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ARTICLE

The association between the legalization of recreational marijuana and both small for gestational age births and NICU admissions in Colorado

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Abstract

Objective To determine the association between recreational marijuana legalization and both small for gestational age (SGA) births and neonatal ICU (NICU) admissions in Colorado.

Study Design Using interrupted time series analysis, we compared the incidence of SGA births and NICU admissions pre-/post-recreational marijuana legalization. Secondary analysis adjusted for marijuana outlet density (MOD) in maternal county of residence.

Results We analyzed 269,922 mother–infant dyads. SGA birth risk dropped 7% immediately post-legalization ($p = 0.04$), but there was no slope difference between cohorts. SGA birth risk for high MOD dyads was 1.4x that of dyads with no outlets ($p < 0.001$) and 1.2x that of low MOD dyads ($p = 0.002$). There was no immediate effect on NICU admission risk, but the slope increased 1%/month post-legalization ($p < 0.001$) including a 1%/month increase for low MOD and 3%/month for high MOD dyads.

Conclusions Incidence of SGA births in Colorado did not change following recreational marijuana legalization. NICU admissions increased post-legalization.

Introduction

In the decade prior to the legalization of recreational marijuana in parts of the United States, the use of marijuana by pregnant women increased by more than 60% [1]. The use of blunts—cigar wrappers containing marijuana—also increased among pregnant women despite a decrease in their use of tobacco-containing products over the same time period [2]. In California, a study utilizing both patient self-report and biochemical testing revealed an annual increase in prevalence of marijuana use among pregnant women of 1.1% [3].

As the use of marijuana by pregnant women has increased, the public perception of marijuana has become more favorable. The American College of Obstetricians and Gynecologists (ACOG) writes: "…women who are pregnant or contemplating pregnancy should be encouraged to discontinue marijuana use. Obstetrician-gynecologists should be discouraged from prescribing or suggesting the use of marijuana for medicinal purposes during preconception, pregnancy, and lactation. Pregnant women or women contemplating pregnancy should be encouraged to discontinue use of marijuana for medicinal purposes in favor of an alternative therapy for which there are better pregnancy-specific safety data" [4]. However, only 1 in 5 public health agencies had this information about prenatal marijuana use published on their websites as of 2016 [5], and nearly 70% of Colorado marijuana dispensaries recommended the use of marijuana for the treatment of morning sickness to pregnant clients [6]. The perception among pregnant women that marijuana use poses no risk to their health increased by more than 2-fold since the early

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2000s [7], and ~1 out of every 3 preconception marijuana users will continue using marijuana during pregnancy [8].

As marijuana use during pregnancy increases and becomes more accepted by the public, the scientific community has responded by studying the effects of marijuana use on the mother and fetus. Over the past 20 years, three meta-analyses have been performed on the association between prenatal marijuana exposure and birth outcomes with inconsistent results [9–11]. The largest and most recent meta-analysis did not find an association between maternal marijuana use and either NICU admission or birth weight [9]. However, many additional observational studies have been published since this meta-analysis.

In response to the legalization of recreational marijuana in Colorado, Crume et al. focused on the association of maternal self-report of marijuana use with birth outcomes among a cohort of the state's population [12]. They found the self-reported prevalence of marijuana use among pregnant women in Colorado rose to approximately 6% following legalization [12]. Additionally, their findings supported the association between marijuana exposure and low birth weight [12]. Our study will build on these findings by focusing on the entire Colorado population to surveil the public health effects of legalization in light of this emerging evidence.

The objective of this study is to assess population-level changes in birth outcomes—specifically small for gestational age (SGA) births and neonatal intensive care unit (NICU) admissions—associated with the legalization of recreational marijuana in Colorado. We hypothesized that infants born after legalization would have increased risk of both SGA birth and NICU admission, and that this risk would be higher among mother–infant dyads who reside in a county with higher densities of retail marijuana stores. To date, no studies have evaluated the population-level association between the legalization of recreational marijuana and birth outcomes in Colorado despite plausible public health significance.

Methods

Study design & data source

For our primary analysis, we used a quasi-experimental, retrospective cohort study design to evaluate birth outcomes over time pre/post-legalization of recreational marijuana in Colorado. Our secondary analysis adjusted the primary analysis for an additional variable: marijuana outlet density (MOD) in the maternal county of residence.

Data for our primary analysis were obtained from the Colorado Birth Dataset managed by the Colorado Department of Public Health and Environment (CDPHE) Vital Statistics Program which is comprised of information collected from the Certificate of Live Birth for all births in Colorado. Data for the secondary analysis were obtained by combining population projections from the Colorado State Demography Office [13] with marijuana retail license counts from the Colorado Department of Public Safety [14] for the year 2015.

The study was approved for conduct by the Colorado Multiple Institutional Review Board at University of Colorado (COMIRB protocol 17–2143) and granted permission for data use by CDPHE.

Study population

Colorado voters legalized recreational marijuana in 2012 via Amendment 64. The first marijuana retail dispensaries opened in Colorado on 01 January 2014. Thus, our study period included singleton births from 01 January 2012 through 31 December 2016 (2 years before and after legalization).

Data were extracted for all births occurring within the study period. Only births to mothers with residence in the state of Colorado were included in our study cohort. Additional exclusion criteria included multiple births as well as data entry errors such as missing data for birth weight or gestational age, duplicate birth IDs, or gestational age <22 or >44 weeks.

A washout period was defined as the first nine months following legalization where pregnancies spanned both time epochs. Births occurring during this washout period were excluded from analysis. Thus, the pre-legalization cohort spanned from 01 January 2012 through 31 December 2013, and the post-legalization cohort spanned from 01 October 2014 through 31 December 2016.

Measures of interest

Our two primary outcome measures were NICU admission and SGA birth. NICU admission during the birth admission was designated directly in the Colorado Birth Dataset. SGA was defined as birth weight less than 10^{th} percentile for completed gestational age in weeks and was calculated using the Fenton 2013 infant growth calculator [15]. Birth weight, gender, and gestational age were needed for this SGA calculation and were designated directly in the Colorado Birth Dataset.

The secondary analysis included an additional exposure that represented marijuana outlet density (MOD) in the maternal county of residence. Alcohol outlet density and proximity to alcohol outlets have been shown to be risk factors for excessive alcohol consumption [16]. Applying that logistical framework to marijuana use, MOD in maternal county of residence was treated as a surrogate for marijuana

exposure given the potential increased risk of consumption associated with closer proximity to marijuana outlets. Marijuana outlets were defined as marijuana dispensaries with retail marijuana licenses. MOD was determined by dividing the number of retail marijuana licenses in each county by the county's projected population for the year 2015. The MOD was then categorized as no outlets (0 outlets per 100,000 population), low density (<17 outlets per 100,000 population), or high density (≥17 outlets per 100,000 population) based on the natural distribution of the data and the median cutoff for counties with any marijuana outlets.

Analysis

A bivariable analysis was performed to compare individual birth characteristics between the pre- and post-legalization cohorts using chi square tests for categorical variables and t-tests or Wilcoxon tests for continuous variables.

An interrupted time series (ITS) or segmented regression analysis was used to measure the impact of recreational marijuana legalization on birth outcomes [17, 18]. Separate logistic regression using generalized estimating equation methods on individual-level data was used to evaluate the relationship between recreational marijuana legalization and the primary outcomes of SGA births and NICU admissions.

Legalization period, time in months, and the interaction term of legalization*time were the primary explanatory variables. This allowed us to determine the presence of an *immediate effect* by evaluating for an intercept change pre-/post-legalization. It also allowed us to determine if the change in incidence over time was significantly different pre-/post-legalization by comparing the *slope* across the two cohorts. Predictions for each individual birth were summarized by month and graphed with the observed monthly values to illustrate the linear trends over time.

Multivariable ITS models were created to adjust for important covariates, identified *a priori* as maternal factors of age, race, ethnicity, education, hypertension, early prenatal visits, tobacco use during pregnancy, alcohol use during pregnancy, and elevation of zip code of residence. Elevation was included because birth at high altitude has been associated with adverse birth outcomes including low birth weight [19, 20]. Subjects with gestational age at birth of ≤35 weeks were excluded from the analysis of NICU admission under the assumption that there would be no difference between cohorts because NICU admission is common in that population due to prematurity.

Secondary analysis was performed by including the MOD variable in the ITS models. Legalization period, time in months, county MOD, and all interaction terms between them were the primary explanatory variables. Predictions for each individual birth were summarized by month and graphed with the observed monthly values to illustrate the linear trends over time. Multivariable models were adjusted for the same covariates as the primary analysis.

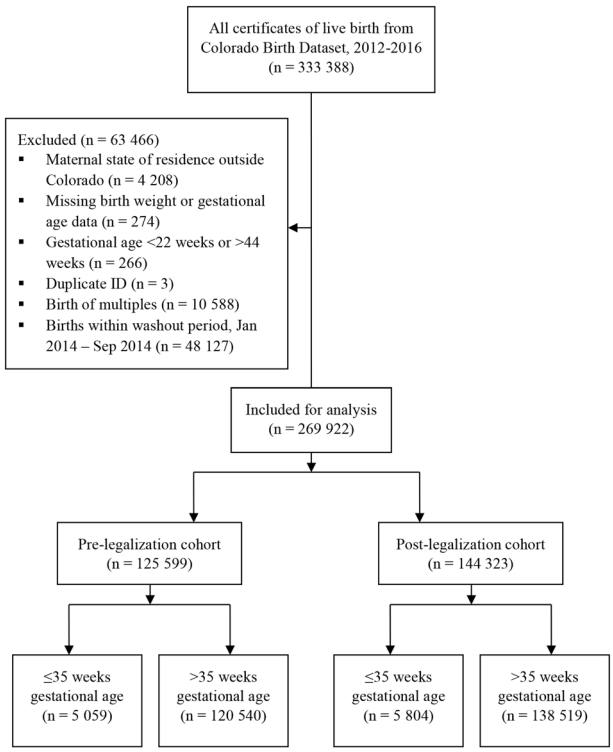

Fig. 1 Consort Diagram showing flow of study population with exclusions. Final study population is further divided by gestational age at birth (as shown) because subjects with gestational age at birth ≤ 35 weeks were excluded from analysis of NICU admission outcome

Data were analyzed using SAS version 9.4 software (Cary, NC). All statistical tests were performed with a level of significance of alpha = 0.05.

Results

The final study population included 125,599 subjects in the pre-legalization cohort and 144,323 in the post-legalization cohort (Fig. 1).

Bivariable analysis

Table 1 demonstrates individual maternal-infant characteristics and bivariable comparisons for all outcomes, explanatory variables, and covariates. Due to the large sample size, the majority of comparisons showed statistical significance using a traditional alpha of 0.05. Compared to mothers in the pre-legalization cohort, mothers post-legalization were on average 0.5 years older (28.6 ± 5.9 v. 29.1 ± 5.8, $p < 0.01$). More mothers used tobacco pre-legalization than post-legalization (7% v. 6%, $p < 0.01$). Proportions of early prenatal care, maternal alcohol use,

Table 1 Characteristics and outcomes of study population, including bivariable comparisons of characteristics between subjects in the pre- and post-legalization cohorts

Variable	Full population Median (IQR) or *n* (%)	Pre legalization Median (IQR) or *n* (%)	Post legalization Median (IQR) or *n* (%)	*p*
	269,922 (100)	125,599 (100)	144,323 (100)	N/A
Maternal race				<0.01
White	221,028 (82)	105,031 (84)	115,997 (80)	
Black	12,834 (5)	5,884 (5)	6,950 (5)	
Other	30,894 (11)	12,765 (10)	18,129 (13)	
Missing	5,166 (2)	1,919 (2)	3,247 (2)	
Maternal ethnicity				0.70
Non-Hispanic	191,423 (71)	88,924 (71)	102,499 (71)	
Hispanic or Latino	75,706 (28)	35,231 (28)	40,475 (28)	
Missing	2,793 (1)	1,444 (1)	1,349 (1)	
Maternal education				<0.01
High school or less	35,044 (13)	17,662 (14)	17,382 (12)	
High school graduate	112,480 (42)	52,548 (42)	59,932 (42)	
College degree	85,507 (32)	38,876 (31)	46,631 (32)	
Graduate degree	34,131 (13)	15,217 (12)	18,914 (13)	
Missing	2,760 (1)	1,296 (1)	1,464 (1)	
Maternal marital status				<0.01
Married	206,621 (77)	95,781 (76)	110,840 (77)	
Not married	62,951 (23)	29,673 (24)	33,278 (23)	
Missing	350 (<1)	145 (<1)	205 (<1)	
Maternal age (years)	28.8 (± 5.8)	28.6 (± 5.9)	29.1 (± 5.8)	<0.01
Smoked cigarettes daily at some point during pregnancy				<0.01
Yes	18,145 (7)	9,133 (7)	9,012 (6)	
No	250,782 (93)	115,797 (92)	134,985 (94)	
Missing	995 (<1)	669 (<1)	326 (<1)	
Drank alcohol weekly at some point during pregnancy				<0.01
Yes	2,802 (1)	1,027 (1)	1,775 (1)	
No	265,454 (98)	123,718 (99)	141,736 (98)	
Missing	1,666 (1)	854 (< 1)	812 (1)	
Income				<0.01
<$15,000	57,230 (21)	28,308 (23)	28,922 (20)	
$15,000–$34,999	53,348 (20)	25,071 (20)	28,277 (20)	
$35,000–$74,999	59,276 (22)	27,921 (22)	31,355 (22)	
$75,000+	74,221 (28)	32,231 (26)	41,990 (29)	
Missing	25,847 (10)	12,068 (10)	13,779 (10)	
C-section				<0.01
Yes	66,415 (25)	30,730 (25)	35,685 (25)	
No	203,507 (75)	94,869 (75)	108,638 (75)	
Gestational age (weeks)	38.8 (± 1.8)	38.8 (± 1.8)	38.8 (± 1.8)	0.97
Early prenatal care				0.03
Yes	212,609 (79)	99,055 (79)	113,554 (79)	
No	47,887 (18)	22,576 (18)	25,311 (18)	
Missing	9,426 (4)	3,968 (3)	5,458 (4)	

Table 1 (continued)

Variable	Full population Median (IQR) or *n* (%)	Pre legalization Median (IQR) or *n* (%)	Post legalization Median (IQR) or *n* (%)	*p*
Infant gender				0.39
Male	138,146 (51)	64,392 (51)	73,754 (51)	
Female	131,773 (49)	61,205 (49)	70,568 (49)	
Missing	3 (<1)	2 (<1)	1 (<1)	
Maternal hypertension				<0.01
Yes	17,203 (6)	17,203 (6)	10,088 (7)	
No	252,719 (94)	118,484 (94)	134,235 (93)	
Elevation				<0.01
High (≥7,000 ft)	12,890 (5)	5,780 (5)	7,110 (5)	
Low (<7,000 ft)	249,905 (93)	116,560 (93)	133,345 (92)	
Missing	7,127 (3)	3,259 (3)	3,868 (3)	
Small for gestational age (SGA)				0.14
Yes	33,399 (12)	15,416 (12)	17,983 (12)	
No	236,523 (88)	110,183 (88)	126,340 (88)	
NICU admission				<0.01
Yes	21,978 (8)	9,698 (8)	12,280 (9)	
No	247,944 (92)	115,901 (92)	132,043 (92)	
Preterm birth (*<37 weeks*)				0.76
Yes	18,928 (7)	8,787 (7)	10,141 (7)	
No	250,994 (93)	116,812 (93)	134,182 (93)	
Low birth weight (<2,500 g)				0.02
Yes	19,074 (7)	8,722 (7)	10,352 (7)	
No	250,848 (93)	116,877 (93)	133,971 (93)	
Infant death				< 0.01
Yes	846 (< 1)	439 (< 1)	407 (< 1)	
No	269,076 (100)	125,160 (100)	143,916 (100)	

Missing values were not included in the statistical comparisons (*p* values) between pre/post cohorts

IQR interquartile range, *SGA* small for gestational age, *NICU* neonatal intensive care unit

elevation of maternal residence, and infant gender were similar between groups.

Primary ITS analysis: effect of legalization

Unadjusted or simple ITS analysis is shown graphically in Fig. 2 and illustrates population trends over time.

Multivariable analysis revealed no significant difference in slope of SGA births across the pre- and post-legalization cohorts, however there was a difference in the intercepts pre-/post-legalization indicating an immediate effect. The risk of SGA birth at the start of the post-legalization cohort was 7% less than that at the end of the pre-legalization cohort ($p = 0.04$) (Table 2).

Multivariable analysis of NICU admissions revealed a significant difference in slope between the pre- and post-legalization cohorts (Table 2). The risk of NICU admissions per month increased by 1% per month post-legalization ($p < 0.001$). There was no significant immediate effect at the time of legalization.

Secondary ITS Analysis: effect of marijuana outlet density

The distribution of MODs by Colorado counties in 2015 is shown in Fig. 3. MODs ranged from zero to 430 marijuana outlets per 100,000 population. Of the 64 counties in Colorado, 45% ($n = 29$) had no marijuana outlets, 28% ($n = 18$) were classified as low MOD, and 27% ($n = 17$) were classified as high MOD.

Secondary analysis with inclusion of the MOD variable revealed infants born to mothers residing in counties with high and low marijuana outlet densities had higher odds of SGA birth than those born to mothers residing in counties with no marijuana outlets (Table 2). After controlling for other variables in the model, mother–infant dyads from high

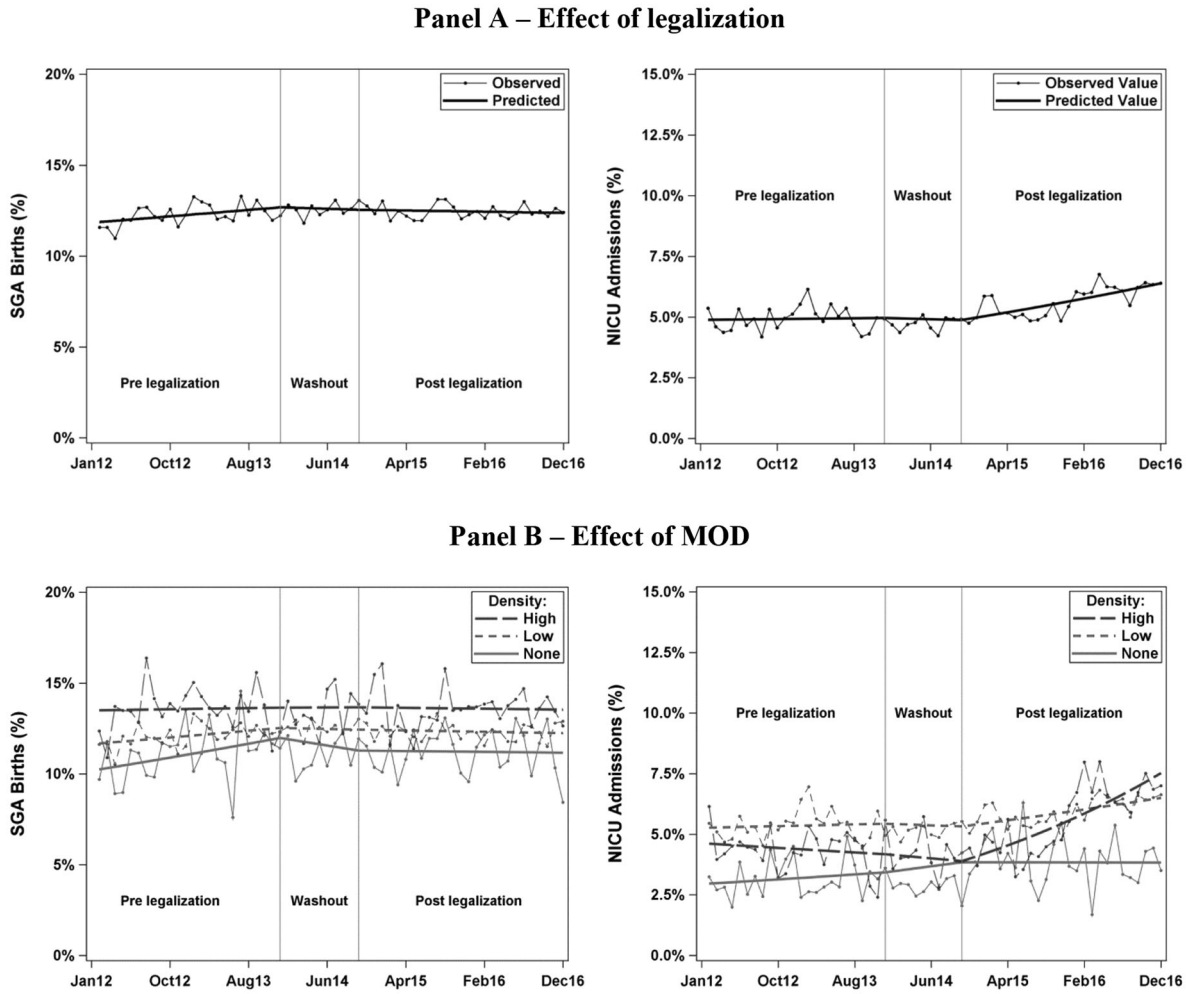

Fig. 2 Unadjusted ITS analyses showing the effect of marijuana legalization and MOD on the incidence of SGA births and NICU admissions over the study period. The secondary analysis includes stratification by marijuana outlet density (MOD). Quantification of immediate effect and slope in pre- and post-legalization cohorts with measures of significance is shown in Table 2. *ITS* interrupted time series, *SGA* small for gestational age, *NICU* neonatal intensive care unit, *MOD* marijuana outlet density

MOD counties had 1.4 (95% CI 1.2–1.6) times higher risk of SGA birth than those from counties with no marijuana outlets ($p < 0.001$) and a 1.2 (95% CI 1.1–1.3) times higher risk than low MOD counties ($p = 0.002$). Mother–infant dyads from low MOD counties had 1.2 (95% CI 1.1–1.4) times higher risk of SGA birth than counties with no marijuana outlets ($p = 0.003$).

Secondary analysis with inclusion of the MOD variable revealed a significant increase in the monthly rate of change in odds of NICU admission after legalization for mother–infant dyads from high and low MOD counties (Table 2). While the rate of change was insignificant pre-legalization, it increased significantly after legalization in both low and high MOD counties. The risk of NICU admission increased 1% (95% CI 0%−1%) per month for mother–infant dyads in low MOD counties and 3% (95% CI 2%−3%) per month for those in high MOD counties. In counties without marijuana outlets, the rate of change was non-significant both pre- and post-legalization.

Discussion

Our analysis showed no evidence of an increase in SGA births over time following the legalization of recreational marijuana in Colorado. The risk of NICU admission, however, increased 1% per month post-legalization. Additionally, our secondary analysis revealed that newborns born to mothers living in counties with high marijuana outlet densities had a higher overall risk of SGA birth and NICU admission than those born to mothers living in counties with no marijuana outlets. After legalization, the risk of NICU admission was increasing at a faster rate in counties with high (3% per month) and low (1% per month)

Table 2 Logistic regression estimates of time and group effects

Effect of legalization				
	Unadjusted ITS Model		Adjusted ITS Model[a]	
	Effect estimate (95% CI)	*p* value	Effect estimate (95% CI)	*p* value
Outcome = SGA				
Slope pre legalization	1.00 (1.00, 1.01)	0.009	1.00 (1.00, 1.01)	<0.001
Slope post legalization	1.00 (1.00, 1.00)	0.56	1.00 (0.998, 1.00)	0.80
Immediate change	0.96 (0.90, 1.02)	0.16	0.93 (0.87, 0.998)	0.04
Outcome = NICU Admission				
Slope pre legalization	1.00 (0.997, 1.00)	0.71	1.00 (0.996, 1.00)	0.84
Slope post legalization	1.01 (1.01, 1.01)	<0.001	1.01 (1.01, 1.01)	<0.001
Immediate change	0.98 (0.89, 1.07)	0.61	0.99 (0.90, 1.10)	0.87

Effect of MOD			
Marijuana outlet density (MOD)	Variable	Adjusted ITS Model[a]	
		Effect estimate (95% CI)	*p* value
Outcome = SGA			
No marijuana outlets	Slope pre legalization	1.01 (1.00, 1.02)	0.01
	Slope post legalization	1.00 (0.99, 1.01)	0.96
	Immediate change	0.82 (0.66, 1.01)	0.07
Low MOD	Slope pre legalization	1.00 (1.00, 1.01)	0.004
	Slope post legalization	1.00 (1.00, 1.00)	0.76
	Immediate change	0.94 (0.86, 1.01)	0.10
High MOD	Slope pre legalization	1.00 (1.00, 1.01)	0.73
	Slope post legalization	1.00 (1.00, 1.00)	0.94
	Immediate change	0.99 (0.85, 1.14)	0.85
High MOD vs low MOD	Difference in baseline risk	1.16 (1.06, 1.27)	0.002
High MOD vs no marijuana outlets	Difference in baseline risk	1.41 (1.22, 1.64)	<0.001
Low MOD vs no marijuana outlets	Difference in baseline risk	1.22 (1.07, 1.40)	0.003
Outcome = NICU admission			
No marijuana outlets	Slope pre legalization	1.00 (0.99, 1.02)	0.58
	Slope post legalization	1.00 (0.98, 1.01)	0.44
	Immediate change	1.18 (0.80, 1.72)	0.39
Low MOD	Slope pre legalization	1.00 (1.00, 1.01)	0.38
	Slope post legalization	1.01 (1.00, 1.01)	<0.001
	Immediate change	0.95 (0.85, 1.07)	0.46
High MOD	Slope pre legalization	0.99 (0.98, 1.00)	0.11
	Slope post legalization	1.03 (1.02, 1.03)	<0.001
	Immediate change	1.06 (0.83, 1.36)	0.64
High MOD vs low MOD	Difference in baseline risk	0.91 (0.79, 1.05)	0.20
High MOD vs no marijuana outlets	Difference in baseline risk	1.59 (1.22, 2.06)	<0.001
Low MOD vs no marijuana outlets	Difference in baseline risk	1.76 (1.39, 2.21)	<0.001

Multivariable ITS analysis for both SGA birth and NICU admission showing the immediate effect and change in slope over time following the legalization of recreational marijuana in Colorado. This primary analysis was then adjusted for the marijuana outlet density (MOD) in the maternal county of residence. MOD is categorized as no outlets (0 per 100,000 population), low (<17 per 100,000 population), and high (≥17 per 100,000 population)

[a]Adjusted for maternal age, race, ethnicity, education, hypertension, elevation of residence, tobacco and alcohol use during pregnancy, and early prenatal visits

ITS interrupted time series, *MOD* Marijuana outlet density, *SGA* small for gestational age, *NICU* neonatal intensive care unit, *CI* confidence interval

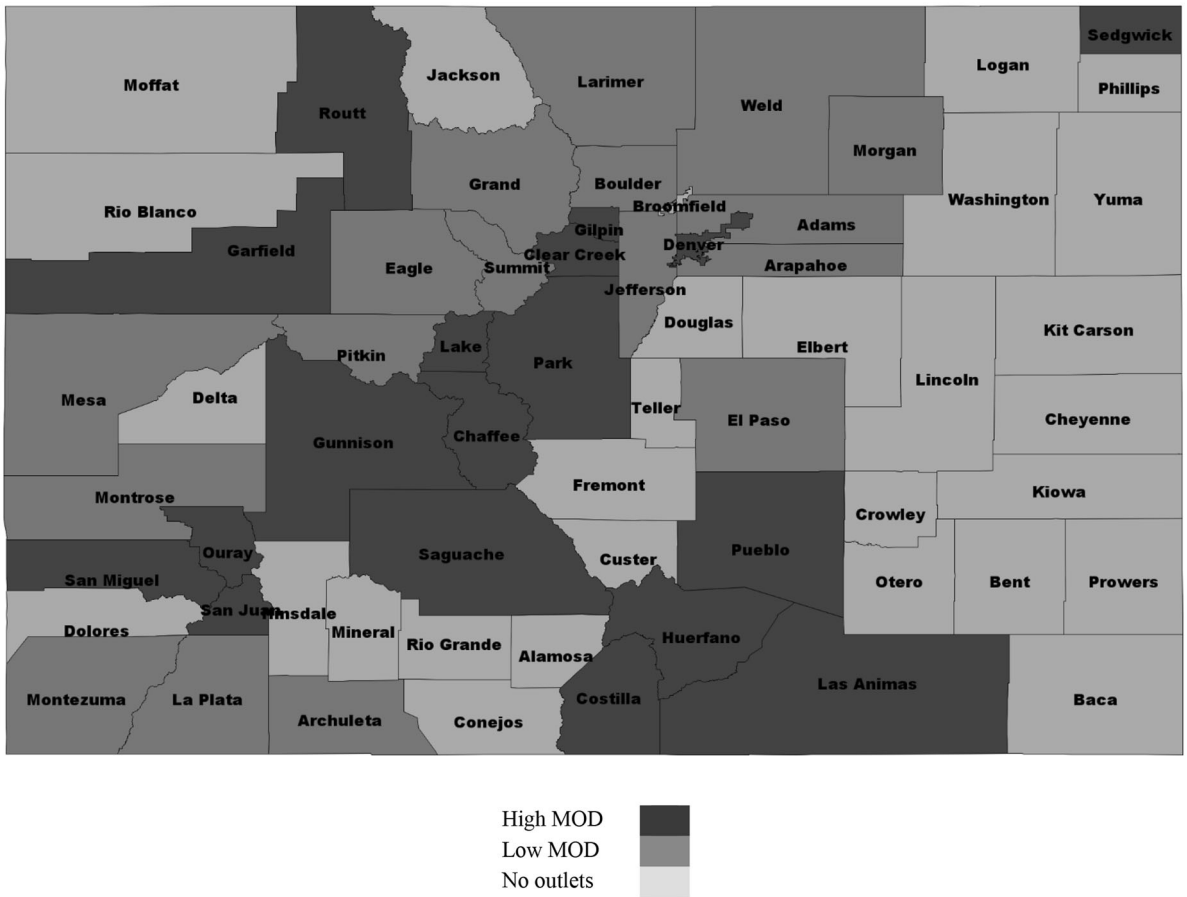

Fig. 3 Colorado map showing marijuana outlet density (MOD) by county using data from 2015. MOD is categorized as no outlets (0 per 100,000 population), low (<17 per 100,000 population), and high (≥17 per 100,000 population). *MOD* marijuana outlet density

marijuana outlet densities than in counties with no marijuana outlets (no increase).

This is an ecological study and is primarily hypothesis generating. We do not claim to identify causation, but rather provide population-level information on trends in Colorado birth outcomes that coincide with the legalization of recreational marijuana in Colorado. Existing literature has attempted to more directly explore the association between marijuana exposure and birth outcomes with inconsistent results. Three meta-analyses have been published on the association between maternal marijuana exposure and birth outcomes. The first, performed in 1997 by English et al., concluded current evidence was inadequate to support an association between marijuana exposure and birth weight given the small number of included studies and inconsistent results [11]. As academic output on the topic has accelerated in recent years with the legalization of medical and recreational marijuana in many states, two recent meta-analyses have shown more convincing—yet still inconsistent—results. Gunn et al. included 24 studies and supported a significant association with both low birth weight and NICU admission [10]. However, the subsequent meta-analysis by Connor et al. included 31 studies and found no association with NICU admission, and positive associations with low birth weight and preterm delivery were nullified after adjusting for tobacco use and other confounders [9]. Observational studies published since these most recent meta-analyses have revealed similarly inconsistent results [12, 21–26], however an experimental animal study demonstrated reduced birth weight in marijuana exposed mice [27]. The inability to directly quantify marijuana exposure and the variability of use throughout pregnancy are major contributors to the heterogenous study designs and inconsistency of results.

The Colorado study by Crume et al. showed a positive association between self-reported maternal marijuana exposure and low birth weight. Our study did not include individual maternal exposure data and, as such, we cannot gauge whether the use of marijuana by pregnant women increased post-legalization or whether this use was directly associated with birth outcomes. Though our study did not show a change in SGA births over time across the Colorado population post-legalization, further surveillance is indicated.

When critically appraising this study, it is important to recognize that the nature of our data and analysis leaves the possibility for unmeasured confounders. SGA birth may be affected by confounders not captured by our data source. For example, maternal opioid use during pregnancy has been associated with poor fetal growth [28–30], and there was a demonstrated increase in the rate of maternal opioid use in the United States preceding our study period [31, 32]. Additionally, maternal opioid use during pregnancy has been shown to disproportionately affect rural communities [33, 34], which may confound our secondary geographical analysis of marijuana outlet density in maternal county of residence. The interaction of opioid use and marijuana law is especially relevant to this discussion, as the legalization of recreational marijuana in Colorado has been associated with a decrease in opioid overdoses across the state [35].

The possibility of unmeasured confounders is especially important when considering the rise in NICU admissions shown post-legalization in our study. There are many possible explanations for this observed increase, and further study is needed to explore trends in incidence of other possible confounding conditions with large public health significance. For example, in the time period after legalization of recreational marijuana in Colorado, the rate of late preterm births (34–36 weeks gestational age) across the United States rose from 6.8% in 2014 to 7.1% in 2016 [36]. Similarly, the rate of neonatal abstinence syndrome admissions in the United States increased from 7 cases to 27 cases per 1,000 admissions in the decade preceding legalization [32]. Other possible causes include but are not limited to changes in provider behavior and—as explored in this study—increases in maternal marijuana exposure. Improved understanding of this upward trend has large public health significance, as our observed 1% per month increase in NICU admissions among late preterm and term infants post-legalization has significant implications for patient outcomes and resource utilization.

Our study has additional limitations. First, our data represents only Colorado, and care must be taken in applying these findings to other populations as more states legalize recreational marijuana. Second, this was an ecological study that did not include individual-level data. Further study is needed to evaluate biological factors associated with marijuana use in pregnancy and birth outcomes.

Conclusion

Our study shows the legalization of recreational marijuana has not had a significant population-level effect on SGA births in Colorado. We have seen an increase in NICU admissions since legalization, and there may be an association between marijuana outlet density in maternal county of residence and birth outcomes. Further research is warranted considering the potential public health impact of increasing marijuana legalization on maternal and infant health outcomes.

Disclaimer

Contents are the authors' sole responsibility and do not necessarily represent official NIH views.

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Author contributions JL is a Pediatric Hospitalist who assisted with study design and data analysis. He has approved the final manuscript as submitted. AM is a biostatistician who assisted with study design and data analysis. She has approved the final manuscript as submitted. AB assisted with study design and data analysis. She has approved the final manuscript as submitted. IF assisted with study design and data analysis. He has approved the final manuscript as submitted. ES assisted with study design and data analysis. She has approved the final manuscript as submitted. EW is a neonatologist who assisted with study design and data analysis. She has approved the final manuscript as submitted.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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