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A machine learning approach to unravel client and program-specific effects in opioid treatment retention

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Abstract

This study examines the impact of workforce diversity, particularly the presence of Black/African American staff, on client retention in opioid use disorder (OUD) treatment, recognizing the historically low retention rates among Black and Hispanic populations in such programs. Using a novel machine learning technique called "causal forest," we explored the heterogeneous treatment effects of staff diversity on client retention, aiming to identify strategies that enhance client retention and improve treatment outcomes. Analyzing data from four waves of the National Drug Abuse Treatment System Survey spanning the years 2000, 2005, 2014, and 2017 ($n = 627$), we focus on the relationship between workforce diversity and retention. The findings revealed diversity-related variations in retention across 61 out of 627 OUD treatment programs (<10%), with potential beneficial effects attenuated by other program characteristics. These characteristics include programs that are more likely to be private-for-profit, have lower percentages of Black and Latino clients, lower staff-to-client ratios, higher proportions of staff with graduate degrees, and lower percentages of unemployed clients. Our results suggest that workforce diversity alone is insufficient for improving retention. Programs with characteristics linked to greater retention are better positioned to leverage a diverse workforce to enhance retention, offering important implications for policy and program design to better support Black clients with OUDs.

Keywords: Workforce diversity; Opioid use disorder; Treatment retention; Causal forest; Heterogeneous treatment effect

1. Introduction

The opioid epidemic continues to adversely impact the public health system of the United States. The Centers for Disease Control and Prevention estimates that there were over 81,000 opioid-related overdose deaths in 2023.[1] Increased opioid use disorder (OUD) treatment retention can improve treatment outcomes, including reduced rates of mortality and of relapse.[2-5] Concurrently, retention rates in OUD treatment are highly variable between programs and demographic groups, with 6-month retention rates commonly dropping below 50% for some groups.[4,6] Several studies measuring retention in OUD programs have found lower retention rates among minoritized individuals who identify as Black/African American and as Latino/Hispanic (Black and Latinos, hereafter).[7-9] Other studies have identified subgroup differences between Black, Latino, and White clients, including variations in predictors of retention and the treatment outcomes associated with retention.[10,11] It is therefore important to consider unique differences, particularly of minoritized patients like Black clients, when exploring strategies to boost retention rates in OUD programs.

Past research on the effect of culturally responsive practices on the retention of Black OUD clients has identified promising culturally responsive organizational factors, including offering bilingual language services; developing specific policies and procedures designed to serve minority clients; and having managers who believe in the importance of cultural sensitivity.[12-16] Workforce diversity, defined as having a higher percentages of Black staff members, is thought to improve Black OUD clients' treatment outcomes by fostering a culturally responsive treatment environment.[13,17-20] However, previous studies on the impacts of workforce diversity on OUD client retention have looked for simple associations and have included only a few basic modifying variables, leading to variable retention outcomes.[16,21]

The heterogeneous nature of these results indicates that workforce diversity may have differential impacts on retention rates in OUD programs with different organizational characteristics. We build on prior studies that have suggested that workforce diversity in the absence of other factors, such as high levels of training and education among staff members, may be insufficient to improve treatment outcomes.[17,18] Unpacking the heterogeneity in associations between workforce diversity and treatment retention can help healthcare policymakers, leaders of OUD treatment programs, and researchers to understand which programs would benefit most from the expansion of workforce diversity, and importantly, the additional conditions necessary to optimize the benefits of workforce diversity.

In this study, we applied heterogeneous treatment effect (HTE) estimation methods to understand which workforce diversity characteristics facilitate positive retention effects. HTE estimation is a machine learning method which was originally designed to study variations in the effects of clinical interventions and has been generalized to other applications such as public policy and marketing.[22-25] Heterogeneous treatment effect (HTE) estimation methods, including causal forests, have been effectively applied in fields such as personalized medicine, public policy, and marketing.[26,27] In personalized medicine, HTE helps tailor treatments to individual patients, improving outcomes by accounting for diverse responses. In public policy, it identifies how different populations are impacted by interventions, guiding more equitable policymaking. In marketing, HTE enables businesses to optimize strategies by understanding how various customer segments respond to different campaigns. The strength of HTE methods lies in their ability to handle complex interactions and high-dimensional data, offering deeper insights than traditional regression models.

In this work, we adopted a state-of-the-art HTE estimation method called "causal forest," to examine the heterogeneous impact of workforce diversity on OUD treatment retention.[28,29] Causal forest is a machine learning method that extends the random forest framework to estimate the varying effects of a treatment across different subgroups within a population. This method involves constructing an ensemble of decision trees, where each tree is specifically designed to identify splits in the data that reveal differences in treatment effects between subpopulations. To ensure accurate and unbiased estimates, causal forest uses a technique known as "honesty," where the data used to determine the optimal splits in the trees is separate from the data used to estimate the treatment effects. This approach allows for a detailed exploration of how the impact of a treatment may differ across various segments of the data.

There are several advantages of this method over traditional regression models. First, due to potential high collinearity and a high false discovery rate, only a limited number of interactions can be included in traditional regression models. Second, causal forest provides variance for individually-estimated treatment effects, that is, one can calculate the asymptotic p-values for the statistical significance of treatment effects for each observation.

By examining HTE, we can untangle the various factors that may influence how workforce diversity impacts OUD client retention. The benefit of this study to the field of healthcare, and disparities within this field in particular, includes informing healthcare policies, and practices, on which program characteristics can be adjusted to maximize the benefits of workforce diversity for OUD client retention. This study is also of relevance to the field of computational science, using machine learning to showcase an application of a novel approach to understanding heterogeneity.

2. Methods

We relied on nationally representative data from the National Drug Abuse Treatment System Survey (NDATSS), a dataset containing eight waves of survey data from outpatient substance use treatment programs (OTPs) from 1988 to 2017.[30,31] Each wave incorporated a large percentage of programs from the previous wave, except programs excluded due to closure. More details on the NDATSS dataset can be found elsewhere.[21] In this paper, we looked at the last four waves of the NDATSS (110 OTPs in 2000, 142 in 2005, 184 in 2014, and 190 in 2017).

2.1. Dependent variable

We used an established measure of retention, the percentage of clients in treatment for more than 3 months in a treatment program, as the dependent variable. This measure has been used in other studies.[4,21,32]

2.2. Independent variables

The key independent variable is workforce diversity, which we define as the percentage of staff self-identified as Black or African American. This measure has been used in other studies.[17,18,21,32] To apply the existing estimation method for HTE, we dichotomized the treatment variable. Thus, we consider programs with more than 20% Black staff as having high workforce diversity. This threshold was chosen because more than 50% of the programs in our sample had less than 20% Black staff. The other relevant independent variables that define the heterogeneity of the treatment effect on client retention rates include program and client characteristics such as percentage of Black clients, percentage of Latino clients, accreditation by The Joint Commission (TJC), ownership status, program type (private-for-profit, private-not-for-profit, public), staff-to-client ratio, proportion of staff who have graduate degrees, percentage of unemployed clients, and whether the program is located in a state that expanded Medicaid coverage.

2.3. Statistical analysis

We conducted a comprehensive comparative analysis of all variables across the four-year period to assess any significant differences or associations. Categorical variables were examined using the Chi-square tests to determine if there were statistically significant associations between variables over time. For continuous variables, we utilized analysis of variance (ANOVA) to compare mean differences across the four years. This approach allowed us to identify patterns, trends, and variations in the data, providing a detailed understanding of how each variable evolved over the study period. To examine the heterogeneity of the association between workforce diversity and retention in OUD treatment, we used the causal forest method in which weights were incorporated to make the data nationally representative.[28,29]

The dataset used in our study was organized at the program level, meaning that each record corresponds to a single program. Therefore, when we refer to percentages of specific client demographics, we are indicating the proportion of those clients relative to the total number of clients within each program.

Causal forest is particularly well-suited for this analysis as it estimates the client and program-specific treatment effects of workforce diversity on retention. By doing so, it highlights how the presence of a diverse workforce might influence retention rates in different programs. In addition, the causal forest method generates variance estimates, which allow us to assess whether the observed treatment effects are statistically significant and different from zero. This approach not only quantifies the impact of workforce diversity but also provides a measure of the confidence we can have in these effects, revealing the conditions under which workforce diversity plays a crucial role in enhancing OUD treatment retention.

3. Results

We found significant differences among variables across the four different years that we examined. Table 1 presents the comparative analysis by year. The percentages of clients in treatment for more than 3 months were significantly different across years ($P < 0.001$). The percentages of Black clients were also significantly different across years ($P < 0.001$), with the percentages of Black clients being lower in the last two waves (2014 and 2017). More programs were from states that expanded Medicaid coverage in 2017 compared with 2014 ($P < 0.001$). There was an increasing trend of program age across years ($P < 0.001$). The results also showed that fewer programs were owned by another organization in the last two waves ($P < 0.001$). The staff-to-client ratio was significantly different across years ($p = 0.024$). The results also showed that the percentages of unemployed clients were higher in the last two waves ($P < 0.001$).

Results from the causal forest method (Table 2) showed that 61 OTPs had statistically significant positive treatment effects for workforce diversity. This means that these 61 OTPs would significantly benefit from having

Table 1. Comparative analysis of Opioid Treatment Programs in NDATSS data

	2000 *n*=110	2005 *n*=142	2014 *n*=184	2017 *n*=190
Percentage of clients in treatment more than 3 months***	84.3 (16.5)	87.9 (13.2)	75.2 (30.5)	79.0 (27.7)
More than 20% of Black staff	61 (55.5%)	70 (49.3%)	78 (42.4%)	93 (48.9%)
Client characteristics				
Percentage of Black clients***	29.4 (28.1)	25.5 (26.4)	18.7 (24.1)	20.8 (23.0)
Program characteristics				
Medicaid expansion***	-	-	116 (63%)	140 (73.7%)
TJC accreditation	27 (24.5%)	52 (36.6%)	60 (32.6%)	55 (28.9%)
Program age***	17.8 (11.6)	20.8 (12.0)	23.7 (14.1)	27.0 (15.1)
Owned by another organization***	78 (70.9%)	103 (72.5%)	43 (23.4%)	59 (31.1%)
Type of programs				
Private for-profit	40 (36.4%)	53 (37.3%)	63 (34.2%)	64 (33.7%)
Private not-for-profit	45 (40.9%)	64 (45.1%)	101 (54.9%)	99 (52.1%)
Public	25 (22.7%)	25 (17.6%)	20 (10.9%)	27 (14.2%)
Staff-to-client ratio in percentage*	4.3 (4.1)	3.9 (2.7)	4.2 (4.4)	6.1 (10.6)
Proportion of graduate staff	0.3 (0.2)	0.4 (0.2)	0.3 (0.2)	0.3 (0.2)
Percentage of unemployed clients***	44.6 (23.0)	43.6 (24.7)	54.7 (26.4)	52.1 (25.8)

Notes: The values inside the parentheses in the table that do not have a "%" sign are the corresponding standard deviations. *$P<0.05$, **$P<0.01$, ***$P<0.001$.
Abbreviations: NDATSS: National Drug Abuse Treatment System Survey; TJC: The Joint Commission.

Table 2. Comparative analysis of programs with no or significant benefit from workforce diversity

	No benefit from diversity (*n*=565)	Benefit from diversity (*n*=61)	p-value
Medicaid expansion	233 (41.2%)	23 (37.7%)	0.69188
Year			0.34624
2000	104 (18.4%)	6 (9.8%)	
2005	129 (22.8%)	13 (21.3%)	
2014	163 (28.8%)	21 (34.4%)	
2017	169 (29.9%)	21 (34.4%)	
Percentage of Black clients	24.9 (25.7)	2.6 (2.9)	2.12E-66
TJC accreditation	182 (32.2%)	12 (19.7%)	0.06199
Owned by another organization	261 (46.2%)	22 (36.1%)	0.16922
Type of programs			2.22E-10
Private for-profit	175 (31%)	45 (73.8%)	
Private not-for-profit	298 (52.7%)	11 (18%)	
Public	92 (16.3%)	5 (8.2%)	
Staff-to-client ratio in percentage	5.0 (7.0)	2.0 (1.1)	2.38E-19
Proportion of graduate staff	0.3 (0.2)	0.5 (0.2)	2.43E-05
Percentage of unemployed clients	52.0 (25.2)	27.1 (17.8)	4.31E-16
Program age	23.9 (13.9)	14.5 (10.8)	1.51E-08

Note: The values inside the parentheses in the table that do not have a "%" sign are the corresponding standard deviations.
Abbreviation: TJC: The Joint Commission.

a high percentage of Black staff in terms of increasing the percentage of clients who stay in treatment longer than 3 months (retention). Among the remaining 565 OTPs, 562 did not have statistically significant treatment effects, while four had statistically significantly negative treatment effects. It is important to note that these four programs with negative treatment effects may potentially represent false discoveries.

The comparison of characteristics of these 61 OTPs with the other 565 OTPs is presented in Table 2. The 61 OTPs that would benefit the most from workforce diversity had significantly lower percentages of Black clients ($P < 0.001$), were more likely to be private-for-profit ($P < 0.001$), had lower staff-to-client ratio ($P < 0.001$), much higher proportion of staff who had graduate degrees ($P < 0.001$), much lower percentage of unemployed clients ($P < 0.001$), and were more likely to be newer programs ($P < 0.001$). The box plots of the percentage of clients in treatment for more than 3 months, categorized based on the presence of high and low percentage of Black staff, in these 61 OTPs and the other 565 OTPs are presented in Figure 1. Higher percentages of Black staff were associated with the increased percentage of clients in treatment to more than 3 months in these 61 OTPs.

4. Discussion

To study the role of the variation of workforce diversity in improving OUD treatment retention, we explored the heterogeneous treatment effect with a novel machine-learning method called causal forest. Our analytical method aimed to advance understanding of the variation in the association between workforce diversity, that is, percentage of Black staff in an OUD treatment program, and OUD treatment retention (percentage of clients in treatment for more than 3 months).

We found that only a small proportion of the sample, that is, 61 out of 627 OTPs (<10%), would statistically significantly benefit from workforce diversity when it comes to retaining clients. This means that, notwithstanding the level of workforce diversity, characteristics of these programs, other than workforce diversity, would cause them to benefit more from diversity. The characteristics that amplified the impact of workforce diversity on retention included: lower percentages of Black clients, lower staff-to-client ratio, higher proportion of staff who had graduate degrees, and lower percentage of unemployed clients. In addition, those OTPs were more likely to be private for-profit and newer.

The characteristics of these 61 OTPs suggest that the impact of workforce diversity is context-dependent, and its effectiveness is shaped by a combination of program-specific factors. For instance, programs with lower percentages of Black clients might benefit more from diversity because the presence of Black staff could provide critical cultural insights and connections that are otherwise lacking. Similarly, a lower staff-to-client ratio and higher staff education levels could facilitate more personalized and culturally competent care, which is particularly beneficial in diverse workforce environments. These findings imply that workforce diversity alone is insufficient for improving retention across all settings; rather, it is the synergy between diversity and other favorable program characteristics that drives positive outcomes.

Moreover, the observation that private for-profit programs were more likely to benefit from diversity could

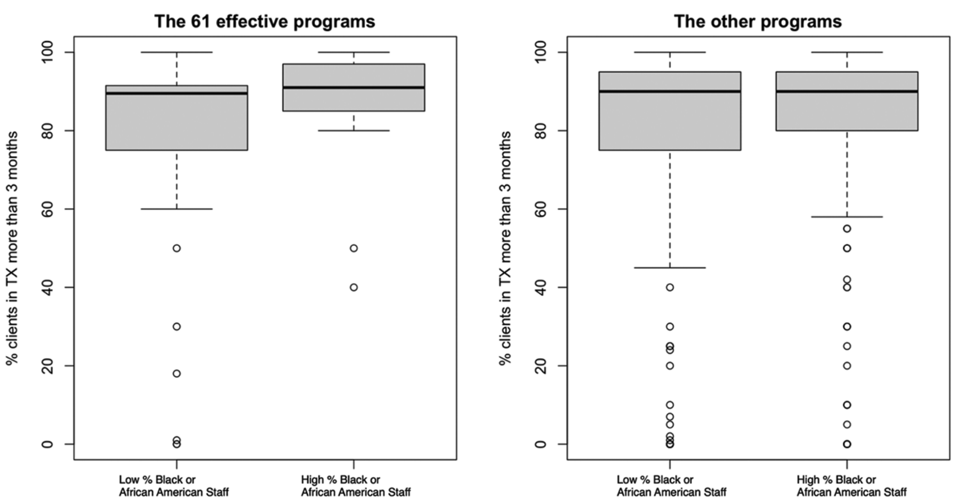

Figure 1. Box plots illustrating the heterogeneous effects of workforce diversity on treatment retention. (Left) Box plots of the percentage of clients in treatment for more than 3 months, categorized based on the presence of high and low percentage of Black staff, in the 61 effective programs. (Right) Box plots of the percentage of clients in treatment for more than three months, categorized based on the presence of high and low percentages of Black staff, in the other 565 ineffective programs.
Abbreviations TX: Texas.

reflect the greater operational flexibility and resource availability in these settings, allowing for more effective implementation of diversity initiatives. This raises important considerations for public and not-for-profit programs, which may need additional support to create environments where workforce diversity can flourish. These programs might require targeted investments in staff training, educational opportunities, and resource allocation to replicate the conditions under which diversity positively impacts retention in private for-profit settings.

The characteristics of these 61 OTPs indicate that workforce diversity is most likely to improve client retention when implemented in less constrained programs, that is, those with attributes often reported in the existing literature to be associated with positive outcomes.[4,32] This may explain why we did not see a significant association between the percentage of Black staff and the percentage of clients in treatment for more than 3 months when considering the full sample of 627 OTPs.

Few studies have examined the general association between Black workforce diversity and treatment retention among Black clients.[16,21] These studies identified significant associations that may have been driven by a small subgroup or population. In ddition, organizational characteristics may alter the impact of workforce diversity in a different direction. Findings in this paper inform rigorous analytical approaches to understand relationships of individual and program features with client outcomes. The benefit of this approach is to help public health policymakers identify OTPs that might benefit from workforce diversity, or alternatively, OTPs with high workforce diversity that could benefit from greater resources.

Our study is also aligned with the national call to diversify the workforce in addiction health services and thus informs how and when diversity could most benefit client-centered outcomes. However, it is also important to recognize that the relationship between workforce diversity and client retention is complex and influenced by multiple factors beyond the demographic composition of the staff. The findings from this study highlight the need for a more nuanced understanding of how diversity interacts with program-specific characteristics to influence outcomes. Future research should continue to explore these interactions, with a particular focus on identifying the conditions under which workforce diversity is most likely to enhance retention, and how these conditions can be fostered across different types of treatment programs.

Policymakers should recognize that while workforce diversity is important, it is not a standalone solution for improving client retention in OUD treatment programs. Policies solely focused on increasing diversity may not yield desired outcomes unless other factors are addressed. This study highlights program characteristics associated with a positive impact of workforce diversity on retention. As such, policymakers may want to allocate resources related to program characteristics that enhance the benefits of a diverse workforce. It is also crucial to strike a balance between resource allocation and diversity goals, as less constrained programs, often linked to positive outcomes, maximize the benefits of diversity. Policies should support adequate resource allocation, including staffing and educational opportunities, while fostering diversity. In addition, targeted strategies should prioritize retention rates among Black clients, addressing their unique challenges through tailored interventions, culturally competent care, and efforts to reduce disparities in access and quality of treatment. Moreover, as the landscape of opioid treatment continues to evolve, it will be essential for policymakers to remain flexible and responsive to new evidence on the factors that influence retention. This includes being open to revising policies and practices as more is learned about the role of workforce diversity in different contexts and the needs of client populations change over time. Overall, policies should consider program characteristics, resource allocation, and diversity goals to improve retention rates, particularly among Black clients, in OUD treatment programs.

Several limitations of this study should be acknowledged. Most existing methods can only estimate the heterogeneous treatment effects for binary variables. Thus, we had to dichotomize the percentage of Black staff to obtain a binary treatment variable. We chose the cutoff of 20% because 48.2% (i.e., about one half) of programs had more than 20% Black staff. Ideally, we would explore the heterogeneity with the original continuous variable, that is, percentage of Black staff. The identified 61 OTPs would have a greater impact on retention given their diverse workforce. However, there may be other heterogeneity among these 61 OTPs in the association between workforce diversity and retention. We did not examine such heterogeneity in this paper because the higher treatment effects on these 61 OTPs were composite effects of several variables. In fact, we cannot observe significant treatment effects by altering the value of just one variable, while keeping the others constant. Moreover, our finding that a lower percentage of Black clients being associated with lower constraints, and therefore greater retention, should be further examined. Future studies should scrutinize this finding to better understand the mechanisms that drive this association and suggest concrete approaches to improve outcomes equally and equitably.

5. Conclusion

Our findings contribute to a deeper understanding of how workforce diversity, particularly in the form of higher percentages of Black staff, can positively impact retention rates among Black clients in opioid treatment programs (OTPs). This underscores the importance of employing advanced statistical methods to identify and quantify when and how diversity enhances treatment outcomes, especially for minority clients. By doing so, we can better address the unique needs of these clients and optimize program resources to serve minority communities effectively.

As federal and state authorities prepare to allocate substantial financial resources from various sources – including pharmaceutical settlements and new tax revenues – to improve access to opioid treatment,[33,34] it is imperative to understand how these investments can best support OTPs in enhancing overall patient outcomes. This is particularly vital for improving outcomes among minority populations, who often face additional barriers to accessing quality care. A diverse workforce not only reflects the communities these programs serve but also has the potential to foster a more inclusive and supportive treatment environment that can significantly impact retention and recovery. Therefore, fully leveraging the benefits of workforce diversity will be crucial in shaping policies and interventions that maximize the effectiveness of opioid treatment programs, especially in underserved and minority communities.

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Conflict of interest

The authors declare they have no competing interests.

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Ethics approval and consent to participate

This study was reviewed and approved by the Institutional Review Board of Texas A&M University (TAMU IRB#2019-0268DCR).

Consent for publication

Not applicable.

Availability of data

Not applicable.

References

1. CDC/National Center for Health Statistics. U.S. Overdose Deaths Decrease in 2023, First Time Since 2018; 2024. Available from: https://www.cdc.gov/nchs/pressroom/nchs_press_releases/2024/20240515.htm [Last accessed on 2024 May 24].

2. Bart G. Maintenance medication for opiate addiction: The foundation of recovery. *J Addict Dis*. 2012;31(3):207-225.

   doi: 10.1080/10550887.2012.694598

3. Chan B, Gean E, Arkhipova-Jenkins I, *et al*. Retention strategies for medications for opioid use disorder in adults. *J Addict Med*. 2020;15(1):74-84.

   doi: 10.1097/adm.0000000000000739

4. Timko C, Schultz NR, Cucciare MA, Vittorio L, Garrison-Diehn C. Retention in medication-assisted treatment for opiate dependence: A systematic review. *J Addict Dis*. 2015;35(1):22-35.

   doi: 10.1080/10550887.2016.1100960

5. Williams AR, Samples H, Crystal S, Olfson M. Acute care, prescription opioid use, and overdose following discontinuation of long-term buprenorphine treatment for opioid use disorder. *Am J Psychiatry*. 2020;177(2):117-124.

   doi: 10.1176/appi.ajp.2019.19060612

6. Carroll KM, Weiss RD. The role of behavioral interventions in buprenorphine maintenance treatment: A review. *Am J Psychiatry*. 2017;174(8):738-747.

   doi: 10.1176/appi.ajp.2016.16070792

7. Manhapra A, Petrakis I, Rosenheck R. Three-year retention in buprenorphine treatment for opioid use disorder nationally in the Veterans health administration. *Am J Addict*. 2017;26(6):572-580.

   doi: 10.1111/ajad.12553

8. Proctor SL, Copeland AL, Kopak AM, Hoffmann NG, Herschman PL, Polukhina N. Predictors of patient retention in methadone maintenance treatment. *Psychol Addict Behav*. 2015;29(4):906-917.

   doi: 10.1037/adb0000090

9. Weinstein ZM, Kim HW, Cheng DM, *et al*. Long-term retention in office based opioid treatment with buprenorphine. *J Subst Abuse Treat*. 2017;74:65-70.

doi: 10.1016/j.jsat.2016.12.010

10. Acevedo A, Garnick D, Ritter G, Horgan C, Lundgren L. Race/ethnicity and quality indicators for outpatient treatment for substance use disorders. *Am J Addict*. 2015;24(6):523-531.

doi: 10.1111/ajad.12256

11. Mennis J, Stahler GJ, El Magd SA, Baron DA. How long does it take to complete outpatient substance use disorder treatment? Disparities among blacks, hispanics, and whites in the US. *Addict Behav*. 2019;93:158-165.

doi: 10.1016/j.addbeh.2019.01.041

12. Guerrero EG. Managerial capacity and adoption of culturally competent practices in outpatient substance abuse treatment organizations. *J Subst Abuse Treat*. 2010;39(4):329-339.

doi: 10.1016/j.jsat.2010.07.004

13. Guerrero EG. Enhancing access and retention in substance abuse treatment: The role of Medicaid payment acceptance and cultural competence. *Drug Alcohol Depend*. 2013;132(3):555-561.

doi: 10.1016/j.drugalcdep.2013.04.005

14. Guerrero EG, Campos M, Urada D, Yang JC. Do cultural and linguistic competence matter in Latinos' completion of mandated substance abuse treatment? *Subst Abuse Treat Prev Policy*. 2012;7:827-836.

doi: 10.1186/1747-597x-7-34

15. Guerrero EG, Khachikian T, Kim T, Kong Y, Vega WA. Spanish language proficiency among providers and Latino clients' engagement in substance abuse treatment. *Addict Behav*. 2013;38(12):2893-2897.

doi: 10.1016/j.addbeh.2013.08.022

16. Guerrero E, Andrews CM. Cultural competence in outpatient substance abuse treatment: Measurement and relationship to wait time and retention. *Drug Alcohol Depend*. 2011;119(1-2):e13-e22.

doi: 10.1016/j.drugalcdep.2011.05.020

17. Howard DL. Are the treatment goals of culturally competent outpatient substance abuse treatment units congruent with their client profile? *J Subst Abuse Treat*. 2003;24(2):103-113.

doi: 10.1016/s0740-5472(02)00349-5

18. Howard DL. Culturally competent treatment of African American clients among a national sample of outpatient substance abuse treatment units. *J Subst Abuse Treat*. 2003;24(2):89-102.

doi: 10.1016/s0740-5472(02)00348-3

19. Jordan A, Jegede O. Building outreach and diversity in the field of addictions. *Am J Addict*. 2020;29(5):413-417.

doi: 10.1111/ajad.13097

20. Weller BE, Harrison J, Adkison-Johnson C. Training a diverse workforce to address the opioid crisis. *Soc Work Mental Health*. 2021;19(6):568-582.

doi: 10.1080/15332985.2021.1975014

21. Guerrero EG, Kong Y, Khachikian T, Wang S, D'Aunno T, Howard DL. Workforce Diversity and Disparities in Opioid Treatment Wait Time and Retention. *Research Square*. Preprint posted online May 18, 2022.

doi: 10.21203/rs.3.rs-1651284/v1

22. Alaa A, Schaar M. Limits of estimating heterogeneous treatment effects: Guidelines for practical algorithm design. *Proc Mach Learn Res*. 2018;80:129-138.

23. Angus DC, Chang CCH. Heterogeneity of Treatment Effect. *JAMA*. 2021;326(22):2312.

doi: 10.1001/jama.2021.20552

24. Kong Y, Zhou J, Zheng Z, Amaro H, Guerrero EG. Using machine learning to advance disparities research: Subgroup analyses of access to opioid treatment. *Health Serv Res*. 2021;57(2):411-421.

doi: 10.1111/1475-6773.13896

25. Künzel SR, Sekhon JS, Bickel PJ, Yu B. Metalearners for estimating heterogeneous treatment effects using machine learning. *Proc Natl Acad Sci U S A*. 2019;116(10):4156-4165.

doi: 10.1073/pnas.1804597116

26. Hill JL. Bayesian nonparametric modeling for causal inference. *J Comput Graph Stat*. 2011;20(1):217-240.

doi: 10.1198/jcgs.2010.08162

27. Grimmer J, Messing S, Westwood SJ. Estimating heterogeneous treatment effects and the effects of heterogeneous treatments with ensemble methods. *Polit Anal*. 2017;25(4):413-434.

doi: 10.1017/pan.2017.15

28. Athey S, Tibshirani J, Wager S. Generalized random forests. *Ann Stat*. 2019;47(2):1148-1178.

doi: 10.1214/18-AOS1709

29. Wager S, Athey S. Estimation and inference of heterogeneous treatment effects using random forests. *J Am Stat Assoc*. 2018;113(523):1228-1242.

doi: 10.1080/01621459.2017.1319839

30. D'Aunno T, Park SE, Pollack HA. Evidence-based treatment for opioid use disorders: A national study of methadone dose levels, 2011-2017. *J Subst Abuse Treat*. 2019;96:18-22.

doi: 10.1016/j.jsat.2018.10.006

31. D'Aunno T, Pollack HA, Frimpong JA, Wuchiett D. Evidence-based treatment for opioid disorders: A 23-year

national study of methadone dose levels. *J Subst Abuse Treat*. 2014;47(4):245-250.

doi: 10.1016/j.jsat.2014.06.001

32. Liu J, Storfer-Isser A, Mark TL, *et al*. Access to and engagement in substance use disorder treatment over time. *Psychiatr Serv*. 2020;71(7):722-725.

doi: 10.1176/appi.ps.201800461

33. Campbell B. *A Proposed Legislative Fund Could Help to Close Racial, Health Gap*; 2021. Available from: https://phadvocates.org/wp-content/uploads/2021/05/FINAL-press-release-for-FUND_052621.pdf [Last accessed on 2024 May 24].

34. Haffajee RL. The public health value of opioid litigation. *J Law Med Ethics*. 2020;48(2):279-292.

doi: 10.1177/1073110520935340