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Dispensaries and Medical Marijuana Certifications and Indications: Unveiling the Geographic Connections in Pennsylvania, USA

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Abstract

Introduction: Pennsylvania opened its first medical marijuana (MMJ) dispensary in 2018. Qualifying conditions include six conditions determined to have no or insufficient evidence to support or refute MMJ effectiveness. We conducted a study to describe MMJ dispensary access in Pennsylvania and to determine whether dispensary proximity was associated with MMJ certifications and community demographics. ***Methods:*** Using data from the Pennsylvania Department of Health, we geocoded MMJ dispensary locations and linked them to US Census Bureau data. We created dispensary access measures from the population-weighted centroid of Zip Code Tabulation Areas (ZCTAs): distance to nearest dispensary and density of dispensaries within a 15-min drive. We evaluated associations between dispensary access and the proportion of adults who received MMJ certification and the proportion of certifications for low evidence conditions (amyotrophic lateral sclerosis, epilepsy, glaucoma, Huntington's disease, opioid use disorder, and Parkinson's disease) using negative binomial modeling, adjusting for community features. To evaluate associations racial and ethnic composition of communities and distance to nearest dispensary, we used logistic regression to estimate the odds ratios (OR) and 95% confidence intervals (CI), adjusting for median income. ***Results:*** Distance and density of MMJ dispensaries were associated with the proportion of the ZCTA population certified and the proportion of certifications for insufficient evidence conditions. Compared to ZCTAs with no dispensary within 15 min, the proportion of adults certified increased by up to 31% and the proportion of certifications for insufficient evidence decreased by up to 22% for ZCTAs with two dispensaries. From 2018 to 2021, the odds of being within five miles of a dispensary was up to 20 times higher in ZCTAs with the highest proportions of individuals who were not White (2019: OR: 20.14, CI: 10.7–37.8) and more than double in ZCTAs with the highest proportion of Hispanic individuals (2018: OR: 2.81, CI: 1.51–5.24), compared to ZCTAs with the lowest proportions. ***Conclusions:*** Greater dispensary access was associated with the proportions of certified residents and certifications for low evidence conditions. Whether these patterns are due to differences in accessibility or demand

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is unknown. Associations between community demographics and dispensary proximity may indicate MMJ access differences.

Introduction

The legalization of medical marijuana (MMJ) is expanding worldwide, including in some parts of the USA, Europe, Asia, and Africa [1]. In the USA, as of January 2024, 38 states allow medical use of cannabis products [2]. States have a growing list of qualifying conditions for MMJ, despite limited evidence of the effectiveness of MMJ for many of these conditions [3]. The geographic location of MMJ dispensaries has been associated with marijuana use [4–6]; however, it is unknown whether the locations of MMJ dispensaries are associated with the qualifying conditions for which individuals are being certified. As MMJ legalization and the number of certifying conditions in the USA expand [2, 7], it is imperative to understand the potential implications of the locations of MMJ dispensaries.

Geographic locations of MMJ dispensaries have been associated with marijuana use patterns. Living near a higher number of MMJ dispensaries has been associated with a greater number of days of marijuana use, greater marijuana demand, and frequency of marijuana use [4–6]. Studies to date have been cross-sectional and have not been able to determine the causal direction of these relationships (i.e., whether location is driving demand or demand is driving location). Much of this research has been conducted in California, the first state to legalize MMJ in 1996. It is unknown whether these findings are generalizable to states in other regions of the country.

Very little is known about whether geographic access to MMJ dispensaries is associated with the types of qualifying conditions for which people are certified. However, prior studies have reported associations between geographic access to clinical care settings and healthcare utilization for some qualifying conditions, including anxiety and autism [8, 9]. In 2017, the National Academies of Sciences, Engineering and Medicine (NASEM) published a comprehensive review of the evidence regarding the health effects of using cannabis and cannabis-derived products [3]. In the report, NASEM categorized conditions into one of five categories: conclusive evidence, substantial evidence, moderate evidence, limited evidence, and no or insufficient evidence to support the association [3]. A subsequent report identified a mismatch between many of the qualifying conditions allowed under state law and the evidence supporting the use of MMJ. In 2019, a national report estimated that 15.4% of patient-reported qualifying conditions had less than substantial evidence of the effectiveness of MMJ treatment [10]. Since then, new states and new qualifying conditions have been added to MMJ regulations [7].

Different community characteristics have been associated with geographic access to MMJ dispensaries, but results have differed across states. In New York State, for example, MMJ services were least available in neighborhoods with highly educated residents [11], while in Oklahoma census tracts with at least one MMJ dispensary had a higher proportion of uninsured individuals living below the poverty level [12]. Unlike in these states, in California and Colorado studies did not find an association between socioeconomic status and MMJ dispensary locations [13, 14]. In New York State, MMJ services were least available in neighborhoods with Black residents [11], while in Los Angeles the presence of MMJ dispensaries was associated with a higher proportion of Hispanic residents [13]. Differences in geographic proximity to MMJ dispensaries may impact access to effective treatment options for conditions such as chronic pain or multiple sclerosis [3]. Conversely, there is some prior evidence that closer proximity may have negative consequences, as proximity has been associated with elevated rates of marijuana-related hospitalizations and crime [15–17].

As the number of MMJ dispensaries grows, it is important to understand the implications of where states locate MMJ dispensaries and how to provide equitable access. Pennsylvania legalized MMJ in 2016 and opened its first dispensary in 2018. As of 2024, there are 24 conditions on the list of qualifying conditions in Pennsylvania (online suppl. 1; for all online suppl. material, see https://doi.org/10.1159/000537841). Individuals can be certified for one or more of these conditions. Using data from the Pennsylvania Department of Health, we conducted a study of the association between proximity to MMJ dispensaries and both the proportion of individuals certified and the proportion of certifications for conditions that have no, insufficient, or limited evidence. We then evaluated the association between racial, ethnic, socioeconomic community features and access to Pennsylvania dispensaries.

Methods

We conducted a cross-sectional study of MMJ dispensaries in Pennsylvania zip code tabulation areas (ZCTAs) from 2018 to 2021 using data from the Pennsylvania Department of Health

obtained in 2022, geographic spatial files from the Census Bureau, and community sociodemographic data from the American Community Survey. According to the Census Bureau, Pennsylvania was the fifth most populous state in 2020 in the USA (population = 13.0 million, 26.6% non-White). We evaluated associations between geographic access, defined using distance and density measures, to MMJ dispensaries and certifications. We then measured associations between community sociodemographic factors and MMJ dispensary access.

Measures of Geographic Access

The Pennsylvania Department of Health provided the addresses and opening dates of MMJ dispensaries in Pennsylvania. Using ArcGIS V.10.8 (ESRI, Redlands, CA, USA), we geocoded dispensary locations for each year between 2018 and 2021 and created two dispensary access measures from the population-weighted centroid of ZCTAs with at least 100 adult residents to ensure the precision of our estimates: Geodesic distance (miles) to nearest dispensary and a density measure of the count of dispensaries within a 15-min driving buffer (0, 1, 2). Drive-time buffers were created using ArcGIS with Network Analyst and StreetMap Premium 2021. These are drive-times by road following posted speed limits. We selected drive-time, rather than distance, as drive-time is readily interpretable, better captures opportunity cost of travel, and it better reflects the information that individuals use to inform travel decisions [18].

Measures of MMJ Use

For each year between 2018 and 2021, the Pennsylvania Department of Health provided certification data at the Zip Code level to Pennsylvania Academic Clinical Research Centers in February 2023. Data included 5-digit zip code for the certifying person, certification status (included: active, inactive, pending, expired, cancelled), creation date of certification, treatment period (by number of months up to 12), and up to 10 qualifying serious medical conditions approved by the Department of Health. Zip Code to ZCTA crosswalk files from UDS Mapper (HRSA, 2018–2021) were used to summarize MMJ certifications at the ZCTA level. For each ZCTA, we calculated the proportion of adults residing in a ZCTA who had a certification in each year and the proportion of certifications for insufficient evidence conditions, per the NASEM report. To calculate the proportion certified, we divided the number of certifications in each year between 2018 and 2021 by the size of the adult population in that ZCTA using data from the American Community Survey data.

We identified six conditions on the Pennsylvania's list of qualifying conditions between 2019 and 2021 that the NASEM categorized as having less than moderate evidence of MMJ effectiveness (i.e., conditions with no, insufficient, or limited evidence of MMJ effectiveness [3]; hereinafter, low evidence conditions): amyotrophic lateral sclerosis, epilepsy, glaucoma, Huntington's disease, opioid use disorder, and Parkinson's disease (online suppl. 1) [3]. Because Pennsylvania expanded their list of qualifying conditions in 2019, we calculated the proportion of certifications that were only for one or more of these conditions for each year between 2019 and 2021 by dividing the number of certifications for the six low evidence conditions by the total number of certifications.

Community Measures

Using data from the American Community Survey, we created measures of income and racial and ethnic composition for each of the ZCTAs. For each year, we quartiled the median household income, the proportion of residents who were not White, and the proportion of residents who were Hispanic. We categorized ZCTAs by the level of urbanicity using the Rural-Urban Commuting Area Codes from the US Department of Agriculture [19]. ZCTAs were categorized as metropolitan, micropolitan/small town, and rural.

Analysis

The goals of these analyses were to describe MMJ location and certification patterns in Pennsylvania; evaluate associations between geographic access to MMJ dispensaries (distance and density) and two MMJ use outcomes: proportion of population certified and proportion of certifications for low evidence conditions; and evaluate associations between community features and MMJ access. We evaluated associations between dispensary access (distance: less than five miles [8.1 km], five to fewer than 10 miles [16.1 km], 10 and more miles; density: 0, 1, 2, or more within a 15-min driving radius), the proportion of adults who received MMJ certification (2018–2021), and the proportion of certifications for low evidence conditions (2019–2021), using negative binomial modeling to estimate the incidence rate ratio and 95% confidence intervals (CIs), separately, for each outcome in each year. For these models, we used count variables (i.e., number of certifications) as the outcomes and log-transformed denominators (i.e., population and count of certifications, respectively) as offset terms. We used an unadjusted model (model 1) and then we added sociodemographic factors, separately, to that model, to avoid violations of nonpositivity: median income (model 2); proportion not White and proportion Hispanic (model 3) [20]. In sensitivity analyses, we re-ran these models using a drive-time of 30 min. To evaluate associations between race and ethnic distributions (proportion of the population that was not White and the proportion that was Hispanic) and distance to nearest dispensary (distance: <5 miles, 5 miles or more), we used logistic regression to estimate the odds ratios and 95% CIs, adjusting for median income. Urbanicity was not included in final models given that, as of 2021, no ZCTAs in Pennsylvania categorized as rural had a MMJ dispensary.

Results

Of 1,831 ZCTAs, 1,608 were included in the analysis. The remaining ZCTAs had fewer than 100 adult residents and were excluded. From 2018 to 2021, the median distance to the nearest dispensary decreased from 14.7 miles to 9.3 miles (23.7 km to 15.0 km). The percent of ZCTAs within five miles of a dispensary nearly doubled, from 16.5% to 30.5%. The percent of ZCTAs with at least two dispensaries within 15 min more than tripled, from 9.2% to 27.8% (shown in Fig. 1; Table 1). The median percent of population certified for MMJ in Pennsylvania ZCTAs increased from 0.55% to

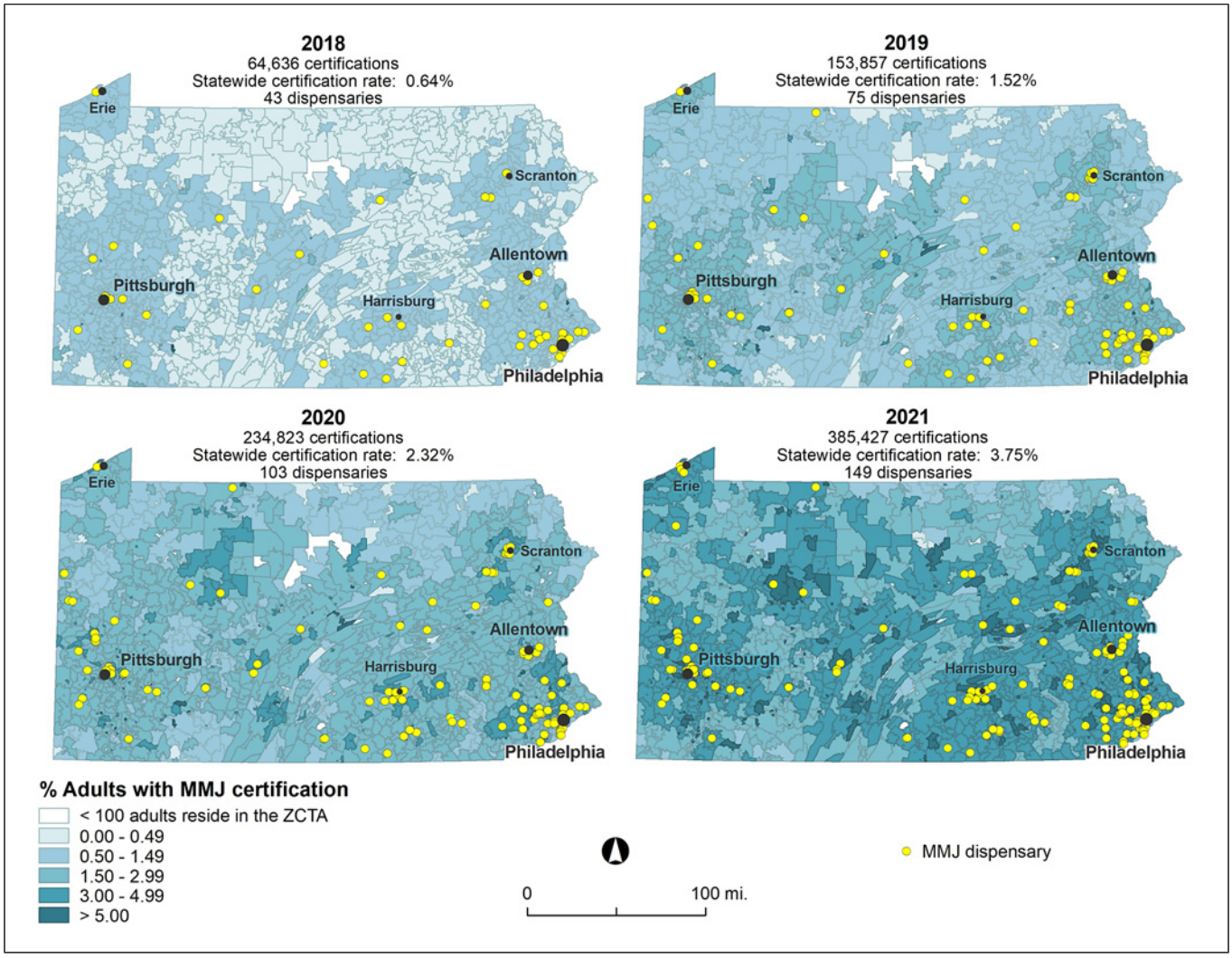

Fig. 1. Pennsylvania maps of percent of adults with MMJ certification 2018–2021 in Zip Code Tabulation Areas with at least 100 adult residents.

3.54% (shown in Fig. 1) and the median percent of certifications for low evidence conditions decreased from 3.3% to 1.9%.

In unadjusted and adjusted models, the proportion of the population certified increased with greater dispensary access (i.e., shorter distance, higher density) (Table 2). This finding was present in each year from 2018 to 2021. Compared to ZCTAs with the nearest dispensary more than 10 miles away, the proportion of adults certified increased by up to 42% for ZCTAs within 5–10 miles of a dispensary and 48% for ZCTAs within 5 miles (2018, model 3). Compared to ZCTAs with zero dispensaries within a 15-min drive, the proportion of adults certified increased by up to 35% for ZCTAs with at least 1 dispensary and 31% for ZCTAs with at least 2 dispensaries (2018, model 1). These associations remained after adjusting for community features (models 2 and 3).

In years 2019–2021, the proportion of certifications for low evidence conditions decreased with greater dispensary access (Table 3). Compared to ZCTAs with the nearest dispensary more than 10 miles away, the proportion of adults certified for low evidence conditions decreased by up to 30% for ZCTAs within 5–10 miles of a dispensary and 38% for ZCTAs within 5 miles (2021, model 1). Compared to ZCTAs with zero dispensaries within a 15-min drive, the proportion of adults certified decreased by up to 34% for ZCTAs with at least 1 dispensary and 22% for ZCTAs with at least 2 dispensaries (2021, model 1). These associations remained after

Table 1. Descriptions of distance and density to MMJ dispensaries and MMJ certifications in Pennsylvania Zip Code Tabulation Areas[1] 2018–2021

	2018			2019			2020			2021		
Distance to nearest dispensary (miles)	≤5	>5 to ≤10	>10	≤5	>5 to ≤10	>10	≤5	>5 to ≤10	>10	≤5	>5 to ≤10	>10
n (%)	266 (16)	287 (18)	1,055 (66)	356 (22)	323 (20)	928 (58)	418 (26)	371 (23)	819 (51)	491 (31)	357 (22)	760 (47)
Percent certified: mean (SD)	0.8 (0.5)	0.7 (0.5)	0.5 (0.3)	1.7 (0.7)	1.7 (0.8)	1.3 (0.8)	2.6 (1.0)	2.3 (1.0)	1.9 (1.1)	4.2 (1.5)	3.8 (1.6)	3.1 (16.4)
Percent certified for insufficient evidence conditions[2]: mean (SD)				4.1 (3.5)	4.3 (4.8)	6.2 (10.9)	2.9 (2.6)	3.2 (4.3)	4.2 (6.4)	2.2 (2.2)	2.7 (4.4)	3.3 (4.4)
	2018			2019			2020			2021		
Density within 15-min drive	0	1	≥2	0	1	≥2	0	1	≥2	0	1	≥2
n (%)	1,230 (76)	230 (14)	148 (9)	1,091 (68)	268 (17)	249 (15)	1,007 (63)	263 (16)	338 (21)	926 (58)	235 (15)	447 (28)
Percent certified: mean (SD)	0.5 (0.4)	0.8 (0.6)	0.8 (0.5)	1.3 (0.8)	1.7 (0.9)	1.7 (0.8)	1.9 (1.1)	2.5 (1.1)	2.6 (1.0)	3.2 (1.6)	4.1 (1.6)	4.1 (1.6)
Percent certified for insufficient evidence conditions[2]: mean (SD)				6.0 (10.2)	4.5 (4.4)	3.7 (2.8)	4.0 (6.1)	3.2 (4.0)	2.8 (2.4)	3.2 (4.5)	2.6 (3.5)	2.2 (2.4)
	2018			2019			2020			2021		
Distance to nearest MMJ dispensary (miles)	Mean (SD)			Mean (SD)			Mean (SD)			Mean (SD)		
Percent non-White												
Quartile 1 (lowest %)	22.8 (12.04)			17.6 (9.0)			16.5 (9.3)			15.6 (9.2)		
Quartile 2	20.9 (12.0)			17.3 (10.3)			16.6 (10.4)			15.5 (10.3)		
Quartile 3	16.1 (11.6)			13.1 (10.2)			11.6 (9.9)			10.7 (9.7)		
Quartile 4 (highest %)	9.6 (10.2)			7.7 (8.5)			5.8 (6.6)			5.3 (6.5)		
Percent Hispanic												
Quartile 1 (lowest %)	21.3 (12.1)			17.1 (9.1)			16.1 (9.3)			15.4 (9.3)		
Quartile 2	20.6 (12.3)			16.3 (10.4)			15.4 (10.7)			14.2 (10.3)		
Quartile 3	15.2 (12.0)			12.2 (10.1)			11.4 (10.1)			10.5 (10.1)		
Quartile 4 (highest %)	12.2 (11.4)			10.0 (9.9)			7.6 (8.0)			7.0 (7.9)		
Median income												
Quartile 1 (lowest %)	19.9 (13.9)			15.4 (11.4)			14.1 (11.4)			13.3 (11.3)		
Quartile 2	21.7 (12.9)			17.0 (10.7)			16.1 (10.8)			15.0 (10.6)		
Quartile 3	17.0 (10.9)			14.2 (9.7)			12.8 (9.4)			12.0 (9.2)		
Quartile 4 (highest %)	10.8 (9.1)			9.0 (7.4)			7.4 (6.2)			6.7 (6.1)		

SD, standard deviation. [1]1608 Zip Code Tabulation Areas with at least 100 adult residents in every year from 2018 to 2021. [2]Qualifying conditions that the National Academies of Sciences, Engineering, and Medicine indicates that there is no or insufficient evidence to support or refute treatment effectiveness of MMJ: amyotrophic lateral sclerosis, epilepsy, glaucoma, Huntington's disease, opioid use disorder, and Parkinson's disease.

adjusting for community features (models 2 and 3). The direction of the results was similar when using a 30-min drive-time (not shown).

ZCTAs with higher proportions of individuals who were not White and ZCTAs with the higher proportion of individuals who were Hispanic had higher odds of

Table 2. Associations between geographic access to MMJ dispensaries in Zip Code Tabulation Areas (ZCTA)[1] and proportion of certified adults in Pennsylvania[2]

	2018	2019	2020	2021
	Incident rate ratio (95% CI)			
Model 1: unadjusted associations. Distance and density modeled separately[2]				
Distance to nearest dispensary (miles)				
≤5	1.45 (1.37, 1.55)	1.07 (0.99, 1.16)	1.13 (1.05, 1.22)	1.09 (1.02, 1.17)
>5 to ≤10	1.43 (1.36, 1.52)	1.23 (1.16, 1.30)	1.21 (1.16, 1.27)	1.17 (1.12, 1.23)
>10 (reference)				
Density w/in 15 min				
0 (reference)				
1	1.35 (1.27, 1.44)	1.15 (1.08, 1.22)	1.16 (1.09, 1.24)	1.13 (1.06, 1.21)
≥2	1.31 (1.22, 1.41)	0.96 (0.88, 1.05)	1.06 (0.98, 1.14)	1.04 (0.97, 1.11)
Model 2: adjusted for median income (quartiled). Distance and density modeled separately[2]				
Distance to nearest dispensary				
≤5	1.39 (1.30, 1.48)	1.13 (1.07, 1.20)	1.15 (1.08, 1.23)	1.10 (1.03, 1.18)
>5 to ≤10	1.32 (1.25, 1.41)	1.16 (1.10, 1.22)	1.13 (1.07, 1.20)	1.12 (1.06, 1.18)
>10 (reference)				
Density w/in 15 min				
0 (reference)				
1	1.29 (1.21, 1.37)	1.14 (1.08, 1.20)	1.16 (1.09, 1.23)	1.11 (1.04, 1.19)
≥2	1.24 (1.16, 1.33)	1.04 (0.98, 1.10)	1.09 (1.03, 1.15)	1.05 (0.99, 1.12)
Model 3: adjusted for race and ethnicity (quartiled). Distance and density modeled separately[2,3]				
Distance to nearest dispensary				
≤5	1.48 (1.38, 1.59)	1.21 (1.13, 1.29)	1.27 (1.20, 1.35)	1.24 (1.18, 1.31)
>5 to ≤10	1.42 (1.34, 1.50)	1.28 (1.21, 1.35)	1.26 (1.20, 1.31)	1.21 (1.16, 1.26)
>10 (reference)				
Density w/in 15 min				
0 (reference)				
1	1.33 (1.25, 1.42)	1.20 (1.13, 1.27)	1.23 (1.16, 1.30)	1.19 (1.12, 1.26)
≥2	1.31 (1.21, 1.42)	1.07 (0.98, 1.16)	1.17 (1.10, 1.24)	1.17 (1.11, 1.23)

[1]1608 ZCTAs with at least 100 adult residents in every year from 2018 to 2021. [2]Negative binomial models separate for each outcome and year that used count variables (i.e., number of certifications) as the outcomes and log-transformed denominators (i.e., population) as offset terms. [3]Adjusted for proportion non-White and proportion Hispanic.

having a dispensary within five miles (vs. greater than five miles) in all years than ZCTAs with the lowest proportion of individuals who were not White and Hispanic individuals, respectively (Table 4). Adjusting for median income and proportion Hispanic, in communities with the highest proportion of individuals who were not White (quartile 4), the odds of having a dispensary within five miles was more than 12 times the odds among communities with the lowest proportion of individuals who were not White (quartile 1) in every year. In these same models, in communities with the highest proportion of Hispanic individuals (quartile 4), the odds of having a dispensary within five miles was more than double in all years. ZCTAs with higher median incomes had lower odds of having a dispensary within five miles, but all of the CIs included the null value.

Discussion

As legalization of MMJ expands worldwide [1], understanding the implications of the availability of MMJ in communities is essential. Geographic access to MMJ dispensaries dramatically increased in Pennsylvania from 2018 to 2021. We conducted the first study of the association between MMJ dispensary locations in Pennsylvania and MMJ certifications and the first study

Table 3. Associations between geographic access to MMJ dispensaries in Zip Code Tabulation Areas (ZCTA)[1] and proportion of certifications for insufficient evidence conditions in Pennsylvania[2]

	2019	2020	2021
	Incident rate ratio (95% CI)		
Model 1: unadjusted associations. Distance and density modeled separately[3]			
Distance to nearest dispensary (miles)			
≤5	0.67 (0.61, 0.73)	0.62 (0.56, 0.67)	0.62 (0.57, 0.67)
>5 to ≤10	0.73 (0.66, 0.80)	0.67 (0.60, 0.74)	0.70 (0.63, 0.77)
>10 (reference)			
Density w/in 15 min			
0 (reference)			
1	0.83 (0.75, 0.92)	0.76 (0.68, 0.85)	0.78 (0.70, 0.87)
≥2	0.67 (0.61, 0.72)	0.68 (0.62, 0.74)	0.66 (0.61, 0.72)
Model 2: adjusted for median income (quartiled). Distance and density modeled separately[3]			
Distance to nearest dispensary			
≤5	0.72 (0.66, 0.79)	0.71 (0.64, 0.78)	0.71 (0.65, 0.77)
>5 to ≤10	0.86 (0.78, 0.94)	0.83 (0.75, 0.91)	0.83 (0.75, 0.91)
>10 (reference)			
Density w/in 15 min			
0 (reference)			
1	0.88 (0.80, 1.12)	0.80 (0.73, 0.88)	0.82 (0.75, 0.91)
≥2	0.69 (0.63, 0.75)	0.74 (0.68, 0.81)	0.72 (0.68, 0.79)
Model 3: adjusted for race and ethnicity (quartiled). Distance and density modeled separately[3,4]			
Distance to nearest dispensary			
≤5	0.87 (0.78, 0.97)	0.83 (0.75, 0.93)	0.78 (0.70, 0.87)
>5 to ≤10	0.82 (0.75, 0.90)	0.76 (0.68, 0.84)	0.75 (0.68, 0.83)
>10 (reference)			
Density w/in 15 min			
0 (reference)			
1	0.96 (0.86, 1.06)	0.91 (0.83, 1.01)	0.86 (0.77, 0.96)
≥2	0.86 (0.78, 0.95)	0.90 (0.81, 0.99)	0.82 (0.75, 0.90)

[1]1608 ZCTAs with at least 100 adult residents in every year from 2018 to 2021. [2]Qualifying conditions that the National Academies of Sciences, Engineering, and Medicine indicates that there is no or insufficient evidence to support or refute treatment effectiveness of MMJ: amyotrophic lateral sclerosis, epilepsy, glaucoma, Huntington's disease, opioid use disorder, and Parkinson's disease. [3]Negative binomial models separate for each outcome and year that used count variables (i.e., number of certifications) as the outcomes and log-transformed denominators (i.e., total number of certifications) as offset terms. [4]Adjusted for proportion non-White and proportion Hispanic.

in the USA of the association between dispensary locations and qualifying conditions. We found that geographic access to MMJ dispensaries since the first dispensary opened in 2018 has consistently differed by the race and ethnic composition of Pennsylvania communities.

As of January 2024, 38 states and Washington DC have legalized MMJ, and within those states [2], certifications have been rapidly growing [21]. In Pennsylvania, the proportion of adults certified for MMJ increased more than sixfold from 2018 to 2021. We observed that greater access, measured by both distance and density, was associated with MMJ certifications, independent of demographic and socioeconomic composition of the population, factors that have been associated with MMJ use [22]. These findings are consistent with other states with a longer history of MMJ legalization. Multiple studies in California, for example, support the association between MMJ proximity and demand and utilization [4–6].

Table 4. Adjusted associations between community features and ≥1 MMJ dispensary within five miles of Zip Code Tabulation Areas (ZCTA)[1]

	2018	2019	2020	2021
	Odds ratio (95% CI)			
Proportion non-White				
Quartile 1 (lowest) (ref)				
Quartile 2	1.34 (0.56, 3.19)	1.55 (0.77, 3.11)	0.94 (0.52, 1.69)	0.99 (0.59, 1.64)
Quartile 3	3.16 (1.48, 6.72)	4.00 (2.11, 7.58)	2.80 (1.64, 4.78)	2.65 (1.64, 4.29)
Quartile 4 (highest)	18.35 (8.86, 38.02)	20.14 (10.7, 37.8)	15.2 (8.9, 25.7)	12.54 (7.72, 20,4)
Proportion Hispanic				
Quartile 1 (lowest) (ref)				
Quartile 2	1.40 (0.69, 2.84)	1.47 (0.81, 2.67)	1.65 (0.98, 2.80)	1.50 (0.94, 2.41)
Quartile 3	2.24 (1.18, 4.24)	2.78 (1.60, 4.84)	2.74 (1.62, 4.63)	2.92 (1.80, 4.72)
Quartile 4 (highest)	2.81 (1.51, 5.24)	2.63 (1.51, 4.57)	2.33 (1.38, 2.93)	2.47 (1.51, 4.02)
Median household income				
Quartile 1 (lowest) (ref)				
Quartile 2	0.64 (0.41, 1.00)	0.67 (0.44, 1.004)	0.63 (0.43, 0.94)	0.60 (0.42, 0.88)
Quartile 3	0.56 (0.35, 0.89)	0.65 (0.43, 0.98)	0.77 (0.51, 1.15)	0.75 (0.51, 1.09)
Quartile 4 (highest)	0.86 (0.59, 1.27)	0.89 (0.62, 1.29)	1.15 (0.80, 1.65)	1.38 (0.97, 1.97)

[1]1608 ZCTAs with at least 100 adult residents in every year from 2018 to 2021.

In addition to the growth in the population certified, Pennsylvania has increased the number of qualifying conditions since legalization in 2016 [23]. Geographic access to MMJ dispensaries was associated with the qualifying conditions for which individuals were certified. Specifically, greater distances and a lower density of MMJ dispensaries were associated with a higher proportion of certifications for qualifying conditions with low evidence [3] of the effectiveness of MMJ treatment. Prior studies have demonstrated that access to care for some of these qualifying conditions, including opioid use disorder [24, 25] and epilepsy [26], is more limited in minority racial and ethnic groups and in low-income populations [27]. However, even after adjusting for these factors, the association between distance, density, and certifications for low evidence conditions remained. It may be that those communities with less access to MMJ dispensaries also have less access to specialty care and treatment that was not captured in our analyses. In Oklahoma, for example, Cohn and colleagues [12] reported that census tracts with at least one dispensary (vs. none) had a greater number of hospitals and pharmacies. Limited access to traditional health care for these conditions could motivate people living in such communities to seek MMJ as an alternative treatment option or could make clinicians more likely to certify for conditions that lack evidence supporting the use of MMJ (i.e., would be better managed in a more traditional health care setting).

Consistent with studies in California and Colorado, we did not observe an association between median income and geographic access to MMJ dispensaries [13, 14]. However, in Oklahoma, higher proportions of residents living poverty and uninsured were associated with geographic access to MMJ dispensaries [12]. In New York State [11], census tracts with a higher proportion of residents with bachelor's degrees or higher were more likely to have at last one certifying provider than those with less education. Differences across states could be due to how access was measured (e.g., in New York, they measured proximity to a certifying provider rather than a dispensary), differences in zoning laws, financial barriers to certification (e.g., fees for required medical exams, applications for certifications, renewals, etc.) [28], or other unmeasured differences among the states.

In Pennsylvania, we observed that ZCTAs with higher proportions of residents who were not White and residents who were Hispanic were more likely to have a MMJ dispensary within five miles. This association was independent of median income. Studies in other states have reported inconsistent findings for associations between racial and ethnic composition and geographic access to

MMJ dispensaries [11, 13, 14]. Better geographic access has been positively associated with higher proportions of Hispanic residents in California [13], but not in Colorado [14] or Oklahoma [12]. In Colorado, there was no association between dispensary access and proportion of Black residents [14]. Similarly, Thomas and Freisthler reported no association with proportion of Black residents in California using data from 2012 [13]. However, after zoning restrictions were changed in 2013, Thomas and Freisthler found that in 2014, census tracts with more dispensaries were positively associated with the proportion of Black residents [29]. Differences in findings across states may, in part, be due to the impact of local and state zoning laws.

Pennsylvania zoning laws (2016 Act 16) for MMJ dispensaries specify that a dispensary may not operate on the same site as a facility used for growing and processing marijuana and may not be located within 1,000 feet of the property line of a public, private, or parochial school or a day care center [30]. Municipalities within the state have adopted a variety of zoning ordinances regarding where MMJ dispensaries can be located [31]. The potential benefits and harms of proximity to MMJ dispensaries are still poorly understood. For individuals with conditions for which there is evidence of the effectiveness of MMJ, such as chronic pain and chemotherapy-induced nausea, proximity may improve access to effective treatment options [3]. However, some studies have reported that closer proximity is also associated with an increase in the number of marijuana hospitalizations [16], crime [15], and rates of physical abuse [174]. Importantly, these studies demonstrate correlations, not necessarily causation. Future research should explore the impact of ordinances on geographic access to MMJ across population subgroups, and the potential benefits and harms [32] of proximity in other states.

This study had some limitations. First, this was an ecological study and is vulnerable to ecological fallacy. Thus, the findings should not be interpreted as individual-level risk factors for certifications. Second, this is a cross-sectional study and it is unknown whether the association between location and certifications is due to greater geographic access or the placement of dispensaries in response to demand. Third, in estimating the proportion of certifications for low evidence conditions, we did not classify qualifying conditions that were not assigned an evidence classification in the NASEM report (e.g., autism). Thus, we may be underestimating the proportion of certifications for conditions with low evidence [3]. Finally, our measure of drive-time to the nearest dispensary did not account for traffic congestion, potentially underestimating the time to the nearest dispensary in communities with more traffic. There are multiple strengths to this novel study. We used two measures of geographic access to MMJ dispensaries, distance and density. In analyzing associations between geographic access and certifications, we adjusted for potential community-level confounders. We evaluated these associations using data from the first 4 years of MMJ in Pennsylvania, a period of rapid acceleration in MMJ dispensary growth and certifications.

Our study found differences in geographic access to dispensaries by the racial and ethnic composition of communities. There may be implications to where MMJ dispensaries are located, including the proportion of individuals certified for MMJ and the qualifying conditions for which they are certified. As US states and countries around the world continue to consider and respond to the legalization of MMJ, it is critical to evaluate the impact of MMJ locations in the use of and access to MMJ.

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Statement of Ethics

The Geisinger Institutional Review Board (GIRB) indicated that the study proposal did not meet the definition of *Research* as defined in 45 CFR 46.102(d): *a systematic investigation, including research development, testing, and evaluation, designed to develop or contribute to generalizable knowledge*. Therefore, this proposal was deemed not subject to human subjects' research regulations and was exempt from oversight by GIRB and also exempt from requiring written informed consent.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

A.G.H., E.A.W., B.P., and L.D.T. were involved in the conception of the work; A.G.H., E.A.W., and B.P. were involved in the design of the study; E.A.W., B.P., J.D., J.Z., E.L.S., and A.L.K. were involved in the acquisition of the data; J.D. and C.M.N. were involved in the analysis of the data; A.G.H., J.D., and CM.N. were involved in the interpretation of the data; A.G.H. drafted the manuscript; and all authors were involved in substantially revising the manuscript.

Data Availability Statement

The datasets generated and/or analyzed during the current study are not publicly available as the data provided regarding MMJ certifications were provided by a third-party source that requires approval of data use by the IRB designated to the Academic Clinical Research Center (Geisinger). However, data are available from the corresponding author on reasonable request from A.G.H [aghirsch@geisinger.edu] upon reasonable request and IRB approval.

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