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Impact of cannabis legalization on healthcare utilization for psychosis and schizophrenia in Colorado

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Abstract

Background: Emergency department (ED) visits involving psychosis and schizophrenia have increased at a rate exceeding population growth in the United States over the past decade. Research shows a strong dose-response relationship between chronic use of high-potency cannabis and odds of developing symptoms of psychosis. The aim of this study was to evaluate the impact of cannabis legalization on psychosis and schizophrenia-related ED visits in Colorado.

Methods: Using administrative data from Colorado Hospital Association (CHA) on county-level quarterly ED visits between January 1, 2013, and December 31, 2018, we applied a difference-in-difference analysis to examine how new exposure to recreational cannabis dispensaries after 2014 differentially influenced the rate of ED visits for psychosis and schizophrenia, comparing counties with no prior medical cannabis dispensary exposure to counties with low or high medical dispensary exposure.

Results: As recreational dispensaries per 10,000 residents increased, there was no significant association with the rate of schizophrenia ED visits per capita (incidence rate ratio or IRR: 0.95, 95% CI [0.69, 1.30]) while the rate of psychosis visits increased 24% (IRR: 1.24, 95% CI [1.02, 1.49]). Counties with no previous medical dispensaries experienced larger increases in

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Declarations of Interest

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Supplementary materials

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schizophrenia ED visits than counties already exposed to a low level of medical dispensaries, but this effect was not significant. Counties with low baseline medical exposure had lower increases in rates of psychosis visits than counties with high baseline medical exposure (IRR 0.83, 95% CI [0.69, 0.99]).

Conclusions: There was a positive association between the number of cannabis dispensaries and rates of psychosis ED visits across all counties in Colorado. Although it is unclear whether it is access to products, or the types of products that may be driving this association, our findings suggest there is a potential impact on the mental health of the local population that is observed after cannabis legalization.

Keywords

Cannabis; Legalization; Psychosis; Schizophrenia; Mental health; Marijuana

Introduction

In the United States, hospital emergency department (ED) visits have been rising at a rate exceeding U.S. population growth since 2009 (Lin et al., 2018; Hooker et al., 2019). Mental health and substance abuse diagnoses are a major contributor to the rise, (Hooker et al., 2019; Moore & Owens, 2017) including psychosis and schizophrenia. During the same time frame, numerous states have liberalized their cannabis policies, which could be related to these trends in ED use (Volkow et al., 2014; Murray & Hall, 2020). Between January 2010 and March 2021, 21 states adopted medical cannabis policies and 17 states plus DC have legalized recreational use, (Legislatures NCfS. State Medical Marijuana Laws, 202) including populous states like New York and New Jersey. Evidence from Colorado suggests that the prevalence of mental health-related ED visits involving cannabis grew five times faster than those without cannabis in the two years when medical cannabis dispensaries proliferated and when recreational dispensaries first opened (between January 2012 and December 2014) (Hall et al., 2018). This early evidence suggests that we might see an increase in mental health-related ED visits at the population level.

Legalization in the U.S. has brought with it not just greater access to cannabis, but increased access to high potency products (Kilmer, 2017). The industry sells traditional plant products (smokable flower), but also concentrated inhaled products (vape, shatters, waxes, etc.) and food products (edibles), with large amounts of tetrahydrocannabinol (THC) (AfHRa, 2018), the principal psychoactive cannabinoid (Goodman et al., 2020). High potency extracts and concentrates can easily exceed 70% THC (Davenport, 2019).

It may take several years before the public health impact of these high potency products sold in legal markets are fully understood, but the potential impact on mental health ED visits is concerning (Murray & Hall, 2020). Prior research has found that chronic cannabis use is associated with an increase in acute psychosis and schizophrenia-type symptoms (Di Forti et al., 2015; D'Souza et al., 2004; Englund et al., 2016; Giordano et al., 2015; Mason et al., 2009; Morrison & Stone, 2011; van Os et al., 2002). Recent research shows this association strengthened with exposure to higher doses of THC (where "high" is defined as > 10% THC), and higher potency cannabis products are correlated with commercial retail markets

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in the U.S. (D'Souza et al., 2004; Sevigny et al., 2014; Smart et al., 2017). While these previous studies have shown associations between increased cannabis access and increased mental health symptoms, it is still not clear whether cannabis use is directly causal to the development of mental health diagnosis (National Academies of Sciences E, 2017).

In this study we offer some new insights regarding the incremental effect of transitioning from a medical market to a full-blown recreational market by examining impacts on the rate of psychosis and schizophrenia visits to an ED. In Colorado, despite state legalization of cannabis, local county jurisdictions decide whether to allow medical or recreational cannabis dispensaries individually. We use this local variation in cannabis access to assess the correlation between changes in local county cannabis availability and changes in ED visits for schizophrenia and psychosis. Given that county borders are highly permeable, with people crossing jurisdictions regularly for work and/or recreational activities, we anticipate that this design, which matches individual to where they live (not where the consumption occurs), will yield a lower bound estimate of the impact of increased recreational access on these outcomes.

Methods

We conducted a retrospective analysis compiling data from multiple administrative sources. First, we used ED visits data from the Colorado Hospital Association (CHA) from 2013–2018 to examine the prevalence rate of psychosis or schizophrenia-related ED visits. CHA collects hospital discharge data from over 100 hospitals and healthcare systems throughout the state, representing nearly all Coloradans. Information collected includes demographics (age, sex), International Classification of Disease (ICD) codes, insurance type, and Zip code of the patient's residence. We identified psychosis and schizophrenia visits using ICD-9 and ICD-10 diagnosis codes for psychosis (ICD9: 298*, V22*; ICD10: F23*, F24*, F28*, F29*) and schizophrenia (ICD9: 295*; ICD10: F20*, F21*, F25*), in any diagnosis code position on a given claim (Appendix Table 1). The counts of ED visits for these two diagnoses of interest were aggregated to the county level per quarter. We assigned the visits to county using the patient's Zip code.

Our main exposure measure was the number of licensed recreational dispensaries per county per quarter using data from the Colorado Department of Revenue. The state began accepting applications for medical dispensary licenses in 2010, when the Marijuana Enforcement Division was established. However, a concerted effort to enforce licensing began in 2013, after the voters passed Prop 64 in 2012 legalizing recreational cannabis. Licensed sale of recreational cannabis began in January 2014, first in existing medical dispensaries until September 2014 when new recreational dispensaries were allowed to open. Information on the name and address of the stores was available on the license, allowing us to geocode stores by Zip code.

Ignoring the size of the medical market before recreational stores open is problematic in a state like Colorado, where it was relatively easy and inexpensive to register as a patient, cannabis was approved for relatively mild and vague conditions (like "pain" rather than "chronic pain"), and medical outlets were loosely regulated. Given the ease with which

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individuals could obtain cannabis through the medical market, counties with large, pre-existing medical markets may have fewer adverse health events because the local population was already 'exposed' to the market. To control for pre-existing medical market size, we classified counties in terms of the number of medical dispensaries in 2012 right before the recreational legalization legislation was passed (no market = 0 dispensaries; low market = 1–9 medical dispensaries; high market = 10+ medical dispensaries). Setting the high baseline medical exposure counties as the reference group, we interacted the categorical baseline exposure with the number of recreational dispensaries per 10,000 residents. Sensitivity analyses were done using the simple raw count of dispensaries within a county and dropping the counties with the highest baseline exposure.

Descriptive statistics were used to examine trends in schizophrenia and psychosis ED visits, and patient demographics at the claim level. Because of the aggregation of individual visits to the county level, we did not include individual-level demographics in the analysis. Due to preliminary findings demonstrating substantial differences across counties with access to medical cannabis, we used a difference-in-difference framework to examine how new exposure to recreational cannabis differentially influenced the rate of ED visits for psychosis and schizophrenia, comparing counties with no medical cannabis dispensary exposure to counties with low or high medical cannabis dispensary exposure according to the following model:

$$E(y)_{cqt} = exp\Big(a + a_t + \theta + C_C\delta 1 Exposure_{cqt} + \delta 2 Exposure_{cqt} * Med\ Exposure_{cl}2012 + \beta^T X_{cqt}\Big)$$

Where y_{cqt} is our cannabis outcome (psychosis or schizophrenia ED visits) in county c in quarter q and year t. The parameter $\delta 1$ captures the impact of new recreational dispensaries opening in the county ($Exposure_{cqt}$), while $\delta 2$ captures the differential impact of recreational dispensaries in counties with low or no medical cannabis dispensary exposure ($Med\ Exposure_{cl}2012$) vis-à-vis counties with high prior exposure to cannabis, telling us whether the new exposure matters. A small number of time-varying county-level characteristics (X_{cqt}) was included that may influence the use of cannabis (β^T) and our outcomes, drawn from the American Health Resource File (HRSA. Area Health Resources Files, 2021) and the Bureau of Labor Statistics, (BLS. Local Area Unemployment Statistics, 2020) including the total number of hospital admissions (which may influence the outcomes) and the county unemployment rate (which may influence cannabis use and the outcomes). We modelled the outcomes using a fixed effects Poisson model, including robust standard errors. Additionally, we controlled for the transition from ICD9 to ICD10 codes during the 4th quarter of 2015 —there are many more ICD10 codes than 9 codes, and other studies have pointed out an increase in visits under ICD10 that may be due to changes in coding, rather than changes in actual visits (Yoon & Chow, 2017).

We used Stata Corp 16.1 for all analyses. The [relevant review board] exempted this research from human subjects protection.

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Results

From January 1, 2013 through December 31, 2018, there were a total of 28,623 schizophrenia and 56,967 psychosis ED visits reported to CHA. Males accounted for slightly more than half of the visits, and most patients were over the age of 26 (Table 1). Government insurance (Medicare and Medicaid—CHA does not distinguish between the two) was the primary payer for most of the visits (65·7% of psychosis and 82·8% of schizophrenia visits).

Fig. 1 shows the trends in the raw number (top panel) and rates per 10,000 residents (bottom panel) of schizophrenia and psychosis ED visits over time, for counties by their baseline medical cannabis dispensary exposure. Visits from all counties in Colorado for schizophrenia decreased between 2013 and 2014, but increased after 2015 to levels exceeding that observed in 2013. In contrast, psychosis ED visits were high in the early period (2013–2014), but then fell sharply with the transition from ICD-9 to ICD-10 (October 1, 2015). Emergency department visits for psychosis then rose again after the adjustment to ICD-10. The top panel of Fig. 1 also shows that the average prevalence of schizophrenia and psychosis related ED visits differ substantially across counties based on the presence of medical dispensaries prior to recreational legalization. Counties with no medical dispensaries had lower average quarterly prevalence rates of schizophrenia and psychosis than those with relatively low number of dispensaries (fewer than 10) and those with a high number of dispensaries (10 or greater). The differences in rates of schizophrenia across counties with no and high baseline exposure remain once these estimates are adjusted for population within the county, but disappear for psychosis visits when adjusted for population.

The average total number of dispensaries (medical and recreational) licensed per county per quarter increased from seven to more than 15 over the study period (Fig. 2). The total number was driven entirely by increases in recreational dispensaries after 2014. While the mean number of medical dispensaries in a county prior to legalization was relatively low, at around 8, the median was substantially lower (median = 1) as 50% of counties had no medical dispensary while the highest had over 200. Only three counties change from having no medical cannabis dispensaries to 1 medical dispensary during the study period.

Table 2 provides the incidence-rate ratios (IRR) and 95% confidence intervals (CI) from our high dimensional fixed effects Poisson models of schizophrenia ED visits per 10,000 residents and psychosis ED visits per 10,000 residents. While we find no statistical association between the number of recreational dispensaries per 10,000 residents and the rate of schizophrenia cases (IRR 0.95, CI 0.69, 1.30), we do find an overall positive association between the number of recreational dispensaries per 10,000 and the rate of psychosis ED visits (IRR 1·23, CI 1·03, 1·49). We found significant interaction effects based on baseline exposure to medical dispensaries. The combined IRRs, shown at the bottom of Table 2, reveal that the positive association between recreational dispensaries per capita and rates of psychosis were primarily driven by counties with either a high baseline rate (IRR = 1.238, p-value = 0.028, suggesting a 24% increase in psychosis visits per capita) and counties with no prior baseline exposure (IRR = 1.100, p-value = 0.00, indicating a 10%

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increase in psychosis visits per capita). The combined IRRs for rates of schizophrenia at the county level suggest that there was a very small (2.5%) increase in the rate of schizophrenia visits per capita in counties with no baseline exposure to medical dispensaries only. This is consistent with our hypothesis that those counties with no prior exposure may experience more negative health outcomes post legalization.

The analyses presented this far use population adjusted number of dispensaries to deal with the challenge that the greatest growth in recreational dispensaries post legalization occurred in large urban centers that already had a large number (in absolute terms) of medical cannabis dispensaries (see Fig. 3). However, Fig. 3 also shows that counties bordering with New Mexico, Wyoming, Nebraska and Kansas, generally small population counties except for one, also were more likely to have medical markets that expanded quickly into recreational markets. These counties clearly targeted populations out-of-state, individuals who would not be counted in our psychosis and schizophrenia ED visit data, but have very high population-level exposure values in the model. Thus, to reduce the influence of these counties without shrinking our number of observations, we replaced our per capita dispensary exposure measure with the raw dispensary count measures (Table 3). Doing so, we find that the interaction effects between recreational dispensaries and prior baseline exposure become significant for both rates of psychosis and schizophrenia ED visits. Counties with no medical dispensaries and higher recreational dispensaries experience greater increases in schizophrenia visits per capita than counties with high medical dispensaries (IR 1·01, CI 1·00, 1·03). Similarly, we find that counties with no medical dispensaries and higher recreational dispensaries experience larger increases in psychosis visits per capita than counties with high baseline medical dispensaries (IRR 1·06, CI 1·03, 1·08). The main effect of exposure to recreational dispensaries are both positive and significant, but the effect sizes are trivially small in magnitude.

Discussion

There is increasing evidence demonstrating adults who use cannabis regularly (daily or near-daily) are more likely than non-users to be diagnosed with psychosis disorders (Di Forti et al., 2015; D'Souza et al., 2004; Englund et al., 2016; Giordano et al., 2015; Mason et al., 2009; Morrison & Stone, 2011; van Os et al., 2002). Acute intoxication from THC can cause acute psychotic symptoms, which is worsened with higher doses (Mason et al., 2009). Recently, Di Forti and colleagues reported an increase in the rate of psychosis across 5 countries in Europe that was correlated with the increase in prevalence of daily cannabis use (Di Forti et al., 2019). Cities where this relationship was most profound were London and Amsterdam, where the highest potency cannabis is available.

Our findings from Colorado, which use exposure to recreational cannabis dispensaries, are consistent with these previous findings for psychosis. Overall, there was a 24% rise in the rate of psychosis visits across all counties in Colorado once recreational stores opened, driven by increases in counties that already had a high baseline exposure to medical cannabis dispensaries per capita as well as those that had no previous exposure to medical cannabis dispensaries. When we compared the growth in psychosis ED visits in Colorado counties that prohibited medical cannabis dispensaries to those that allowed,

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thereby assessing the differential impact of opening a recreational dispensary in a previously unexposed county, we found that there is a 6% greater increase in psychosis ED visits for each recreational dispensary opened (Table 3). When adjusted for population, thereby dampening the effect of the first few recreational stores opening, we found that counties with previous high medical cannabis dispensaries experience a higher rate of increase in psychosis than counties without prior medical cannabis dispensary exposure. We interpret these combined results as an indication that new markets were particularly vulnerable to increases in acute psychosis associated perhaps with naïve consumption, but that established markets are not immune, due perhaps to the higher potency products already offered in these more established markets (Firth et al., 2020).

Our findings with respect to schizophrenia tell a more nuanced story. We did not find a statistically significant impact of exposure to recreational dispensaries when measured on a per capita basis for the counties overall, or differentially by previous exposure to medical dispensaries. However, as shown by the combined IRRs, we do see counties with no prior per capita exposure to medical dispensaries experienced a small increase in rates of schizophrenia ED visits that was not seen in any of the other counties. The results in Table 2 together suggest that this rise cannot be attributed to increases in the exposure per capita in recreational dispensaries. However, Table 3 shows that when we look at exposure in terms of just the raw number of recreational dispensaries, we did see counties with no previous medical dispensary exposure experienced a very small (1%) statistically significant increase in the rate of schizophrenia as compared to counties with high medical cannabis exposure per unit increase in the number of dispensaries. Overall, we see that the number of recreational dispensaries was associated with an extremely small, but statistically significant, decrease in rates of schizophrenia ED visits across counties, just not for these counties with no prior exposure. Previous ecological studies on a broader scale have found increased incidence of schizophrenia due to an increase in cannabis use or an increase in the potency of cannabis products available in London, Denmark, and Portugal (Boydell et al., 2006; Hjorthøj et al., 2019; Gonçalves-Pinho et al., 2020). Our results suggest that any increase may be due to naïve users in new markets being exposed to these products rather than established markets.

Our findings regarding the increase in overall psychosis visits, given baseline levels, were modest and was unlikely to translate into a huge influx in ED volume or hospital costs. Furthermore, as we noted in the introduction, the causality of cannabis use and mental health diagnosis has not been fully elucidated. Despite the uncertainty, as the cannabis industry grows, or as more jurisdictions legalize, this could translate into a more significant impact at a larger scale. Recreational markets broaden access to cannabis, and a wider range of high potency cannabis products, particularly in the US where there are no legal restrictions on THC potency. In nine states that have legalized both forms of cannabis, the average THC concentration advertised online in medicinal programs was similar to recreational programs (Cash et al., 2020). Adverse effects among immature consumers was previously observed during the immediate time frames after legalization of both medical and recreational cannabis in Colorado, and mental health-related diagnoses and complaints were common in local EDs and calls to the regional poison center (Hall et al., 2018; Wang et al., 2017; Shelton et al., 2020). With growing evidence on the impact of higher doses

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of THC to the risk of psychosis, states and countries that legalize cannabis could consider potency limitations, or limitations on purchase amounts to limit THC dose exposures, as recommended recently by Fischer et al (2021). There should be emphasis on public health prevention, education, and treatment of cannabis use and cannabis use disorder, particularly among two at -risk groups: those vulnerable to mental illness and youth.

While we used a novel approach to identify the impact of these markets, there are limitations to our study. First, as mentioned previously, our estimates of an association between recreational dispensaries and mental health outcomes were likely biased downward due to spillover effects from neighboring counties. Growth in the illegal market in counties without legal dispensaries may also dilute the effect of the measured difference. Our inability to account for either of these generates a bias toward zero in our findings. However, there was also a possibility, given our focus on local jurisdictions, of a problem caused by reverse causality, particularly if local politicians made legalization decisions based on their expectations of high demand. We have done our best to limit any bias potentially caused by reverse causality by focusing our identification on exposure to medical dispensaries prior to the state's passage of recreational cannabis. It was the largest medical markets that saw the largest rise in dispensaries post recreational legalization (visible to some degree in Fig. 3).

There are several limitations related to the measurement of our outcome, that are broader limitations associated with using claims data to evaluate the public health impacts of cannabis legalization in general. While CHA data represents most hospital healthcare visits in Colorado, our outcome rates are dependent on hospitals reporting data to CHA and the coding practices of hospitals. There is variation in the hospital reporting to CHA and ED data was only available from 2013. Thus, we have a very short pre-policy time-period in which to develop a baseline trend. Additional analysis for inpatient data could be performed, but hospital admission for acute psychosis from cannabis and schizophrenia diagnoses were low, reducing power to conduct these analyses. Further, our outcome rates are dependent on hospital staff appropriately coding psychosis and schizophrenia diagnoses, and there may be variation across hospitals over time and across staff within hospitals in the extent these codes are used. Relatedly, we did not analyze cannabis-involved ED visits because cannabis-related diagnoses may not be suffciently or consistently coded on hospital visits, and coding may itself have been influenced by legalization. For example, hospital diagnoses may suffer from reporting biases over time, as clinicians are influenced by public health messaging and education on the impacts of cannabis legalization. This would lead to more clinicians inquiring about cannabis use when treating persons with psychosis after cannabis legalization.

A final, related source of measurement error in our outcome is that Colorado is a physically large and rural state, where not everyone experiencing a psychosis or schizophrenia event serious enough to warrant an ED visit can travel to an ED. As such, our outcome is likely an underestimate the number of acute events. Due to the risk of differential reporting of cannabis-involvement pre and post policy, we included all visits for schizophrenia and psychosis, not just those co-coded with cannabis use. Border counties could also impact findings. Border counties can have cross-border purchasing, but we only included Colorado residents in our hospital claims analysis. We did conduct a sensitivity analysis removing

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border counties and results were similar for schizophrenia. As far as psychosis, there are some observed changes in the relative importance of previously exposed counties, but the relationship remains. (Appendix Table 2). Finally, during the ICD-9 to ICD-10 update, specifications for drug specific psychotic disorders also changed. ICD-9 only has a general drug induced psychosis, while ICD-10 has specific drug related psychosis. Because we could not crosswalk these diagnosis accurately, drug-specific diagnosis were omitted. Thus, we did not account for other potential drug-specific-induced psychosis, such as stimulants and hallucinogens.

Conclusion

Markets evolve slowly when cannabis is legalized, but it is more than just the opening of dispensaries that gets expanded in some jurisdictions. In jurisdictions with for-profit entities licensed to sell, legalization comes with a robust industry promoting high potency cannabis products, which have been associated with psychosis symptoms. In Colorado, there was a positive association between the number of dispensaries (medical and recreational) and rates of psychosis ED visits across all counties. More work is needed to understand if the correlation identified here is driven by the availability of high potency products, or the expansion in access that comes with more dispensaries operating. In either case, our findings suggest that as more states legalize cannabis, there is the potential impact on the mental health of the population; this is something that legalizing states should prepare to address.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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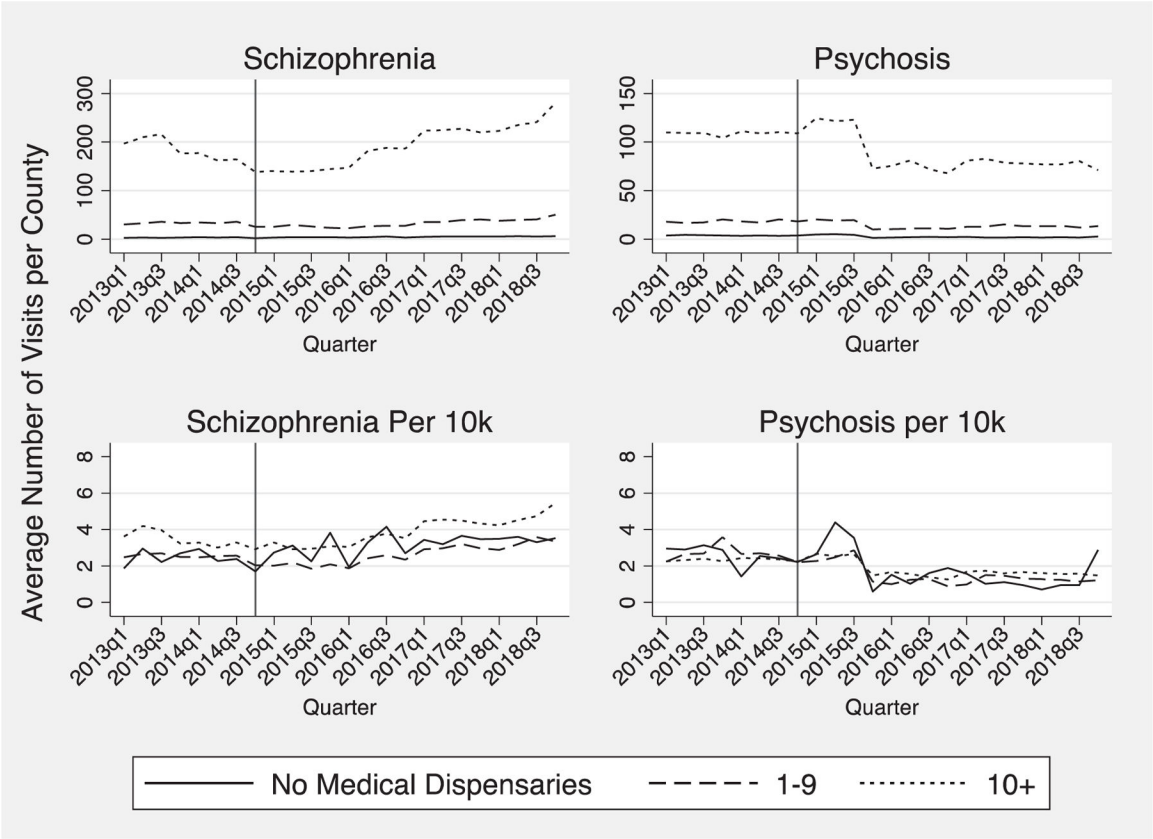

Fig. 1.

Trends in Number of Emergency Department (ED) Visits for Psychosis and Schizophrenia by County, by Baseline Medical Cannabis Dispensaries Exposure, 2013–2018 Notes: The vertical line represents the start of independent recreational cannabis sales in the third quarter of 2014. Counties are categorized according to the number of medical dispensaries in Quarter 3, 2012: Low dispensaries counties are those with 1–9 medical dispensaries; high dispensaries counties are those with 10 or more medical dispensaries.

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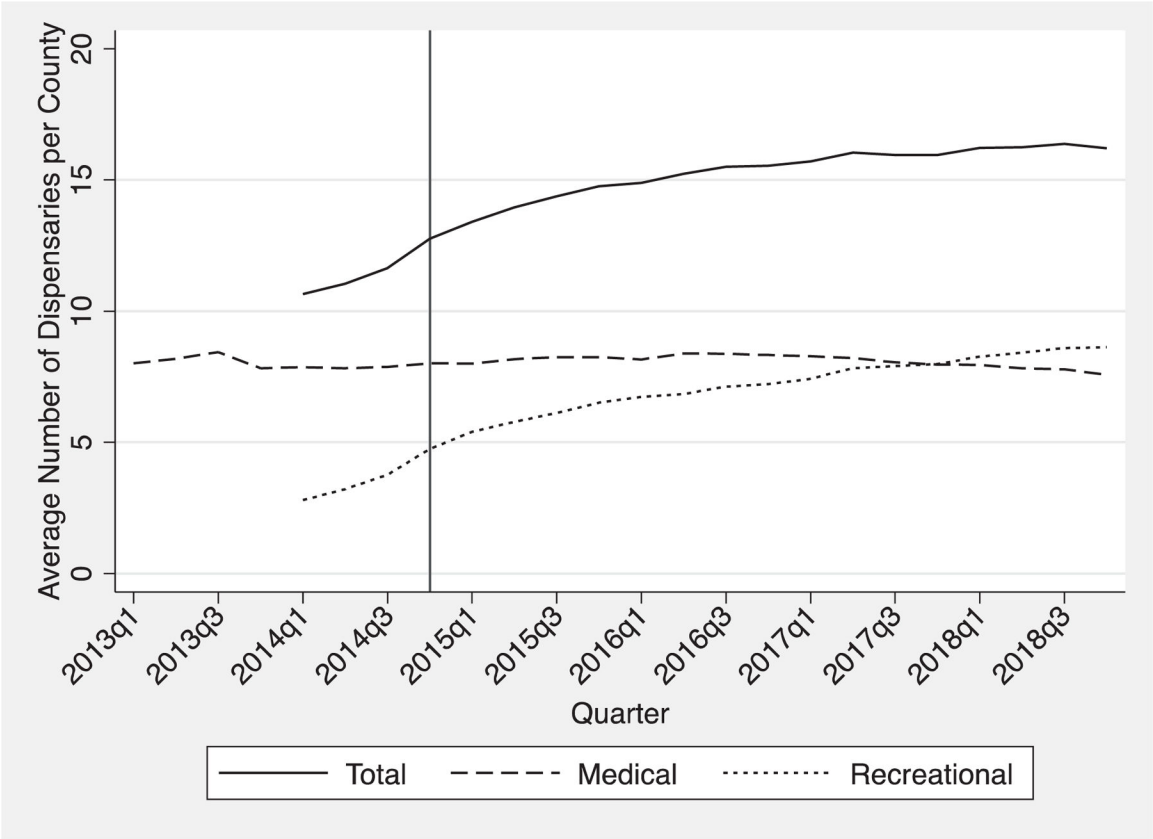

Fig. 2.

Trend in Median Number of Medical and Total (Medical and Recreational) Dispensaries by County in Colorado, 2013–2018 Notes: Sale of recreational marijuana from existing medical dispensaries began in the first quarter of 2014. The vertical line represents the start of independent recreational cannabis sales in the third quarter of 2014.

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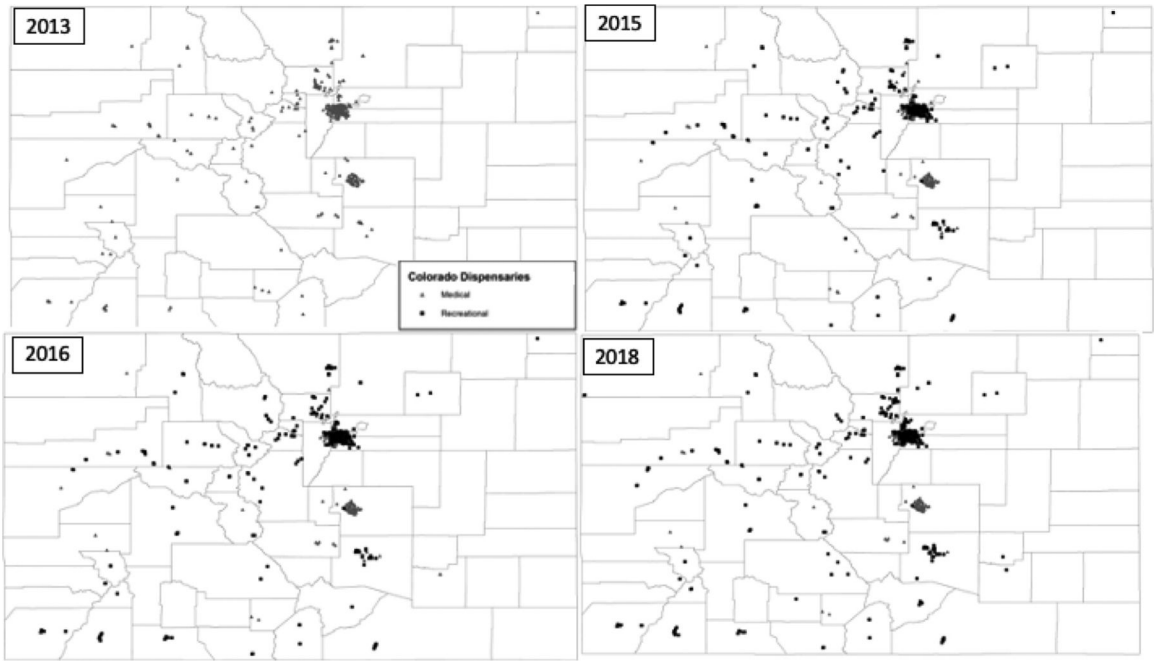

Fig. 3.
Medical and Recreational Cannabis Dispensary Exposure by County, 2013–2018

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Table 1

Emergency Department (ED) visits for psychosis and schizophrenia reported to the Colorado hospital association, 2013–2018.

	Psychosis ED Visits	Schizophrenia ED Visits
Total ED Visits (N)	25,306	51,547
Age 0–18	8·0%	2·5%
Age 19–25	15·1%	12·8%
Age 26+	76·9%	84·8%
% Male	54·8%	64·2%
% Commercial	19·.6%	8·5%
% Government	67·2%	84·1%
% Other Insurance	1·6%	1·4%

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Table 2

Fixed effects panel Poisson Regression Results of Exposure to Recreational (Rec) outlets on psychosis and schizophrenia Emergency Department (ED) visits per capita.

Dependent Variable	Schizophrenia		Psychosis	
	IRR	95% CI	IRR	95% CI
Num. of Rec Outlets per 10K	0·95	[0·69,1·30]	1·23	[1·02,1·49]
Rec Outlets per 10K in Low Medical Cannabis County [a]	1·05	[0·76,1·44]	0·83	[0·69,0·99]
Rec Outlets per 10K in Non-Medical Cannabis County	1·08	[0·79,1·49]	0·89	[0·74,1·08]
Seasonal Quarter (Q1-Jan-Mar Reference Group)				
Second Q (Apr-June)	1·10	[0·97,1·25]	1·14	[1·00,1·29]
Third Q (July-Sept)	1·10	[1·00,1·21]	1·13	[1·02,1·26]
Fourth Q (Oct-Dec)	1·02	[0·95,1·10]	1·23	[1·06,1·42]
Year (2013 Reference Group)				
2014	1·03	[0·75,1·41]	1·24	[0·84,1·83]
2015	1·08	[0·66,1·75]	2·15	[1·20,3·86]
2016	0·98	[0·51,1·88]	4·08	[1·89,8·81]
2017	1.21	[0·58,2·55]	4·36	[1·93,9·85]
2018	1·23	[0·63,2·42]	4·08	[1·88,8·84]
Post ICD9	1·30	[0·75,2·24]	0·26	[0·19,0·36]
Unemployment Rate	1·05	[0·92,1·20]	1·25	[1·07,1·46]
Total Hospital Admissions	1·00	[1·00,1·00]	1·00	[1·00,1·00]
County Fixed Effect	Yes		Yes	
Log Likelihood	−2809·51		−2557·49	
N	1536		1512	
Combined IRR for main exposure, p-value				
No baseline medical cannabis exposure	1·025	0·048	1·100	0·000
Low baseline medical cannabis exposure	0·991	0·799	1·015	0·737
High baseline medical cannabis exposure	0·946	0·732	1·230	0·032

[a]Recreational outlets in a county with high med outlets at baseline is the reference group. Counties are categorized according to the number of medical outlets in Quarter 3, 2012 (0, 1–9, 10+). Rec: Recreational; Med: Medical; CI: Confidence Interval. All models estimated using xtpoisson in STATA 16.1 with robust standard errors. The combined IRRs for each level of exposure add together the estimates for the independent effect of recreational outlets plus the interaction term.

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Table 3

Sensitivity checks: robustness of our findings to alternative measures of exposure.

Dependent Variable	Schizophrenia		Psychosis	
	IRR	95% CI	IRR	95% CI
Sensitivity Analysis #1				
Count of Recreational Outlets	1·00	[0·99,1·00]	1·00+	[1·00,1·01]
Recreational Outlet Count in Low Medical Cannabis County	0·98	[0·97,1·00]	1·02	[1·00,1·04]
Recreational Outlet Count in Non-Medical Cannabis County	1·01	[1.00,1.03]	1·06	[1·03,1·08]
Log Likelihood	−2794.15		−2559.17	
N	1536		1512	

Notes: Sensitivity analysis uses the raw count of recreational outlets instead of the per capita exposure. Recreational outlets in a county with high med outlets at baseline is the reference group. Counties are categorized according to the number of medical outlets in Quarter 3, 2012 (0, 1–9, 10+). CI: Confidence Interval. All models estimated using xtpoisson in STATA 16.1 with robust standard errors.