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Social Deprivation and the Risk of Screening Positive for Glaucoma in the MI-SIGHT Telemedicine Based Glaucoma Detection Program

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Abstract

Purpose: To assess whether increased poverty is associated with increased risk of screening positive for glaucoma or suspected glaucoma in a large public screening and intervention program.

Design: Cross-sectional study from 2020–22.

Participants: Adults 18 years old without acute ocular symptoms.

Methods: Michigan Screening and Intervention for Glaucoma and eye Health through Telemedicine (MI-SIGHT) Program participants' socio-demographic characteristics and area deprivation index (ADI) values were summarized from the clinical sites, which included a free clinic and a Federally Qualified Health Center (FQHC). ADI, a composite measure of neighborhood deprivation [range 1–10; 10 is worst deprivation] was assigned based on participants' addresses. Group comparisons were performed via two-sample t-tests or Wilcoxon-

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Mann-Whitney tests for continuous measures and Chi-square tests or Fisher exact tests with Monte Carlo simulation for categorical measures; Holm adjustment was used for multiple comparisons.

Main Outcome Measures: Risk factors for screening positive for glaucoma/suspected glaucoma.

Results: Of the 1,171 enrolled participants, 1,165 (99.5%) completed the screening; 34% at the free clinic and 66% at the FQHC. Participants were on average 55.1 ± 14.5 years old, 62% women, 54% self-reported being Black/African-American, 34% White, and 10% Latino/a/x, 70% earned less than \$30,000 annually. The mean ADI was 7.2 ± 3.1 . The FQHC had higher (worse) ADI than the free clinic (free clinic: 4.5 ± 2.9 , FQHC: 8.5 ± 2.1 , $p < 0.0001$). A quarter (24%) of participants screened positive for glaucoma/suspected glaucoma. Screening positive for glaucoma/suspected glaucoma was associated with being older ($p = 0.01$), identifying as Black/African-American ($p = 0.0001$), having an established eyecare clinician ($p = 0.0005$), and not driving a personal vehicle to the appointment ($p = 0.001$), which is a proxy for increased poverty. Participants who screened positive had worse ADI compared to those who screened negative (7.7 ± 2.8 vs 7.0 ± 3.2 , $p = 0.002$). A larger percentage of White participants screened positive at the FQHC compared to White participants at the free clinic (21.3% vs 12.3%, $p = 0.01$). FQHC White participants had worse ADI than free clinic White participants (7.5 ± 2.5 vs 3.7 ± 2.7 , $p < 0.0001$).

Conclusions: Personal poverty, assessed as not driving a personal vehicle to the appointment, and neighborhood level poverty were both associated with increased rates of screening positive for glaucoma/suspected glaucoma.

Precis

In a medically underserved cohort, we found that having increased personal poverty and living in a neighborhood with worse deprivation was associated with screening positive for glaucoma and suspected glaucoma.

Keywords

Glaucoma; Social Deprivation; Telemedicine; Social Determinants of Health

Introduction:

Glaucoma is the leading cause of irreversible blindness in the world; an estimated 76 million people worldwide and 3 million people in the United States (US) have glaucoma.¹⁻³ In the US, living in poverty and identifying as Black are both risk factors for having glaucoma and losing vision from glaucoma. After adjusting for race and co-morbid medical conditions, people with lower socioeconomic status are more likely to develop glaucoma than those with higher socioeconomic status.⁴ Because numerous societal policies in the US have kept Black Americans from accumulating wealth at the same rate as White Americans, Black Americans represent a disproportionate share of those who live with poverty in the US.⁵ A disproportionate number of Black Americans are blind from glaucoma,⁶ and the onset of glaucoma in Black Americans typically occurs a decade earlier than other racial groups,^{7,8} significantly impacting individuals in their working years. Black Americans are more likely to have advanced field loss at initial diagnosis.^{8,9} Earlier onset of disease coupled with

more severe disease at presentation significantly impacts overall morbidity and quality of life.^{6,7,10} Additionally, it is estimated that half of patients with open-angle glaucoma (OAG) are unaware of their diagnosis¹¹ and thus are not using available, effective treatments.^{12–14} However, to date, the US Preventive Task Force has opined that insufficient evidence exists to be able to recommend for or against routine glaucoma screening, citing unclear benefits at a population level.¹⁵

Using community-engaged research principles, the Michigan Screening and Intervention for Glaucoma and Eye Health through Telemedicine (MI-SIGHT) program¹⁶ has integrated telemedicine-based eye care within two community clinics that serve low-income populations.¹⁷ We found that implementing glaucoma and eye health screening programs within trusted community clinics in two cities that have high rates of poverty and large populations of Black Americans identified glaucoma/suspected glaucoma at three times national averages (24% glaucoma/suspected glaucoma compared to 2% glaucoma and 4–6% glaucoma suspect in the general US population).^{18,19}

The purpose of this paper is to assess whether social risk factors, including both personal-level and neighborhood-level deprivation, are associated with a higher risk of screening positive for glaucoma or suspected glaucoma in the MI-SIGHT program. Understanding social and geographic risk factors for glaucoma will help shape policy and direct resources to locations where glaucoma detection programs will be most useful in identifying undiagnosed glaucoma.

Methods

This analysis includes participants enrolled in the first year of the MI-SIGHT program at two community clinics, including the Hope Clinic, a free clinic in Ypsilanti, Michigan, and the Hamilton Community Health Network, a Federally Qualified Health Center (FQHC) in Flint, Michigan. Both cities have large populations of people from racial and ethnic minority groups and large populations of people living with lower incomes. The two cities in which these clinics reside have median household incomes at approximately half of the US average - \$39,332 in Ypsilanti and \$28,834 in Flint compared to \$68,703 nationally.²⁰ In Ypsilanti, 27% of the population identify as Black and 6% identify as Hispanic; in Flint, 54% of the population identify as Black and 5% identify as Hispanic. Both clinics have a 39-year history of service to these two cities. Participants enrolled in the first year of the program in each clinic (July 28, 2020 – July 27, 2021 for the free clinic and January 27, 2021 – January 26, 2022 for the FQHC) were included in this analysis.

The MI-SIGHT program included community residents 18 years or older who were interested in undergoing a free eye health exam. Exclusion criteria, as determined by an initial screening intake, included: 1) significant eye pain; 2) sudden decrease in vision in the past week; 3) binocular diplopia (double vision in both eyes); 4) cognitive impairment; 5) pregnancy; 6) current incarceration; or 7) planning to move outside of driving distance to the clinic within the next 6 months. Participants were recruited directly from each clinic with additional outreach to the wider community, guided by the MI-SIGHT Community Advisory Board. Outreach strategies included placing 11,000 flyers placed in the community clinics,

in neighborhood food banks, in low-income senior housing, in barbershops, and in churches. Participants were given extra flyers to share with friends and family. Advertising was done on local buses, local radio, local health fairs, and community access television.

Written informed consent was obtained from all eligible participants. The free clinic serves a population wherein approximately 20% of patients do not speak English and there is no majority second language spoken. Therefore, consent forms were provided in English, Spanish, Albanian, and Arabic. Short-form consents were provided in Mandarin, French, Hindi, Korean, Tagalog, and Igbo. People who did not speak any of the above languages were excluded. This study was reviewed and approved by the University of Michigan Institutional Review Board (HUM00169371), is registered at [Clinicaltrials.gov \(NCT04274764\)](https://clinicaltrials.gov/ct2/show/study/NCT04274764), and adheres to the Tenets of the Declaration of Helsinki.

Following informed consent, participants at each site completed surveys that documented socio-demographic information, clinical information, vision-related quality of life,²¹ and various social risk factors prior to undergoing a series of tests to assess for eye disease administered by ophthalmic technicians. For the glaucoma detection and eye disease screening component, ophthalmic technicians obtained participants' presenting visual acuity with a Snellen chart. Refractive error was obtained with an autorefractor (ARK-Autorefractor & Keratometer, Marco Ophthalmic, Jacksonville, FL) and refined with a phoropter. Pupillary response and anterior chamber angle were assessed by penlight exam. Extraocular motility and alignment were also assessed. Three measurements of intraocular pressure (IOP) were obtained (iCare tonometer, Raleigh, NC). Tropicamide 0.5% was used to dilate those without a narrow angle on penlight exam and with IOP < 30 mm Hg to mitigate the potential risk of acute angle closure. Mydriatic imaging of the posterior pole was obtained with fundus photography with three images focused on the disc, the macula, and the superotemporal arcade (Topcon, Tokyo, Japan) and with optical coherence tomography (OCT) to measure the retinal nerve fiber layer (RNFL) thickness (Topcon, Tokyo, Japan).

Ophthalmologists remotely reviewed the patient information, imaging, and test results in the electronic health record within four business days. Those participants who screened positive for glaucoma or suspected glaucoma were identified using the following criteria:²² 1. narrow angle on penlight exam; 2. patient previously treated for glaucoma (e.g. already taking glaucoma medications or previous glaucoma surgery); 3. cup-to-disc ratio (c/d) 0.7 on fundus photographs;²³ 4. asymmetry of the c/d by 0.2 where the larger cup is 0.6 on fundus photographs;²³ 5. abnormal OCT (overall RNFL thickness <80 microns or thinning at <1% of population norms in the inferior or superior quadrants);^{24,25} or 6. IOP >21 mmHg (median of the three measures taken, interpreted according to the subsequently described criteria). IOP was interpreted as follows: if the IOP was 22–24 mmHg and the c/d ratio was <0.35 with no other glaucoma risk factors, then there was no referral; but if the c/d was 0.35 then participants were referred within 6 months; participants with IOP 25–29 mmHg, 30–40 mmHg, or >40 mmHg were referred within one month, within one week, or immediately if possible or within 24 hours, respectively. The remote ophthalmologists used these criteria alongside their clinical judgment to determine whether the participant screened positive for glaucoma or suspected glaucoma. All those who screened positive for

either glaucoma or suspected glaucoma were referred to an ophthalmologist for an in-person examination. For the purpose of this analysis, the categories of glaucoma and suspected glaucoma are combined, as either diagnosis led to referral for an in-person examination.

Participant-level Assessment of Social Risk Factors

Social risk factors and clinical measures obtained from the survey responses included age, gender, race, ethnicity, annual household income, educational attainment, marital status, employment status, mode of transportation to the appointment, and having medical insurance, an established eyecare provider, a family history of glaucoma, or living alone. Mode of transportation was collected as not having a personal vehicle is an additional marker of personal poverty.²⁶ Participant's mode of transportation to the appointment was dichotomized into "driving a personal vehicle to an appointment" versus "not driving a personal vehicle to an appointment" (received a ride from a family member or friend, ride-share service or taxi, public transit, clinic arranged transport, walked, or other). We excluded participants who reported they do not drive due to poor vision, using responses to the question regarding driving from the 9-item National Eye Institute Visual Function Questionnaire (VFQ9).²¹

Neighborhood-level Assessment of Social Risk Factors – Area Deprivation Index (ADI)

Participants' residences were geocoded by linking addresses to the 2021 Master Address File/Topologically Integrated Geographic Encoding and Referencing (MAF/TIGER) database provided by the US Census.²⁷ This mapping identified the census block group (or neighborhood) of each geocode and its ADI state decile score. The ADI is a factor-based index that uses seventeen US Census-based poverty, education, housing quality, and employment indicators to characterize and rank the socioeconomic contextual disadvantage of a particular neighborhood.^{28–30} The ADI state decile score ranges from 1 to 10, with higher values indicating more socioeconomic deprivation. Approximately 96% of our sample (n=1,121 of 1,171) was successfully geocoded with non-missing ADI ranks.

Statistical Methods

The MI-SIGHT study participants' socio-demographic characteristics were summarized with descriptive statistics overall and stratified by the two clinic sites. Continuous variables are presented with means, standard deviations (SD), medians, and interquartile ranges (IQR). Categorical variables are reported with frequencies and percentages. A cross table was used to display the relationship between annual household income and driving a personal vehicle to an appointment. Participant demographics and social risk factors were compared between those who screened positive versus negative for glaucoma or suspected glaucoma via 2-sample t-tests for continuous variables and chi-square or Fisher exact tests with Monte Carlo simulation for categorical measures. A p-value < 0.05 was considered statistically significant. Significant chi-square or Fisher exact tests were followed by post-hoc Holm-adjusted³¹ pairwise comparisons. Logistic regression was used to estimate the probability of screening positive for glaucoma or suspected glaucoma after adjustment for patient age and race. Characteristics investigated in models included participant demographics and participant-level and neighborhood-level social risk factors. Interactions between race and each social risk factor were also investigated for their association with screening

positive for glaucoma, to understand difference in disease prevalence between clinics with respect to race. Results are reported with odds ratio (OR) and 95% confidence interval (CI) with Benjamin-Hochberg (BH) adjustment. A polygon map is used to visualize the spatial distribution of ADI around each clinic. Analyses were performed using the statistical programming language R (R version 4.1.1; Foundation for Statistical Computing, Vienna, Austria).

Results

A total of 1,171 participants were enrolled in the first year of the MI-SIGHT program and 1,165 completed the screening process (99.5%). The free clinic enrolled 34% (n=397) of participants and the FQHC enrolled 66% (n=774) of participants. Participants' sociodemographic characteristics are summarized in Table 1. Participants reported being an average of 55.1 years old (Standard Deviation (SD)=14.5), 62% identified as women, 54% identified as Black or African-American, 34% as White, 10% as Hispanic or Latino, and 50% reported less than \$20k of annual household income. The ADI of our sample was a mean of 7.2 (SD=3.1). Approximately 32.4% of participants did not drive a personal vehicle to their clinic appointments. A larger percentage of participants who did not drive a personal vehicle to an appointment had <\$10k annual household income compared to those who did drive a personal vehicle to the appointment (42.0% vs 17.1%, $p<0.0001$; Table 2).

Overall, 24% (n=284 of 1,165) of participants screened positive for glaucoma or suspected glaucoma, including 20% at the free clinic and 26% at the FQHC ($p=0.02$). Participant characteristics significantly associated with screening positive for glaucoma or suspected glaucoma are shown in Table 3. Participants who were older ($p=0.01$), identified as Black ($p=0.0001$), had an established eyecare provider ($p=0.0005$), and did not drive a personal vehicle to the clinic appointment ($p=0.003$) were all significantly associated with screening positive for glaucoma or suspected glaucoma. Those who screened positive for glaucoma or suspected glaucoma had a significantly worse average ADI compared to those who screened negative (7.7 [SD=2.8] vs 7.0 [SD=3.2], respectively, $p=0.0018$).

Significant relationships between sociodemographic characteristics and screening positive for glaucoma or suspected glaucoma were also observed when participants from each site were analyzed separately. At the free clinic, associations with race, mode of transportation, and a family history of glaucoma were significantly associated with screening positive for glaucoma or suspected glaucoma. Specifically, Black participants were more likely to screen positive for glaucoma than White participants (31.5% vs 11.7%, Holm-adjusted p-value from post-hoc comparison=0.0001). Participants who did not drive a personal vehicle to their appointments (28% vs 16.7%, $p=0.01$) and those who had a family history of glaucoma (31.1% vs 19.3%, $p=0.04$) were more likely to screen positive for glaucoma than those who did not. At the FQHC, having an established eyecare provider was the only sociodemographic factor found to be significantly associated with screening positive for glaucoma or suspected glaucoma. Specifically, participants who had an established eyecare clinician were more likely to screen positive for glaucoma than those who did not (31% vs 23%, $p=0.009$).

At the free clinic, there was a trend toward those who screened positive for glaucoma to be living in a neighborhood with worse ADI compared to those who screened negative but there was no association at the FQHC (free clinic: mean of 4.3 [SD=2.9] vs 5.1 [SD=2.8], $p=0.049$, FQHC: mean of 8.5 [SD=2.2] vs 8.7 [SD=2.0], $p=0.35$). Two clinic sites and the variation in ADI by neighborhood across the 14-county region are displayed geographically on a map (Figure 1). The FQHC is located in an urban area with higher overall ADI and less overall variability in ADI. Participants screened at the FQHC lived in more deprived neighborhoods compared to the free clinic.

Differences in participant characteristics between clinics stratifying by race (White and Black participants separately) are summarized in Table 4. A larger percentage of White participants screened positive for glaucoma at the FQHC compared to the free clinic (21.3% vs 12.3%, $p=0.01$) and White participants at the FQHC had significantly worse ADI than White participants at the free clinic (mean of 7.5 [SD=2.5] vs 3.7 [SD=2.7], $p<0.0001$). White participants at the FQHC had lower educational attainment (6.3% vs 24.5% with a college degree, Holm-adjusted $p<0.0001$) and lower income (24.3% vs 14.1% with annual income $< \$10K$, unadjusted $p=0.02$ and Holm-adjusted $p=0.13$) compared to White participants at the free clinic. A larger percentage of White participants at the FQHC reported they were unable to work or were disabled compared to White participants at the free clinic (23.9% vs 11%, Holm-adjusted $p=0.01$). While Black participants at the FQHC also had lower educational attainment (8.1% vs 18.7% with a college degree, Holm-adjusted $p=0.03$) and worse ADI (mean of 9 [SD=1.7] vs 5.9 [SD=2.6], $p<0.0001$) compared to Black participants at the free clinic, there was no significant difference in income (26.2% vs 27.0% with annual income $< \$10K$, $p=0.61$) and no significant differences in screening positive for glaucoma were found between Black participants at either clinic (FQHC: 29.1%, free clinic: 31.5%, $p=0.7$).

After adjustment for age and race, logistic regression modeling demonstrated that driving a personal vehicle to the appointment (main effect) was significantly associated with the probability of screening positive for glaucoma or suspected glaucoma. Due to the difference in disease prevalence between clinics with respect to race, we also investigated interactions between race and socioeconomic measures. We found that the interaction between race and driving a personal vehicle to the appointment was significantly associated with screening positive for glaucoma or suspected glaucoma (Figure 2 and Table 5, available at <https://www.aojournal.org>). After stratifying by site, Black participants who did not drive a personal vehicle to the appointment were more likely to screen positive for glaucoma compared to White participants who drove a personal vehicle to the appointment (Free clinic: OR=7.56, 95% CI=2.10–27.25, $p<0.0001$; FQHC: OR=2.33, 95% CI=1.06–5.13, $p=0.03$). Black participants who drove a personal vehicle to the appointment had no higher risk of screening positive for glaucoma compared to White participants who drove a personal vehicle to the appointment (Free clinic: OR=3.07, 95% CI=0.84–11.23, $p=0.15$; FQHC: OR=1.79, 95% CI=0.87–3.67, $p=0.2$). Black participants who did not drive a personal vehicle to the appointment were not more likely to screen positive than White participants who did not drive a personal vehicle to the appointment at the free clinic (OR=3.72, 95% CI=0.81–17.02, $p=0.15$) or at the FQHC (OR=1.03, 95% CI=0.40–2.65, $p=1.00$).

Discussion:

In the first year of MI-SIGHT program enrollment in two community clinics, nearly a quarter of enrolled participants (24%) screened positive for glaucoma or suspected glaucoma – a rate three times higher than the national average of 6–8%.¹⁸ This outcome demonstrates the community health benefit of targeting glaucoma screening to high-risk populations. Screening positive for glaucoma or suspected glaucoma was significantly associated with living in a more deprived neighborhood, not driving a personal vehicle to the screening appointment, identifying as Black, and having an eye care provider. Though there was not a relationship between income and positive screening for glaucoma, the majority of the sample (70%) reported income less than half of the median in the US (<\$30,000). Therefore, the variability in income level was too limited to adequately assess the relationship between income level and glaucoma risk. Not driving a personal vehicle to the appointment is often used as a marker of more extreme poverty especially in locations that lack public transportation, such as in the two cities in this study,²⁶ and was associated with having lower income in our study sample.

A significant interaction exists between not driving a personal vehicle to the appointment, race, and screening positive for glaucoma even after excluding those from the analysis who reported not driving due to vision impairment. Black participants who did not drive a personal vehicle to the appointment were more likely to screen positive for glaucoma/suspected glaucoma than White participants who drove a personal vehicle to the appointment but not more likely than White participants who did not drive a personal vehicle to the appointment. Black participants who drove a personal vehicle to the appointment were not more likely to screen positive for glaucoma compared to White participants who drove a personal vehicle to the appointment. We hypothesize that not driving a personal vehicle is a marker of more extreme poverty in this sample of people with very limited incomes, thus the basis for this association.

When we stratified our results by clinic, our findings suggest that poverty is a risk factor for screening positive for glaucoma. In the free clinic the associations between ADI score, Black race, and not driving a personal vehicle were significant risk factors for positive screening for glaucoma. However, in the FQHC, none of these variables were significantly associated with positive screening. The free clinic serves an area with more variable neighborhood deprivation and overall has less deprivation, with interquartile ADI ranges from 2–7 as compared to the FQHC, which serves neighborhoods with interquartile ADI ranges from 8–10, where 10 reflects the highest level of neighborhood deprivation. The estimated poverty rate in Flint, Michigan (the location of the FQHC) is estimated to be 38.8% compared to 15.5% for the general US population.³² In the FQHC, where both Black and White participants lived in equally deprived neighborhoods and had more equal levels of personal poverty, the rates of screening positive for glaucoma did not significantly differ by race. Socioeconomic status and race are inextricably linked in the US. In the current analyses, poverty was a more significant risk factor for screening positive for glaucoma than race.

Despite much work attempting to elucidate the genetic mechanism underlying the higher rate of glaucoma among those who identify as Black compared to those who identify

as White, known genetic variation only explains a small fraction of glaucoma risk. The Primary Open-Angle African American Glaucoma Genetics (POAAGG) study included 2,290 primary open-angle glaucoma (POAG) cases and 2,538 controls without ocular disease among participants who self-identified as African American, African, or Black. The investigators used a genome-wide association study and found that though higher levels of autosomal-wide African ancestry was a risk factor for POAG, no specific African ancestry markers were identified as significant risk factors for POAG.³³ The Epidemiologic Architecture for Genes Linked to Environment (EAGLE) study observed similar findings in their cohort.³⁴ A genome-wide association study undertaken in the large and ethnically diverse Genetic Epidemiology Research in Adult Health and Aging (GERA) cohort, which consisted of 4,986 POAG cases and 58,426 controls, identified 12 loci associated with POAG. This massive research endeavor increased the proportion of variance explained by genetic variation on glaucoma risk from 2.1% to 3.0% in non-Hispanic Whites, from 0.5% to 3.1% among African-Americans, from 2.0% to 3.3% among Latinos, and from 0.3% to 0.5% among East Asians.³⁵ Understanding the influence of social and environmental factors on how genes are expressed may yield a greater understanding of the variance of glaucoma prevalence and risk.

Further research is needed to understand why we see a higher prevalence of White Americans screening positive for glaucoma in Flint, Michigan, a community where White Americans and Black Americans face more similar degrees of economic deprivation. In the 19th century, Rudolf Virchow identified that although typhus was bacterial in origin, its spread was related to social risk factors. Social risk factors describe how social determinants of health impact the individual, such as having low income, low education, food or housing insecurity, or high exposure to environmental pollutants.³⁶ Virchow observed that the socioeconomic scaffold laid the foundation for the spread of typhoid fever. Typhoid fever was called “hunger-typhus” colloquially as its spread began among those who suffered from food shortages and starvation and spread quickly due to crowded living conditions. It then moved on to infect people from the wealthier classes as there was inadequate sanitation infrastructure in place to stop its spread.^{37,38} Identifying whether the built environment influences how genetic predisposition to glaucoma may manifest might yield important insights into the pathophysiology of glaucoma.

The ADI is a validated, multifactor-based measure that can be used to quantify socioeconomic disadvantage for a census block group based on a composite score of SDoH.²⁸ Some of the factors included in the ADI score are rates of unemployment, family poverty, and home ownership. Census tracts in the US with higher poverty or greater percentages of people who identify as Black or Hispanic also have less access to green spaces,³⁹ have a higher prevalence of toxic waste sites,⁴⁰ have higher proportions of fast-food restaurants compared to non-fast food restaurants,⁴¹ and as school funding is tied to local property values, have less resources available for the public school system. The median ADI for participants from the FQHC was 9 on a 10-point scale, where 10 reflects the highest level of neighborhood deprivation. The FQHC is located in Flint, Michigan which endured more than half a decade of a poor water quality resulting in a health crisis from 2014 to 2019. The water crisis was the result of policies that chose to curtail spending at the risk of the public’s health.⁴² In this community with such high levels of neighborhood

deprivation and lack of public infrastructure, the advantages of White race in ocular health status were not evident. There was a much higher rate of screening positive for glaucoma or suspected glaucoma for White participants who were living in Flint compared to those living in communities around the free clinic where neighborhood deprivation for White participants was not as severe. This was not true for Black participants, who had a similar rate of screening positive at both clinics. This difference paves the way for further research into social and environmental risk factors for developing glaucoma that may be unequally distributed based on race.

The strengths of this analysis include its focus on engaging participants who live in neighborhoods with high levels of poverty and economic deprivation in the research. However, this limits the variability in the data from Flint, where the entire sub-population from the FQHC has extremely high neighborhood levels of poverty. This study is not representative of the larger population in the state of Michigan or in the US as it does not use stratified randomized neighborhood level sampling, but rather has recruited whoever wanted to participate in a free eye health screening program. This could lead to inclusion bias, either from a healthy volunteer bias where those who are more concerned about their health participate in the program potentially leading to an underestimate of disease, or from a volunteer bias where those with ocular symptoms or family history of disease are more likely to participate and potentially more likely to screen positive for disease. Additionally, though ADI was obtained on the near-majority of our study population, 96%, some addresses could not be geocoded. ADI cannot be captured in certain geographic locations because of missing source data from the American Community Survey in areas with low population or high proportion of the population living in group quarters. The Census Bureau classifies “group quarters” as people not living in a housing unit (house, apartment, mobile home, or rented room) such as those who live in an institutional facility, a college dormitory, military barracks, a group home, or shelter. Additionally, ADI cannot be obtained for people who list Post Office boxes as addresses.⁴³

Glaucoma has been a leading cause of blindness in the US; however, the US Preventive Services Task Force (USPSTF) in 2013 and 2021 reports concluded that insufficient evidence existed to support screening for glaucoma in asymptomatic adults.^{44,45} The USPSTF cited relatively low disease prevalence, questionable reliability of screening testing when performed in a primary care settings and potential adverse effects from initiating topical glaucoma therapy in false positive cases.⁴⁶ This CDC-funded screening program provides new evidence to help the USPSTF revise its conclusions. One-quarter (24%) of program participants screened positive for glaucoma – approximately three times the national average. The data suggests that programs should screen and support populations at high risk of glaucoma in the US. Neighborhood deprivation appears to be a risk factor for glaucoma. We recommend that high-quality telemedicine or technology-based programs to detect glaucoma - that also support people in accessing further eye care when needed - are placed in neighborhoods with high rates of poverty at community locations such as FQHCs to improve access to glaucoma diagnosis and treatment. Of note, the trust built in the program likely occurred due to ongoing support after a positive diagnosis, so participants did not have to find care themselves. Identifying patients who need early treatment for glaucoma will

mitigate the high rates of needless, irreversible glaucomatous vision loss and blindness that are seen in the US.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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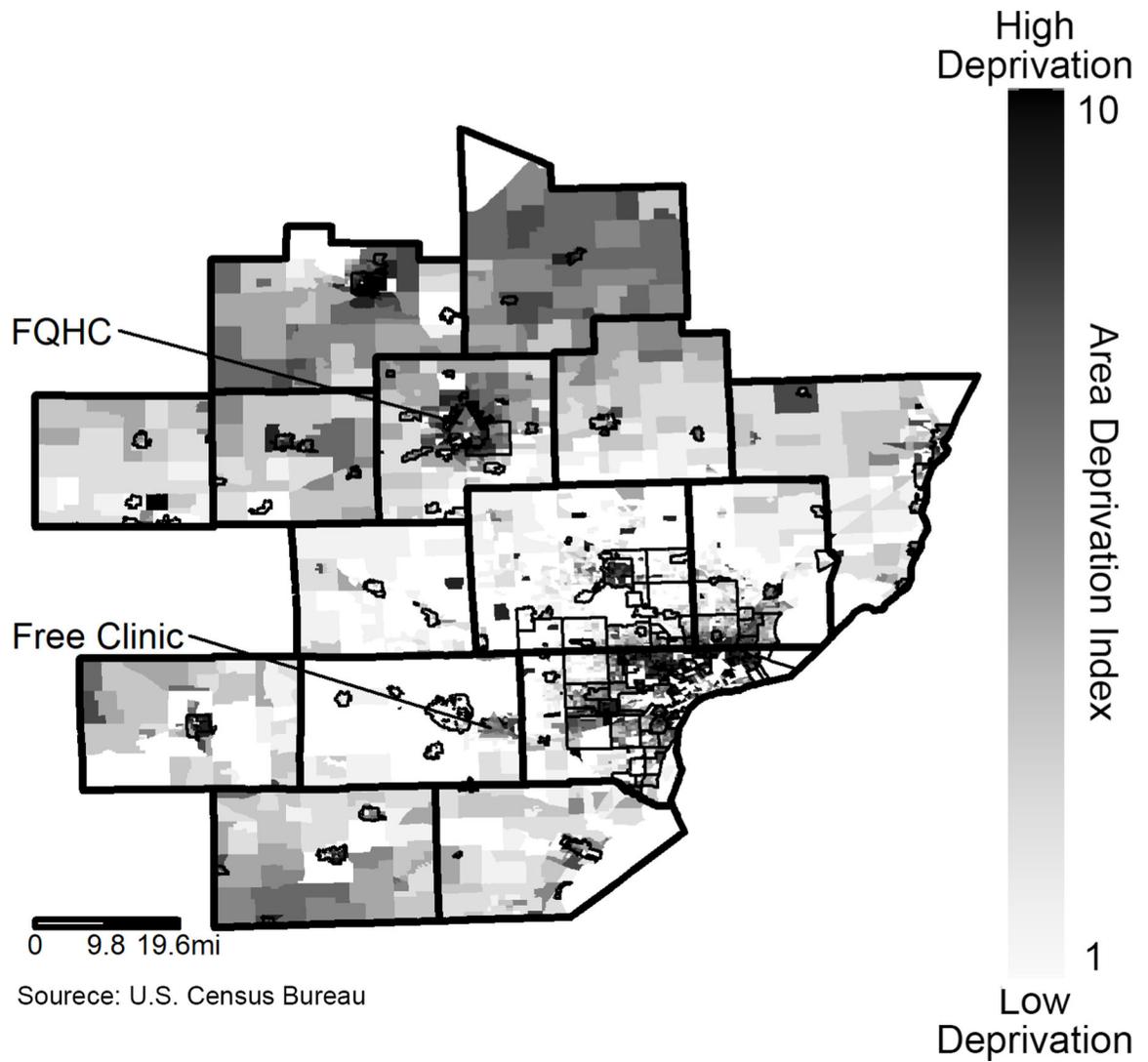


Figure 1. Geographic representation of area deprivation around the two participating MI-SIGHT clinics.

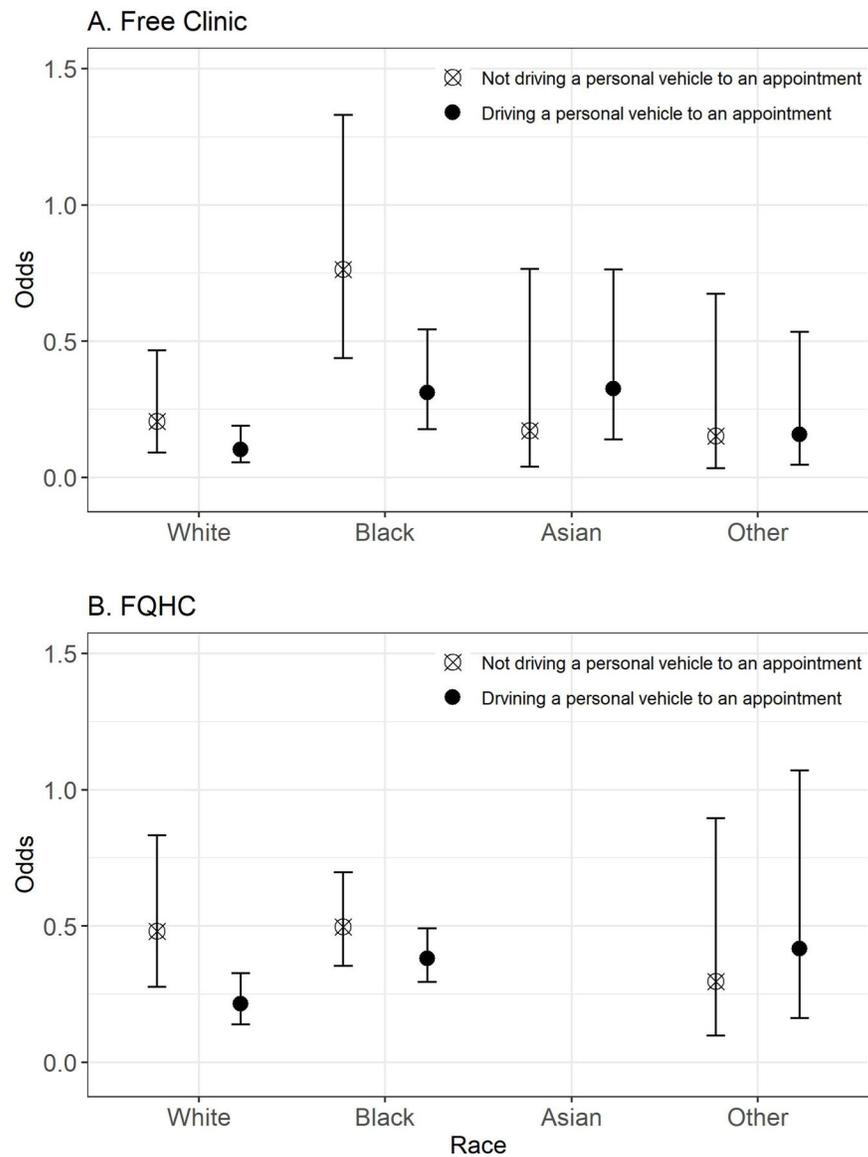


Figure 2. Forest plots displaying odds and 95% confidence interval of screening positive for glaucoma between race and driving a personal vehicle at each of two clinics. Asian participants were excluded from the logistic regression model at the FQHC due to the small sample size.

Table 1.

Participant Characteristics in the first year MI-SIGHT sample.

Continuous Variable	Overall (n=1171)			Free Clinic (n=397)			FQHC (n=774)			P-value
	Mean (SD)	Median (IQR)	Frequency (%)	Mean (SD)	Median (IQR)	Frequency (%)	Mean (SD)	Median (IQR)	Frequency (%)	
Age (years)	55.1 (14.5)	57 (47–65)		55.7 (14.6)	58 (47–66)		54.8 (14.5)	56 (47–64)		0.2903
Area Deprivation Index	7.2 (3.1)	9 (5–10)		4.5 (2.9)	4 (2–7)		8.5 (2.1)	9 (8–10)		<0.0001
Categorical Variable		Frequency (%)			Frequency (%)			Frequency (%)		P-value
Gender										
Male	437 (37.7)			141 (36.1)			296 (38.6)			0.4008
Female	721 (62.3)			250 (63.9)			471 (61.4)			
Ethnicity										
Hispanic	101 (10.4)			33 (10.6)			68 (10.4)			0.9200
Non-Hispanic	867 (89.6)			279 (89.4)			588 (89.6)			
Race										
White	371 (33.9)			164 (43.6)			207 (28.9)			<0.0001*
Black	591 (54.1)			127 (33.8)			464 (64.7)			
Asian	48 (4.4)			44 (11.7)			4 (0.6)			
Other	83 (7.6)			41 (10.9)			42 (5.9)			
Drove Personal Vehicle										
No	367 (32.4)			127 (33.3)			240 (32.0)			0.6508
Yes	764 (67.6)			254 (66.7)			510 (68.0)			
Language										
English	1042 (89.5)			319 (80.6)			723 (94.1)			<0.0001
Non-English	122 (10.5)			77 (19.4)			45 (5.9)			
Education										
<HS	119 (10.3)			37 (9.6)			82 (10.7)			
HS	373 (32.4)			92 (23.8)			281 (36.8)			
Some College	391 (34.0)			113 (29.2)			278 (36.4)			<0.0001 [†]
College Degree	139 (12.1)			80 (20.7)			59 (7.7)			
Graduate Degree	129 (11.2)			65 (16.8)			64 (8.4)			
Income (USD)										

Continuous Variable	Overall (n=1171)		Free Clinic (n=397)		FQHC (n=774)		P-value
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	
<\$10k	248 (25.0)		67 (20.9)		181 (26.9)		
\$10k-\$19,999	246 (24.8)		79 (24.7)		167 (24.8)		
\$20k-\$29,999	202 (20.3)		75 (23.4)		127 (18.9)		0.1812
\$30k-\$49,999	172 (17.3)		52 (16.2)		120 (17.8)		
\$50k-\$69,000	60 (6.0)		24 (7.5)		36 (5.3)		
\$70k+	65 (6.5)		23 (7.2)		42 (6.5)		
Marital Status							
Single	449 (38.9)		121 (31.3)		328 (42.8)		
Married / Living with partner	407 (35.3)		165 (42.6)		242 (31.6)		<0.0001 [‡]
Divorced / Separated / Widowed	298 (25.8)		101 (26.1)		197 (25.7)		
Employment Status							
Full-time	251 (21.8)		68 (17.6)		183 (24.0)		
Part-time	127 (11.0)		54 (14.0)		73 (9.6)		
Self-employed	81 (7.0)		28 (7.3)		53 (6.9)		
Unemployed	197 (17.1)		84 (21.8)		113 (14.8)		<0.0001 [§]
Retired	249 (21.7)		82 (21.2)		167 (21.9)		
Unable to work / Disabled	167 (14.5)		32 (8.3)		135 (17.7)		
Caregiver / Homemaker / Student / Other	78 (6.8)		38 (9.8)		40 (5.2)		
Medical Insurance							
No	228 (20.0)		174 (45.1)		54 (7.1)		<0.0001
Yes	914 (80.0)		212 (54.9)		702 (92.9)		
Eyecare Provider							
No	743 (64.6)		309 (79.8)		434 (56.8)		<0.0001
Yes	408 (35.4)		78 (20.2)		330 (43.2)		
Family History of Glaucoma							
No	667 (72.7)		200 (73.0)		467 (72.6)		0.9097
Yes	250 (27.3)		74 (27.0)		176 (27.4)		
Live Alone							
No	811 (70.8)		274 (71.5)		537 (70.4)		
Yes	335 (29.2)		109 (28.5)		226 (29.6)		0.6837

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SD, standard deviation; IQR, Interquartile range; HS, high school; USD, United States dollar; k, \$1000.

* Post-hoc pairwise comparison showed significant differences in race between the free clinic versus the FHQC for: White (Holm-adjusted $p < 0.0001$), Black (Holm-adjusted $p < 0.0001$), Asian (Holm-adjusted $p < 0.0001$), and other race participants (Holm-adjusted $p = 0.0028$).

† Post-hoc pairwise comparison showed significant differences in educational attainment between the free clinic versus the FHQC for: high school (Holm-adjusted $p < 0.0001$), some college (Holm-adjusted $p = 0.03$), college degree (Holm-adjusted $p < 0.0001$), and graduate degree (Holm-adjusted $p < 0.0001$).

‡ Post-hoc pairwise comparison showed significant differences in marital status between the free clinic versus the FHQC for: single (Holm-adjusted $p < 0.0001$) and married or living with a partner (Holm-adjusted $p < 0.0001$).

§ Post-hoc pairwise comparison showed significant differences in employment status between the free clinic versus the FHQC for: unemployed (Holm-adjusted $p = 0.0183$), unable to work or disabled (Holm-adjusted $p < 0.0001$), and caregiver/homemaker/student/other (Holm-adjusted $p = 0.0183$).

Table 2.

Cross table displaying the relationship between annual household income and whether a participant reported driving a personal vehicle to their clinical appointment

Income (USD)	Drove Personal Vehicle		P-value
	No	Yes	
	Frequency (Column %)		
<\$10k	123 (42.0)	114 (17.1)	
\$10k-\$19,999	74 (25.3)	162 (24.3)	
\$20k-\$29,999	55 (18.8)	140 (21.0)	
\$30k-\$49,999	27 (9.2)	143 (21.4)	0.0004*
\$50k-\$69,000	4 (1.4)	54 (8.1)	
\$70k+	10 (3.4)	55 (8.2)	

* Post-hoc pairwise comparison showed significant differences between those participants who reported they did versus did not drive a personal vehicle to their clinical appointment for: <\$10k (Holm-adjusted p<0.0001), \$30k-\$49,999 (Holm-adjusted p<0.0001), and \$50k-\$69,000 (Holm-adjusted p<0.0001).

USD, United States dollar; k, \$1000

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Table 3.

Comparison of participant socio-demographics by glaucoma screening result.

Glaucoma	Overall (n=1,165)			Free Clinic (n=392)			FQHC (n=773)		
	Glaucoma -	Glaucoma +	P-value	Glaucoma -	Glaucoma +	P-value	Glaucoma -	Glaucoma +	P-value
	Mean (SD)	Mean (SD)	Frequency (Row %)	Mean (SD)	Mean (SD)	Frequency (Row %)	Mean (SD)	Mean (SD)	Frequency (Row %)
Age (years)	54.5 (14.4)	56.9 (14.7)	0.0144	55.1 (14.7)	58.1 (14.4)	0.1052	54.1 (14.3)	56.4 (14.8)	0.0510
Area Deprivation Index	7.0 (3.2)	7.7 (2.8)	0.0018	4.3 (2.9)	5.1 (2.8)	0.0493	8.5 (2.2)	8.7 (2.0)	0.3498
Gender									
Male	319 (73.3)	116 (26.7)	0.1744	106 (76.3)	33 (23.7)	0.2316	213 (72.0)	83 (28.0)	0.4335
Female	552 (76.9)	166 (23.1)		201 (81.4)	46 (18.6)		351 (74.5)	120 (25.5)	
Ethnicity									
Hispanic/Latinx	81 (81.8)	18 (18.2)	0.0850	26 (83.9)	5 (16.1)	0.6429	55 (80.9)	13 (19.1)	0.1043
Non-Hispanic/Non-Latinx	639 (73.9)	226 (26.1)		218 (78.7)	59 (21.3)		421 (71.6)	167 (28.4)	
Race									
White	305 (82.7)	64 (17.3)		143 (88.3)	19 (11.7)		162 (78.3)	45 (21.7)	
Black	412 (69.7)	179 (30.3)	<0.0001*	87 (68.5)	40 (31.5)	0.0003*	325 (70.0)	139 (30.0)	0.0910
Asian	39 (81.2)	9 (18.8)		35 (79.5)	9 (20.5)		4 (100.0)	NA	
Other	66 (81.5)	15 (18.5)		34 (87.2)	5 (12.8)		32 (76.2)	10 (23.8)	
Drove Personal Vehicle									
No	256 (70.1)	109 (29.9)	0.0031	90 (72.0)	35 (28.0)	0.0102	166 (69.2)	74 (30.8)	0.0588
Yes	596 (78.2)	166 (21.8)		210 (83.3)	42 (16.7)		386 (75.7)	124 (24.3)	
Language									
English	785 (75.6)	254 (24.4)	0.9461	256 (81.0)	60 (19.0)	0.1383	529 (73.2)	194 (26.8)	0.3132
Non-English	91 (75.8)	29 (24.2)		55 (73.3)	20 (26.7)		36 (80.0)	9 (20.0)	
Education									
<HS	78 (66.1)	40 (33.9)		23 (63.9)	13 (36.1)		55 (67.1)	27 (32.9)	
HS	282 (76.2)	88 (23.8)		75 (84.3)	14 (15.7)		207 (73.7)	74 (26.3)	
Some College	296 (75.9)	94 (24.1)	0.1201	92 (82.1)	20 (17.9)	0.1102	204 (73.4)	74 (26.6)	0.5239
College Degree	109 (78.4)	30 (21.6)		62 (77.5)	18 (22.5)		47 (79.7)	12 (20.3)	
Graduate Degree	102 (79.1)	27 (20.9)		53 (81.5)	12 (18.5)		49 (76.6)	15 (23.4)	

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Glaucoma	Overall (n=1,165)		Free Clinic (n=392)		FQHC (n=773)		P-value
	Glaucoma -	Glaucoma +	Glaucoma -	Glaucoma +	Glaucoma -	Glaucoma +	
Yes	240 (71.9)	94 (28.1)	82 (75.9)	26 (24.1)	158 (69.9)	68 (30.1)	

SD, standard deviation; HS, high school; USD, United States dollar; k, \$1000.

* Post-hoc pairwise comparison showed significant glaucoma screening result differences for Black versus White participants (Overall: Holm-adjusted $p < 0.0001$; Free clinic: Holm-adjusted $p = 0.0001$).

Table 4. Comparison of participant socio-demographics between the free clinic and the FQHC for White and Black participants.

	White (n=371)		Black (n=591)		P-value
	Free Clinic	FQHC	Free Clinic	FQHC	
Age (years)	Mean (SD)		Mean (SD)		
	57.7 (14.2)	55.9 (12.5)	57.5 (13.1)	55.5 (15.2)	0.1589
Area Deprivation Index	Frequency (Column Percent)		Frequency (Column Percent)		
	3.7 (2.7)	7.5 (2.5)	5.9 (2.6)	9.0 (1.7)	<0.0001
Gender	Frequency (Column Percent)		Frequency (Column Percent)		
Male	61 (37.2)	85 (41.1)	40 (32.3)	171 (37.1)	0.3196
Female	103 (62.8)	122 (58.9)	84 (67.7)	290 (62.9)	
Ethnicity	Frequency (Column Percent)		Frequency (Column Percent)		
Hispanic	7 (5.1)	6 (3.5)	1 (1.1)	2 (0.5)	0.4699
Non-Hispanic	129 (94.9)	164 (96.5)	93 (98.9)	398 (99.5)	
Drove Personal Vehicle	Frequency (Column Percent)		Frequency (Column Percent)		
No	41 (25.8)	58 (28.6)	52 (43.3)	152 (33.9)	0.0544
Yes	118 (74.2)	145 (71.4)	68 (56.7)	297 (66.1)	
Language	Frequency (Column Percent)		Frequency (Column Percent)		
English	149 (90.9)	206 (99.5)	114 (89.8)	459 (100.0)	<0.0001
Non-English	15 (9.1)	1 (0.5)	13 (10.2)	0 (0.0)	
Education	Frequency (Column Percent)		Frequency (Column Percent)		
<HS	7 (4.3)	28 (13.5)	18 (14.6)	40 (8.8)	0.0008
HS	38 (23.3)	70 (33.8)	30 (24.4)	170 (37.2)	
Some College	49 (30.1)	81 (39.1)	41 (33.3)	170 (37.2)	
College Degree	40 (24.5)	13 (6.3)	23 (18.7)	37 (8.1)	
Graduate Degree	29 (17.8)	15 (7.2)	11 (8.9)	40 (8.8)	
Income (USD)	Frequency (Column Percent)		Frequency (Column Percent)		
<\$10k	20 (14.1)	46 (24.3)	27 (26.2)	109 (27.0)	0.6167
\$10k-\$19,999	37 (26.1)	45 (23.8)	28 (27.2)	103 (25.5)	
\$20k-\$29,999	35 (24.6)	42 (22.2)	21 (20.4)	71 (17.6)	
\$30k-\$49,999	19 (13.4)	39 (20.6)	20 (19.4)	67 (16.6)	

	White (n=371)		Black (n=591)		P-value
	Free Clinic	FQHC	Free Clinic	FQHC	
\$50k-\$69,000	16 (11.3)	9 (4.8)	3 (2.9)	24 (5.9)	
\$70k+	15 (10.6)	8 (4.2)	4 (3.9)	30 (7.4)	
Marital Status					
Single	48 (29.4)	64 (30.9)	44 (36.1)	234 (50.9)	
Married / Living with partner	73 (44.8)	79 (38.2)	36 (29.5)	111 (24.1)	0.0129
Divorced / Separated / Widowed	42 (25.8)	64 (30.9)	42 (34.4)	115 (25.0)	
Employment Status					
Full-time	24 (14.7)	45 (22.0)	24 (19.5)	115 (25.1)	
Part-time	22 (13.5)	13 (6.3)	15 (12.2)	51 (11.1)	
Self-employed	12 (7.4)	12 (5.9)	5 (4.1)	28 (6.1)	
Unemployed	26 (16.0)	36 (17.6)	34 (27.6)	52 (11.4)	0.0010
Retired	47 (28.8)	42 (20.5)	22 (17.9)	117 (25.5)	
Unable to work / Disabled	18 (11.0)	49 (23.9)	12 (9.8)	75 (16.4)	
Caregiver / Homemaker / Student / Other	14 (8.6)	8 (3.9)	11 (8.9)	20 (4.4)	
Medical Insurance					
No	51 (31.5)	15 (7.3)	59 (48.8)	14 (3.1)	<0.0001
Yes	111 (68.5)	190 (92.7)	62 (51.2)	441 (96.9)	
Eyecare Provider					
No	122 (75.8)	125 (61.3)	103 (81.7)	238 (51.6)	<0.0001
Yes	39 (24.2)	79 (38.7)	23 (18.3)	223 (48.4)	
Family History of Glaucoma					
No	74 (69.8)	120 (71.9)	75 (75.8)	284 (72.6)	
Yes	32 (30.2)	47 (28.1)	24 (24.2)	107 (27.4)	0.5305
Live Alone					
No	104 (64.6)	158 (77.1)	88 (71.0)	295 (64.3)	0.1633
Yes	57 (35.4)	47 (22.9)	36 (29.0)	164 (35.7)	

SD, standard deviation; HS, high school; USD, United States dollar; k, \$1000.

* Post-hoc pairwise comparison showed significant differences in educational attainment among White participants between the free clinic versus the FQHC for: less than high school (Holm-adjusted p=0.0078), college degree (Holm-adjusted p<0.0001), and graduate degree (Holm-adjusted p=0.0075); significant differences in educational attainment among Black participants between two clinics were for: high school (Holm-adjusted p=0.0319) and college degree (Holm-adjusted p=0.0003).

Post-hoc pairwise comparison showed significant differences in employment status among White participants between the free clinic versus the FHQC for unable to work or disabled (Holm-adjusted $p=0.0105$); significant differences in employment status among Black participants between two clinics were for unemployed (Holm-adjusted $p<0.0001$)

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