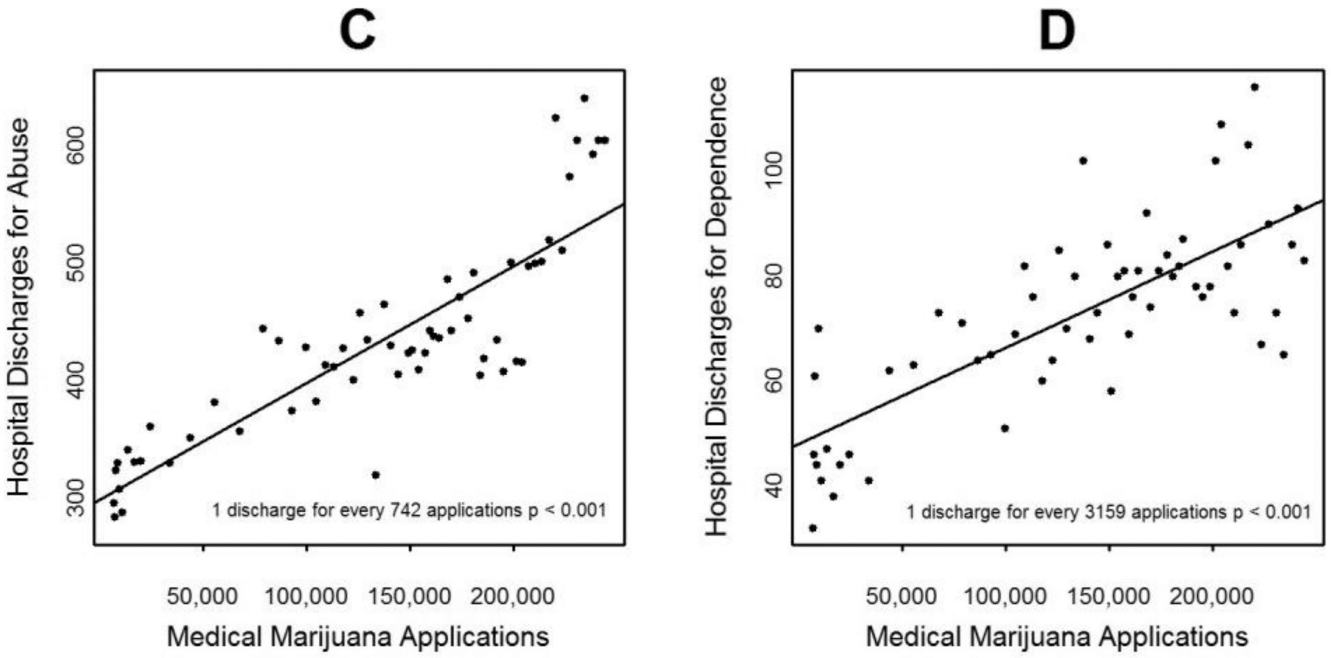

Figure 2.

The linear relationship between MMRs and Hospital Discharges coded as dependence (C), and as abuse (D).

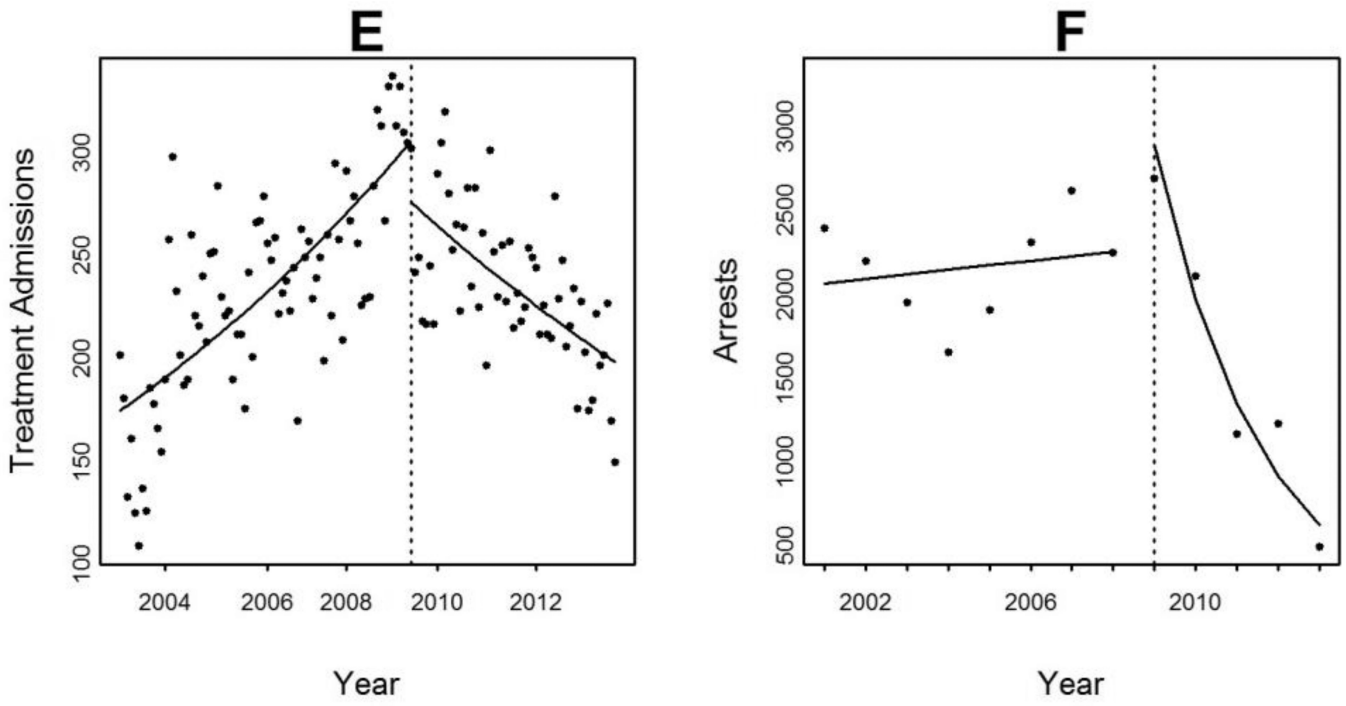

Figure 3.

Marijuana related treatment admissions and arrests. Panel E depicts monthly marijuana treatment admissions over time in the Denver metro area. Panel F depicts annual marijuana related adult arrests over time in the Denver metro area. The dotted line corresponds to July 2009 (panel E), or the year 2009 (panel F).

Table 1

Results of Regression Analyses of Marijuana Related Outcomes

	Difference in means between time periods		Difference in trends		Trend starting 2009	
	% Difference	**95% CI**	**% Change**	**95% CI**	**% Trend**	**95% CI**
Hospital Discharges [a] (abuse)	43.5	**35.2, 52.3****	0.2	−0.2, 0.6	0.8[a]	**0.7, 0.9****
Hospital Discharges [a] (dependence)	56.9	**43.4, 72.0****	0.2	−0.6,1.0	1.0[a]	**0.8, 1.1****
Poison Control Calls [b]	55.7	**49.0, 62.8****	1.3	**0.5, 2.1***	0.8	**0.2, 1.4***
Treatment Entrants [c]	−6.2	−12.3, 0.2	−1.3	**−1.6, −1.4****	−0.7	**−0.9, −0.5****
Arrests [d]	−34.4	−56.2, −1.7	−32.6	**−39.2, −25.0,****	−26.0	**−31.1, −20.3****

Note: Boldface indicates statistical significance.

* $p<0.01$;

** $p<0.001$

[a] Trend per unit time over the time period starting in 2007

[b] Time period from 2004 through 2013

[c] Time period from 2003 through 2013

[d] Time period from 2001 through 2013

The % Difference column is the % difference in means between time periods. The % Change column is the interaction term, or the difference in slopes between the time periods. The % Trend column is the slope of the best fit line after 2009 (or in the case of Hospital Discharges the trend is starting 2007).