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The heterogeneous effect of marijuana decriminalization policy on arrest rates in Philadelphia, Pennsylvania, 2009–2018

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ABSTRACT

Background: Marijuana decriminalization holds potential to reduce health inequities. However, limited attention has focused on assessing the impact of decriminalization policies across different populations. This study aims to determine the differential effect of a marijuana decriminalization policy change in Philadelphia, PA on marijuana arrests by demographic characteristics.

Methods: Using a comparative interrupted time series design, we assessed whether the onset of marijuana decriminalization in Philadelphia County was associated with reduction in arrests rates from 2009 to 2018 compared to Dauphin County. Stratified models were used to describe the differential impact of decriminalization across different demographic populations.

Results: Compared to Dauphin, the mean arrest rate for all marijuana-related crimes in Philadelphia declined by 19.9 per 100,000 residents (34.9% reduction), 17.1 per 100,000 residents (43.1% reduction) for possession, and 2.8 per 100,000 resident (15.9% reduction) for sales/manufacturing. Arrest rates also differed by demographic characteristics post-decriminalization. Notably, African Americans had a greater absolute/relative reduction in possession-based arrests than Whites. However, relative reductions for sales/manufacturing-based arrests was nearly 3 times lower for African Americans. Males had greater absolute/relative reduction for possession-based arrests, but lower relative reduction for sales/manufacturing-based arrests compared to females. There were no substantial absolute differences by age; however, youths (vs. adults) experienced higher relative reduction in arrest rates.

Conclusions: Findings suggest an absolute/relative reduction for possession-based arrests post-decriminalization; however, relative disparities in sales/manufacturing-based arrests, specifically for African Americans, increased. More consideration towards the heterogeneous effect of marijuana decriminalization are needed given the unintended harmful effects of arrest on already vulnerable populations.

1. Introduction

Marijuana policy has become increasingly dynamic in the United States in recent years as states continue to decriminalize marijuana possession or legalize use for medicinal and recreational purposes. In contrast to legalization, marijuana decriminalization is the reduction of penalties for marijuana manufacturing, distribution, and possession (Caulkins and Kilmer, 2016), such that first-time offenders may receive a small fine without a criminal arrest (Marijuana Policy Project, 2017). This shift towards decriminalization and legalization is a result of many factors. Advocates generally cite potential consequences of possessing a criminal record, such as loss of employment opportunities, health benefits, housing, and financial aid for higher education, as well as the burgeoning cost related to enforcing marijuana possession laws, estimated to be $90 – $105 million (Edward et al., 2013; Iguchi et al., 2002; Kilmer et al., 2019; Kirk and Sampson, 2013).

As of February 2020, 25 states and the District of Columbia have decriminalized marijuana possession such that small, personal-consumption amounts (generally ≤ 30 g) are a civil violation (i.e., a low-level misdemeanor with no possibility of jail time for qualifying offenses) and not a state crime (NORML, 2020a). Of these states, 11 have passed and implemented legislation to legalize marijuana for adult

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recreational use (NORML, 2020b). In contrast, Pennsylvania does not have a statewide decriminalization policy; however, nine cities in Pennsylvania have implemented local ordinances to decriminalize marijuana. Initially introduced in May 2014, Philadelphia was the first of these cities to propose a bill that would decriminalize marijuana possession (for ≤ 30 g), effectively reclassifying the criminal offense to a civil one for first time offenders (The Philadelphia Code, 2016). Additionally, Pennsylvania legalized marijuana for medical use in 2016 and the first medical marijuana dispensaries opened in 2018.

To understand the association of marijuana decriminalization and arrest rates, a growing number of studies have evaluated the effect of this policy change on arrests for possession (Grucza et al., 2018; Maier et al., 2017; Pacula et al., 2005, 2003; Plunk et al., 2019) and how it differs between youths and adults (Grucza et al., 2018; Plunk et al., 2019). However, the impact of decriminalization on arrest rates disparities across race, sex, and age as well as other marijuana offenses such as sales/manufacturing has received limited attention. This knowledge gap is important because of the differential impact that decriminalization policies may have for different groups of individuals. For example, considerable evidence has documented racial biases in the criminal justice system (Edward et al., 2013; Milner et al., 2016; Mitchell and Caudy, 2015; Purtle, 2013; Ulmer et al., 2016). In 2010, African Americans were nearly four times as likely to be arrested for marijuana possession as White individuals, despite similar rates of use (Edward et al., 2013). Research also indicates that African American men are at greater risk for police interaction (Gelman et al., 2007; Milner et al., 2016) as well as incarceration (Blankenship et al., 2018; Massoglia, 2008; Purtle, 2013), a risk factor for poorer health outcomes given that a criminal record constrains access across many social determinants of health (Allison et al., 2017; Blankenship et al., 2018; Freudenberg et al., 2005; Massoglia, 2008; Nowotny and Kuptsevych-Timmer, 2018; Purtle, 2013; Schnittker et al., 2011). It is also unclear whether decriminalization of marijuana possession leads to reprioritization of law enforcement to focus on other marijuana-related offenses such as possession with the intent to deliver, which carries a criminal penalty in Pennsylvania.

Given the heterogeneity of populations that are affected by decriminalization laws and the potential increases in arrests for other marijuana charges, the effect of decriminalization on arrest rates may differ depending on the population and type of offense being studied. Thus, the first objective of our study was to estimate the effect of Philadelphia's marijuana decriminalization policy on rates of arrests due to all marijuana-related arrests, arrests for possession, and arrests for sales and manufacturing. The second objective was to assess whether there was a differential impact of implementing decriminalization across race, age, and sex. By identifying important differences in the effect of marijuana decriminalization across these demographic groups, we can assess whether the policy reduces or exacerbates disparities in marijuana arrest rates. Findings from our study will aid in future marijuana-related policies in similar cities/urban settings.

2. Methods

2.1. Study design

This study used a comparative interrupted time series (CITS) study design to analyze monthly rates of marijuana-related arrests in Philadelphia County (which has the same geographic boundaries as the City of Philadelphia) from 2009 to 2018 pre- and post-marijuana decriminalization compared to Dauphin County; a noncontiguous control county to Philadelphia that includes Harrisburg (a large urban setting), similar sociodemographic profiles, and has yet to implement a county-wide decriminalization policy (Table S1 in Appendix). CITS is an extension of the basic interrupted times series (ITS) design and involves adding a control series to model the counterfactual and calculate the difference-in-difference (DID) estimate (Bernal et al., 2017, 2018). The primary benefit to CITS is that it can control for time-varying confounding due to events co-occurring with the intervention, improving the basic ITS approach which is only robust to time-invariant confounders (Bernal et al., 2017, 2018).

2.2. Data source and covariates

Data were extracted from the Pennsylvania Uniform Crime Reporting (UCR) system, which collects monthly crime data throughout the Commonwealth of Pennsylvania. Details regarding the UCR have been previously reported (Grucza et al., 2018; Plunk et al., 2019). In summary, the UCR is maintained by the Federal Bureau of Investigation, which assembles crime data from more than 18,000 law enforcement agencies in the U.S. For this analysis, we collected publicly available arrests data related to marijuana for Philadelphia and Dauphin County between January 2009 to December 2018 and county-level population estimates from the American Community Survey. In addition, information about the county of arrests (in Philadelphia or Dauphin), cause of the arrests (marijuana possession and sale/manufacturing), demographic characteristics of aggregated number of county-level arrests (race, age, and sex), and the month of arrests were also collected from the UCR. Annual law enforcement officers per 100,000 residents were from the Federal Bureau of Investigation's Crime in the United States publications for Pennsylvania.

2.3. Exposure and outcomes

The Philadelphia's City Council initially introduced the marijuana decriminalization bill on May 1, 2014, which was first passed on June 19, 2014. However, additional revisions delayed signing the bill into law until October 1, 2014. To allow for the possibility of an anticipatory response from law enforcement due to the introduction of the decriminalization bill, we considered a phase-in period of four months prior to the policy implementation in Philadelphia and Dauphin and excluded these four data points from the primary analysis. Thus, we define June 1, 2014 as the end of the pre-decriminalization period and October 1, 2014 as the beginning of the post-decriminalization period. To better understand the overall impact of marijuana decriminalization and how it specifically affects different causes of arrest, we modeled three monthly time series outcomes: 1) all marijuana-related arrests, 2) arrests related to possession, and 3) arrests related to sales and manufacturing. Arrest rates were calculated based on the estimated number of individuals living in Philadelphia (or Dauphin) using annual ACS one-year estimates from 2009 to 2018. In total, each time series spanned 116 months (65 pre-decriminalization and 51 post-decriminalization).

2.4. Statistical analysis

Mean and standard deviation were used to summarize arrest-related data for Philadelphia and Dauphin counties. Although a Poisson distribution is assumed for individual counts of arrest, we had very large numbers and the aggregated data were well approximated by a Gaussian distribution (see Figure S1 in Appendix). Thus, we used simple ordinary least squares models for our analyses. To formally test for the parallel trend assumption, we fitted a model with only arrest data prior to decriminalization (before June 1, 2014) using a continuous measure of time, a binary location variable (Philadelphia vs. Dauphin), and the interaction between the two. We ran separate models for overall marijuana-related arrests, possession-based arrests, and sales/manufacturing-based arrests. Result suggests that the parallel trends assumption was met for our analyses (see Table S2 in Appendix).

2.4.1. Simple ITS and CITS models

To estimate whether the onset of the decriminalization policy (primary predictor of interest) was associated with an immediate

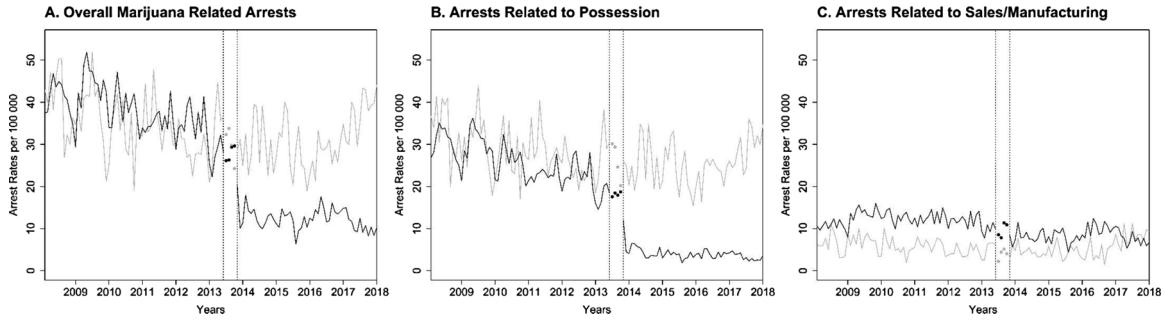

Fig. 1. Effect of Marijuana Decriminalization on all marijuana related arrests (A), arrests specific to marijuana possession (B), and arrests specific to marijuana sales and manufacturing (C). Trends represent monthly rates of arrest in Philadelphia and Dauphin counties, PA between 2009 and 2018. Philadelphia (black solid line and points) is compared with Dauphin (gray solid line and points). The vertical dotted line indicates the phase-in period of Philadelphia's marijuana decriminalization bill.

decrease in marijuana-related arrest rates, we initially fitted a simple ITS model for Philadelphia and Dauphin counties separately to determine the adjusted difference in arrest rates following the policy implementation. The simple ITS models contained a binary decriminalization variable and four time-varying confounders, including medical marijuana legalization to control for expanded marijuana access, harmonic functions of seasonal trends to control for seasonality (Bernal et al., 2017), a continuous measure of time to control for baseline secular trend, and annual changes in the number of law enforcement officers per 100,000 residents. Given the potential time lag between the legalization of medical marijuana (April 2016) and the opening of dispensaries (February 2018) in Pennsylvania, we modeled a 22-month time lag for the effect of medical marijuana legalization (a confounder). To quantify the DID estimate, we fitted three separate CITS models using a binary location (Philadelphia vs. Dauphin) and decriminalization (before vs. after decriminalization) variable as well as the interaction between them while adjusting for our time-varying confounders.

$$\begin{aligned} Arrest\ rate = {} & \beta_0 + \beta_1 Decriminalization + \beta_2 Location + \beta_3 Time \\ & + \beta_4 Medical\ Marijuana\ Legalization + \beta_5 Seasonality \\ & + \beta_6 Law\ Enforcement\ Officers \\ & + \beta_7 (Decriminalization\ x\ Location) + \varepsilon \end{aligned}$$

We used bootstrapping to obtain confidence intervals (CI) for all analyses. The adjusted percent change was calculated by taking the DID estimate and dividing it by the mean arrest rate in Philadelphia before decriminalization was implemented.

2.4.2. Stratified models

We hypothesized that arrest rates would vary by demographic characteristics and conducted stratified analyses by race (African American/White), age (< 18 years/ ≥ 18 years), and sex (male/female). Bootstrapping was used to acquire robust standard errors and CI. Given the potential issues that could arise from multiple stratified analyses (i.e., increased probability of a type I error), we used the Bonferroni correction method to derive a more conservative threshold for evaluating significance and present 99.5% CI (i.e., $p < 0.005$) rather than the standard 95% CI (VanderWeele and Mathur, 2019). To evaluate the potential impact of autocorrelation in the time series data, we examined the autocorrelation and partial autocorrelation plot of monthly arrest rates as presence of autocorrelation would violate assumptions of linear models and affect standard errors. The autocorrelation and partial autocorrelation plots demonstrated little evidence of autocorrelation in the arrest rates (see Figure S2 in Appendix).

2.5. Sensitivity analysis

We conducted three sensitivity analyses. First, given the temporal heterogeneity in which marijuana-related policies may take effect (Pacula and Smart, 2017), we examined the effect of time lags at 1, 3, and 6 months for marijuana decriminalization (see Table S3 in Appendix). Second, we used all 120 time points to compare models with and without the phase-in period (see Table S4 and S5 in Appendix). Third, two placebo tests were conducted by introducing an interaction between decriminalization and location at 24- and 48-month in the pre-decriminalization data. Results from our sensitivity analysis can be found in the Appendix (Table S6). All statistical analyses were performed with R statistical software version 3.5.2, using the stats (R Core Team, 2018) and tsmodels (Peng and McDermott, 2013) package. Source code and data are available at https://doi.org/10.5281/zenodo.3695055.

3. Results

3.1. Changes in marijuana-related arrest rates

There was an immediate reduction in the arrest rates following marijuana decriminalization for all marijuana-related crimes and those specific to possession (Fig. 1 and Table 1). The average arrest rate of all marijuana-based crimes between the pre- and post-decriminalization period in Philadelphia decreased from 37.7–12.4 arrests per 100,000 residents and in Dauphin from 34.8–31.1 arrests per 100,000 residents. Possession-based arrest rates decreased from 25.6 to 4.0 arrests per 100,000 residents in Philadelphia and 29.0–25.6 arrests per 100,000 residents in Dauphin. A similar, yet smaller, effect was observed for arrest rates related to sales/manufacturing, which declined from 12.1–8.4 arrests per 100,000 residents in Philadelphia and 5.9 to 5.5 arrests per 100,000 residents in Dauphin. Consistent with these unadjusted estimates, the basic ITS models controlling for confounders demonstrated a significant decline in mean arrest rates by 15.1 (95 % CI: −18.1, −12.6) arrests per 100,000 residents for all marijuana-related crimes, 11.6 (95% CI: −12.7, −9.8) arrests per 100,000 residents for possession-based crimes, and 3.5 (95% CI: −5.0, −2.3) arrests per 100,000 residents for sales/manufacturing-based crimes in Philadelphia. We compared these findings with Dauphin County and found no significant changes in the post-decriminalization rates for all three outcomes. The CITS analyses indicated that arrest rates for all marijuana-related crimes in Philadelphia decreased by 19.9 per 100,000 residents (95% CI: −23.0, −17.1) compared to Dauphin, which resulted in a 52.8% lower rate in arrests following decriminalization. When broken down by type of marijuana crimes, possession-based arrest rates lowered by 17.1 per 100,000 residents (95% CI: −19.8, −14.7; a 66.9% reduction) while sales/manufacturing-based arrest rates lowered by 2.8 per 100,000 residents (95% CI: −3.8, −1.7; a 22.8% reduction).

Table 1
Effect of marijuana decriminalization on arrest rates.

Marijuana arrests	Philadelphia County			Dauphin County				
	Mean monthly arrests per 100,000 population (SD)			Mean monthly arrests per 100,000 population (SD)				
	Before policy	After policy	Adjusted difference estimate 95% CI)[a,b]	Before policy	After policy	Adjusted difference estimate (95% CI)[a,b]	Adjusted % change in arrest rates[c]	Adjusted difference-in-difference estimate (95% CI)[a,c]
Overall	37.7 (6.1)	12.4 (2.6)	−15.1 (−18.1, −12.6)	34.8 (7.4)	31.1 (6.5)	2.4 (−1.9, 7.2)	−34.9%	−19.9 (−23.0, −17.1)
Possession	25.6 (5.0)	4.0 (1.5)	−11.6 (−12.7, −9.8)	29.0 (6.4)	25.6 (5.2)	2.3 (−1.3, 6.2)	−43.1%	−17.1 (−19.8, −14.7)
Sales/Manufacturing	12.1 (1.8)	8.4 (1.8)	−3.5 (−5.0, −2.3)	5.9 (2.0)	5.5 (2.3)	0.1 (−1.2, 1.4)	−15.9%	−2.8 (−3.8, −1.7)

Abbreviations: SD, standard deviation; CI, confidence interval.

[a] Models were adjusted for baseline temporal trends, seasonality, medical marijuana legalization, and annual proportion of police officers per 100,000 residents.

[b] Adjusted difference estimates are based on simple interrupted time series regression analyses.

[c] Adjusted percent change and difference-in-difference estimates are based on comparative interrupted time series regression analyses. The percent change was calculated by dividing the difference-in-difference estimates by the sum of the intercept plus the estimate for Philadelphia. The numerator represents the change in rates of marijuana arrest post-decriminalization compared to pre-decriminalization controlling for confounding using Dauphin County as a control and the denominator represents the mean of the marijuana arrest rates in Philadelphia County pre-decriminalization.

3.2. Arrest rates prior to decriminalization by demographic characteristics

Results of the stratified models by each demographic characteristic (i.e., race, age, and sex) assessing the impact marijuana decriminalization on arrest rates are shown in Table 2. Prior to decriminalization, the mean arrest rates were consistently higher for African Americans (vs. Whites), adults (vs. youths), and males (vs. females) across all three outcomes, with the greatest arrest disparities between males and females (i.e., a relative difference by about 11-folds for three outcomes). Arrest rates by race and age had a more modest relative difference prior to decriminalization; African Americans were three to five times as likely as their White counterparts to be arrested for marijuana-based crimes while adults were 2–4 times as likely as youths to be arrested.

3.3. Changes in marijuana-related arrest rates by race

Reclassification of marijuana possession to a civil infraction was associated with a statistically significant reduction in arrest rates for all marijuana-based crimes, possession-based crimes, and sales/manufacturing-based crimes across different demographic characteristics. In the CITS models stratified by race, the mean arrest rates for all marijuana crimes in Philadelphia compared to Dauphin declined by 34.9% among African Americans and 13.0% among Whites. The adjusted DID estimates are -38.6 per 100,000 residents (99.5% CI: −51.3, −26.7) and −3.3 per 100,000 residents (99.5% CI: −6.8, 0.04), respectively. When broken down by type of crimes, the percent reduction in possession-based arrest rates is higher for African Americans (−46.6% among African Americans compared to −8.8% among Whites) while Whites had a higher percent reduction in arrest rates related to sales/manufacturing (−7.1% among African Americans compared to −20.9% among Whites).

3.4. Changes in marijuana-related arrest rates by sex

When CITS models were stratified by sex, both males and females had a significant decrease in arrest rates. The DID estimates indicated that males had a larger absolute decrease in arrest rates in Philadelphia compared to Dauphin for all marijuana-based crimes (DID estimate: −38.3; 99.5% CI: −45.9, −31.4 among males compared to DID estimate: −3.7; 99.5% CI: −5.8, −1.2 among females), possession-based crimes (DID estimate: −33.3; 99.5% CI: −39.0, −27.7 among males compared to DID estimate: −2.8; 99.5% CI: −4.9, −0.6 among females), and sales/manufacturing-based crimes (DID estimate: −5.0; 99.5% CI: −7.6, −2.4 among males compared to DID estimate: −0.8; 99.5% CI: −1.6, −0.1 among females). However, females in Philadelphia, compared to Dauphin, had a higher percent reduction following marijuana decriminalization, particularly for sales/manufacturing-based crimes (-29.6% among females compared to -15.0% among males).

3.5. Changes in marijuana-related arrest rates by age

There was a significant decline in arrests rates for youths (< 18) and adults (≥ 18) for all three outcomes but decriminalization did not appear to have a differential effect between these two age groups (i.e., there was overlap in the 99.5% CI of DID estimates). Adults in Philadelphia compared to those in Dauphin had a greater decrease in arrest rates for all marijuana-based crimes (DID estimate: −21.8; 99.5% CI: −26.1, −17.4) and for marijuana possession (DID estimate: −18.9; 99.5% CI: −22.4, −15.3) than youths. However, the percent reduction in arrest rates for those two outcomes were slightly higher for youths by -34.5% (vs. −32.2% among adults) and 51.5% (vs. −35.0% among adults), respectively. In contrast, the DID estimates for sale/manufacturing-based crimes were similar for both age groups while the percent reduction remains higher for youths (−45.9%) compared to adults (−15.0%).

Table 2
Effect of marijuana decriminalization on arrest rates by demographic characteristics.

	Philadelphia County			Dauphin County				
	Mean monthly arrests per 100,000 population (SD)			Mean Monthly Arrests Per 100,000 Population (SD)				
Marijuana arrests	Before policy	After policy	Adjusted difference estimate (99.5% CI)[a,b,c]	Before policy	After policy	Adjusted difference estimate (99.5% CI) [a,b,c]	Adjusted % change in arrest rates[d]	Adjusted difference-in-difference estimate (99.5% CI) [a,b,d]
Overall								
Racial Groups								
White	15.3 (3.1)	5.7 (2.0)	−5.3 (−7.4.−3.1)	24.9 (7.0)	17.4 (5.10)	1.7 (−3.5, 7.8)	−13.0%	−3.3 (−6.8, 0.04)
African American	66.0 (10.6)	23.9 (8.6)	−28.0 (−34.8, −21.5)	78.8 (20.0)	77.0 (17.4)	15.3 (−2.5, 32.9)	−34.9%	−38.6 (−51.3, −26.7)
Age Groups								
< 18	18.3 (4.2)	5.2 (2.4)	−7.1 (−10.5, −3.8)	27.9 (7.7)	30.0 (8.7)	4.4 (−3.7, 12.9)	−34.5%	−13.5 (−18.5, −8.3)
≥18	43.3 (7.0)	15.9 (5.8)	−17.4 (−21.8, −13.6)	36.8 (8.0)	31.3 (6.7)	1.6 (−4.8, 8.2)	−32.2%	−21.8 (−26.1, −17.4)
Sex								
Female	6.1 (1.5)	2.4 (1.0)	−2.3 (−3.3, −1.3)	12.3 (3.4)	13.4 (3.8)	1.9 (−1.6, 5.7)	−22.7%	−3.7 (−5.8, −1.2)
Male	73.0 (11.6)	25.9 (9.3)	−29.5 (−36.9, −23.1)	58.8 (12.8)	50.1 (10.7)	2.7 (−7.6, 13.4)	−37.4%	−38.3 (−45.9, −31.4)
Possession								
Racial Groups								
White	9.3 (2.1)	2.3 (1.4)	−3.4 (−4.9, −2.2)	21.8 (6.3)	16.5 (4.4)	1.6 (−2.9, 6.9)	−8.8%	−1.5 (−4.1, 1.4)
African American	45.9 (9.0)	8.7 (7.3)	−22.2 (−27.7, −17.5)	61.4 (15.7)	61.3 (13.8)	12.6 (−3.5, 26.8)	−46.6%	−36.3 (−46.4, −26.8)
Age Groups								
< 18	14.4 (3.5)	3.2 (2.2)	−6.0 (−9.1, −3.4)	24.8 (7.2)	26.6 (8.5)	2.4 (−5.6, 11.0)	−51.5%	−11.1 (−15.8, −6.2)
≥18	28.8 (5.9)	4.6 (4.8)	−13.2 (−16.1, −10.5)	30.1 (6.9)	25.3 (5.3)	2.1 (−4.2, 7.7)	−35.0%	−18.9 (−22.4, −15.3)
Sex								
Female	4.2 (1.2)	1.1 (0.7)	−1.6 (−2.6, −0.8)	11.0 (3.2)	11.6 (3.7)	1.1 (-2.4, 4.8)	−21.3%	−2.8 (−4.9, -0.6)
Male	49.6 (9.7)	9.4 (7.9)	−22.7 (−27.9, −18.1)	48.1 (11.0)	40.6 (8.5)	3.5 (−6.6, 12.5)	−48.2%	−33.3 (−39.0, −27.7)
Sales/Manufacturing								
Racial Groups								
White	6.0 (1.5)	3.4 (1.2)	−1.9 (−3.4, −0.5)	3.1 (1.7)	2.6 (1.6)	0.03 (−1.4, 1.7)	−20.9%	−1.9 (−3.0, −0.8)
African American	20.0 (3.3)	15.2 (3.1)	−5.8 (−9.3, −3.0)	17.4 (7.3)	15.7 (7.1)	2.7 (−4.1, 9.7)	−7.1%	−2.3 (−6.8, 2.1)
Age Groups								
< 18	3.9 (1.3)	2.0 (1.0)	−1.2 (−2.2, 0.03)	3.1 (2.6)	3.3 (2.8)	2.0 (−0.2, 4.5)	−45.9%	−2.4 (−4.0, −0.8)
≥18	14.4 (2.2)	10.3 (2.2)	−4.2 (−6.6, −1.9)	6.7 (2.1)	5.9 (2.6)	−0.5, (−2.5, 1.7)	−13.7%	−2.9 (−4.5, −1.3)
Sex								
Female	1.9 (0.6)	1.3 (0.5)	−0.7 (−1.3, −0.1)	1.4 (1.2)	1.5 (1.2)	0.9 (−0.1, 2.0)	−29.6%	−0.8 (−1.6, −0.1)
Male	23.4 (3.6)	16.5 (3.4)	−6.7 (−10.6, −2.9)	10.6 (3.4)	9.5 (4.1)	−0.8 (−3.9, 2.7)	−15.0%	−5.0 (−7.6, −2.4)

Abbreviations: SD = standard deviation; CI = confidence interval.

[a] Models were adjusted for baseline temporal trends, seasonality, medical marijuana legalization, and annual proportion of police officers per 100,000 residents.

[b] A Bonferroni correction method was applied to the standard 95 % confidence interval to derive the 99.5 % confidence interval for multiple interaction model comparisons.

[c] Adjusted difference estimates are based on simple interrupted time series regression analyses.

[d] Adjusted percent change and difference-in-difference estimates are based on comparative interrupted time series regression analyses. The percent change was calculated by dividing the difference-in-difference estimates by the sum of the intercept plus the estimate for Philadelphia. The numerator represents the change in rates of marijuana arrest post-decriminalization compared to pre-decriminalization controlling for confounding using Dauphin County as a control and the denominator represents the mean of the marijuana arrest rates in Philadelphia County pre-decriminalization.

3.6. Sensitivity analysis

First, results from our sensitivity analysis comparing the time-lag effects showed that estimates were similar in magnitude and direction of effect for all three outcomes (See Fig. S3 in Appendix). Second, using all time points demonstrated that estimates without the phase-in period were similar in magnitude and directionality to models with the phase-in period (see Table S3 and S4 in Appendix). Finally, sensitivity analysis evaluating each placebo test at 24- and 48-months indicated a non-significant association for all marijuana-based crimes ($p = 0.50$ at 24-months; $p = 0.73$ at 48 months), possession-based crimes ($p = 0.15$ at 24-months; $p = 0.54$ at 48-months) and sales/manufacturing-based crimes ($p = 0.14$ at 24-months; $p = 0.63$ at 48 months). Specific estimates and details are reported in the Appendix (Table S5).

4. Discussion

Implementation of marijuana decriminalization policy led to a precipitous drop in arrest rates for all marijuana related arrests, those specific to possession, and those specific to sales and manufacturing in Philadelphia, with absolute and relative decreases ranging from 0.8–38.6 per 100,000 residents and 7.1%–51.5%, respectively. This is consistent with prior research, particularly for arrest rates due to marijuana possession (Grucza et al., 2018; Plunk et al., 2019), which exhibited the greatest decline after decriminalization in our analysis. Significantly, declining arrests translate into substantial cost savings by city or county governments (Kilmer et al., 2019; Shanahan and Ritter, 2014) as well as reduced harms to citizens who avoid entanglement in the criminal justice system (Taxman et al., 2005). We also observed substantial heterogeneity in the impact of marijuana decriminalization across different groups of individuals and types of arrest, while our sensitivity analysis indicated that the overall effect of decriminalization on arrest rates was robust to the phase-in period and across time-lags. Therefore, our study documents that, despite the overall decline in marijuana arrests after decriminalization, there are still important differences to be examined within different populations.

Marijuana arrest rates were high among African Americans prior to decriminalization. We found that African Americans experienced greater absolute reduction in arrest rates once marijuana possession was reclassified as a civil offense compared to Whites; however, arrest rate disparities, specifically for sales/manufacturing, increased between African Americans and Whites. For instance, relative reduction for sales/manufacturing-based arrest rates was nearly 3 times lower for African Americans than their White counterparts after decriminalization. This is similar to recent work documenting increases in relative arrest rate disparities despite decreases in absolute disparities following marijuana legalization between Whites and African Americans (Firth et al., 2019).

There are two possible rationales that may explain the differential patterns in arrest rates by race. One rationale is that our data do not reflect actual law enforcement behaviors, particularly biases in the criminal justice system, that would contribute to the continual disparities in arrest rates (Gelman et al., 2007; Milner et al., 2016; Mitchell and Caudy, 2015; Ulmer et al., 2016). This may explain, in part, how African Americans continue to be unfairly targeted by law enforcement officers relative to White individuals. However, recent work suggests that perceptions around policing of small drug use and purchases are changing among law enforcement officers (Rouhani et al., 2019). The other rationale posits that arrest rates disparities may be partially explained by differential purchasing patterns that place Africans Americans at greater risk for arrest, including purchasing marijuana outdoors, from strangers, and far from their homes (Ramchand et al., 2006). These hypotheses, however, require further evaluation to disentangle the mechanisms contributing to the persistent arrest rate disparities between Whites and African Americans.

Our results also suggest differential impact of decriminalization by sex. Males experienced greater absolute/relative reduction for possession-based arrests, but females appear to experience a higher relative reduction for sales/manufacturing, which the percent decline among females was twice as much as it was among males. This heterogeneity of effect may, in part, be a result of the preexisting gender differences in arrest rates prior to decriminalization. Females had an overall lower arrest rate before marijuana decriminalization, thus, any declines in arrest rates, even small ones, can result in a large relative reduction. Further exploration of gender-based differences following decriminalization is warranted.

Finally, the impact of decriminalization appears to be somewhat similar across age groups. This is congruent with prior work to show that decriminalization policies lead to significantly lower rates of possession-based arrest (up to 75%) for both adults and youths (Plunk et al., 2019). Our research, however, further extends prior work to show that, even though absolute differences may be similar between age groups, there were relative differences for sales/manufacturing-based arrest rates by up to an order of 3-folds. It has been speculated that law enforcement officers may compensate for their inability to arrest youths for marijuana possession by arresting them more frequently for marijuana sales/manufacturing (i.e., possession with intent to distribute) (Smart and Kleiman, 2019). This was not supported by our data. In fact, sales/manufacturing-based arrest rates did not increase following marijuana decriminalization for any of the demographic groups in our analyses.

These results serve as a strong empirical case for how drug policy reform can impact arrest rate disparities across different populations. For example, research has documented how African Americans are disproportionately represented in the criminal justice system (Gelman et al., 2007; Milner et al., 2016; Mitchell and Caudy, 2015; Ulmer et al., 2016) as well as the association of mass incarceration and adverse health outcomes (Allison et al., 2017; Blankenship et al., 2018; Massoglia, 2008; Schnittker et al., 2011). Other researchers have also conceptualized how institutionalized racism within the criminal justice system perpetuates health inequities by acting through the social determinants of health (Nowotny and Kuptsevych-Timmer, 2018; Purtle, 2013); thus, impeding access to health promoting resources. Given these evidences, it is plausible to assume that the disproportionate impact of the criminal justice system among African Americans as well as its association to adverse health outcomes can be mitigated, in part, by drug policy reforms. Furthermore, youths may be particularly vulnerable to criminalization of marijuana possession given the potential damage to the life prospects of those arrested. It should be noted, however, that arrest rates in our study were calculated based on population size and interpretation of our results is predicated on understanding the impact of decriminalization on arrest rates among individuals at risk for arrest. Future research may want to explore using the total number of arrests as the denominator to further understand the relative importance of marijuana arrest rate disparities between demographic groups. Our study extends upon prior research by documenting how marijuana decriminalization impacts the frequency of, and disparities in, arrests within an urban setting—which would theoretically impact disparities in health for those that have historically been targeted by punitive drug policies. This, in light of well-established research to indicate that decriminalization has no measurable association to prevalence or severity of marijuana use (Grucza et al., 2018; MacCoun et al., 2009), further documents the need for more urban settings to adopt policies that decriminalize marijuana to prevent the further exacerbation of health disparities.

4.1. Limitations

Our study has several limitations. First, we used a dichotomous measure for marijuana decriminalization, which may not capture all the substantial variation in implementation. We attempted to assess the impact of such variation with our time-lag analysis, which

demonstrated that our estimates were robust to temporal variation associated with policy implementation. Second, it is possible that the observed changes in trends could have been from other concurrent events targeting marijuana arrests but did not occur in our control population. One potential event is the growing number of medical marijuana dispensaries in Philadelphia, which may differ to Dauphin. We attempted to capture some of this effect by including a time-lagged variable of medical marijuana legalization; however, this may not be adequate in capturing potential increases in marijuana access. Third, publicly available data for marijuana arrests do not report the amount of marijuana in possession at the time of the arrest. It is possible that marijuana arrests were misclassified prior to decriminalization given the ambiguity in the amount of marijuana that would warrant an arrest for possession vs. sales and manufacturing. This may lead to an overestimation of the policy's effect on sales/manufacturing-based arrest rates. Finally, our results in Philadelphia may not reflect experiences of those in other jurisdictions, particularly in states that have legalized marijuana for recreational use. Such geographic variation should be accounted for in future studies using more advance statistical methods such as geographically weighted regression (Brunsdon et al., 2010).

5. Conclusion

Our findings indicate that marijuana decriminalization has been effective in reducing the absolute rates of arrest across different populations for marijuana-related crimes in Philadelphia and has implications for substantial cost saving benefits. However, study findings suggest that disparities related to possession- and sales/manufacturing-based arrests continue to persist; specifically, African Americans may have continual vulnerabilities to policing for marijuana possession with the intent to use as well as distribute. Given the potential health consequences of having a criminal record, disparities across all groups of individuals in contact with the criminal justice systems needs to be addressed to ensure equitable marijuana policy reform.

Contributors

NKT and LPT conceptualized the project. NKT conducted the analysis and wrote the initial manuscript. All authors contributed to the revisions and approved the manuscript.

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Declaration of Competing Interest

None.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi: https://doi.org/10.1016/j.drugalcdep.2020.108058.

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