Investigating Health Inequality in Primary Care Spatial Accessibility Among Races and Ethnicities in King County Using a Geospatial Approach

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Abstract

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Distance to healthcare providers is a significant barrier to health care access in the U.S. Healthcare utilization and disease burden have been found to increase as the distance between patients and primary care physicians increase. Although spatial accessibility to primary care resources has been studied using different methods in recent decades, few studies have addressed disparities such accessibility among races/ethnicities. Therefore, we used Enhanced Two-Step Floating Catchment Area (E2SFCA), a gravity-based model that measures spatial accessibility by combining distance decay concept within a certain catchment, 2019 American Community Survey (ACS) 5-year estimates, and primary care physician data to assess the variation of spatial accessibility among races/ethnicities to primary care in King County, Washington. We observed regional

differences for spatial accessibility across census tracts. Most census tracts in King County had poorer spatial accessibility than the average. In addition, race/ethnicity of the population and spatial accessibility to primary care physicians was found to be weakly associated to one another. Non-Hispanic Asians had better spatial accessibility, whereas Hispanic and non-Hispanic Native Hawaiian and Pacific Islander populations had less accessibility to primary care providers than people of other races/ethnicities. Area configuration of healthcare resources and improvement targeting of racial/ethnic minorities can help reduce the disparities in spatial accessibility to care.

Introduction

Primary Care in the U.S.

Primary care is the cornerstone of successful health systems and is required to meet the essential health needs of populations (Starfield et al., 2005). Primary care providers include primary care physicians, physician assistants, and nurse practitioners. Satisfactory primary care provider supply is associated with better population health outcomes (e.g., lower all-cause mortality, reduction in stroke mortality, improvement in self-rated good health) regardless of administrative unit examined (Macinko et al., 2007). At the state-level, an increase in primary care supply is associated with a reduction all-cause mortality by 41 - 85 per 100,000 population (Macinko et al., 2007). At the county-level, increasing primary care supply is associated with decreasing cardiovascular disease and cancer mortality rates (Macinko et al., 2007). Non-metropolitan statistical areas with higher primary care densities experienced lower rates of all-cause, cardiovascular disease-, and cancer-related mortality compared to areas with lower primary care provider densities (Shi et al., 2005).

Measures of Accessibility

Despite the population health benefits associated with greater numbers of primary care providers within an administrative area, a sufficient number of primary care providers alone does not necessarily mean that all people have adequate accessibility to primary care services. Distance to healthcare providers is one of the three significant barriers to health care access in the U.S. (i.e., delays from barriers related to care seeking, access, and delivery). Additionally, travel distance to healthcare services prevents patients from receiving treatment for depression and alcohol abuse disorder (Fortney et al., 1999; Fortney et al., 1995). Spatial accessibility is the fusion of number of providers from which a person can choose from (availability) and travel impedance (i.e., distance or time) to provider (accessibility), which measures the potential for health care delivery. Spatial accessibility is influenced by the supply and distribution of medical services, demand population, and travel costs between the service and population (Guagliardo, 2004).

There are several approaches to measure spatial accessibility. Measurement approaches can be classified into four categories: provider-to-population ratios, distance to nearest provider, average distance to a set of providers, and gravity models of provider influence (Guagliardo, 2004). Gravity models, which were developed from Newton's Law of gravitation and initially used to predict retail travel (Reilly, 1931), are appealing for census tract-level analyses because they avoid the erroneous assumption that patients only visit providers within their home tract and allow for both proximity and number of providers to contribute to accessibility. However, gravity model output can be challenging to interpret. Enhanced two-step floating catchment area (E2SFCA), a gravity model proposed by Luo and Qi (2009), improves on prior gravity models by using a two-step processed provider-to-population ratio that includes the distance decay concept within a certain catchment. The E2SFCA score is thus interpretable as a ratio between provider and population.

Health Disparity Among People of Different Races and Ethnicities

Due to disadvantages associated with poorer socioeconomic status and the effects of structural and institutional racism, disparities in health exist along race and ethnicity lines (Dressler et al., 2005; Egede, 2006; Kawachi et al., 2005). Although spatial accessibility to primary care resources has been studied using multiple methods in the past decades (Gilliland et.al, 2019; Luo & Wang, 2003;), few reports have assessed whether and how spatial accessibility to adult primary care varies between races and ethnicities.

Specific Aims

The aim of this study was to investigate whether there were differences in primary care spatial accessibility across racial/ethnic groups in King County, Washington. First, we examined the variation in spatial accessibility of primary care for the overall population by computing and mapping E2SFCA scores for each census tract. Second, we compared E2SFCA scores across racial/ethnic groups. By integrating the physician supply, physician-to-population distance, and demand racial/ethnic populations, we hoped to understand disparities in spatial accessibility by race/ethnicity to primary care and identify specific groups and administrative area targets for interventions.

Methods

Study Setting

We investigated spatial accessibility to primary care physicians among different racial and ethnic groups in King County of Washington State. King County is the 13th most populous county in the U.S., with a population of about 2 million people. This project was funded by the Pacific Hospital Preservation and Development Authority and aimed to inform recommendations on strategies to reduce health inequities in King County.

Data sources

<u>Primary Care Physicians</u>

Information about primary care physicians and their distribution in King County was obtained from the Office of Financial Management (OFM) of Washington State. The physician data were cross-checked with three databases including Network Access Reports (NARs), National Provider Identifiers (NPIs) registry, and provider license database.

- Health insurance companies conducting business in Washington State are required to file a monthly NAR to the State's Office of the Insurance Commissioner (OIC) to demonstrate that the company has an adequate supply of health care providers in its network. These reports contain information about physicians including name, credentials, specialties, and practice location(s).
- NPI is a unique 10-digit and identification number assigned only once to an individual or organizational health care provider in the U.S. by the Centers for Medicare and Medicaid Services (CMS).
- Health care providers are required to obtain a provider license from the Washington State Department of Health (DoH) in order to practice in the State. After initial licensing, physicians must renew their license every two years.

The OFM matched NARs to NPIs and provider license data to ensure data quality. The NARs for June 2019 were downloaded from OIC's website (Washington State Office of the Insurance Commissioner, n.d.). In addition, they only matched records with non-expired licenses as of June 2019. The inclusion criteria for primary care physicians were physicians who worked in King County with specialties of family medicine, general practice, geriatric medicine, internal medicine (general), and pediatrics (general). Records that were in other counties that shared any of the NPIs with King County were included, too. For example, if a physician has two working addresses inside King County and one address in Pierce County. All three records were included in the dataset.

The processed NAR data contained duplicative records that resulted from variations in the text for the working addresses. We standardized addresses by changing all abbreviations into full names, then removed records where NPI and address were duplicated. In addition, the data included multiple records for physicians who had multiple practice locations. We assigned a weight for each record based on the number of working locations for each physician to estimate available primary care physician resources more accurately. For example, when a physician had two working addresses, we considered each of the two locations corresponding to those addresses to have 1/2 of a physician. After geocoding all data with Nominatim, an open-source geocoding tool that uses OpenStreetMap data, records with coordinates outside King County were removed. Finally, records were aggregated by their coordinates and the weights of physicians at the same location were summed to reflect collective physician resources within a single practice. Physicians whose workplace address could not be geocoded were not counted.

Census Data

Population data for King County were obtained from the American Community Survey (ACS) provided by the U.S. Census Bureau. ACS is an annual nationwide survey that collects and provides population information on social, economic, housing, and demographic characteristics (United States Census Bureau, 2017). Following recommendations for cross-sectional comparisons between census tracts, we used ACS 5-year estimates. A census tract shapefile was downloaded from King County GIS Center (King County GIS Center, 2018), and the centroid point for each census tract was computed.

We included census tracts within King County collected by ACS between January 1, 2015 and December 31, 2019. For ethnicity, the ACS survey asked the survey respondent to report on each person in a household's ethnic origin as follows: "Is this person of Hispanic, Latino, or Spanish origin?". People who responded "Yes" to Hispanic, Latino, or Spanish origin were considered to be Hispanic for this study, while those who responded "No" were considered to be non-Hispanic. The corresponding question identifying race was "What is this person's race?". The options were "White, Black or African American, American Indian or Alaska Native, Asian, Native Hawaiian and Other Pacific Islander, or some other race" (United States Census Bureau, 2018). We did not consider people with more than one race or did not respond to ethnicity or race questions in the population estimates.

Transportation Network

We used transportation network data to calculate the travel time between population and primary care physicians to estimate spatial accessibility. For simplicity, we assumed travel to primary care was by car. We used Metro Transportation Network (TNET) for Car Mode data from King County GIS Center to estimate driving time (King County GIS Center, n.d.).

Data analysis

Floating Catchment Area Method

We used the Enhanced 2-Step Floating Catchment Area (E2SFCA) method developed by Luo and Qi (2009) to measure spatial accessibility. E2SFCA is an improvement of the two-step floating catchment area method (2SFCA) proposed by Radke and Mu (2000) and modified by Luo and Wang (2003). It is a special form of gravity model with the advantage of interpretability and is used to measure supply to demand ratios within certain catchment area. In this study, the supply resource was primary care physicians, while the demand was the population in King County. The gravity model usually takes the form:

$$A_i^G = \sum_{j=1}^{n} \frac{S_j d_{ij}^{-\beta}}{\sum_{k=1}^{m} P_k d_{kj}^{-\beta}}$$

A_i^G represents accessibility at population location *i*, where n and m are the total number of provider locations and population locations, respectively. S_j is the number of physicians at location j, while P_k is the population size at point k. d_{ij} and d_{kj} are the travel distance and β is the distance decay coefficient. β is usually unknown and need to be determined by physician-patient interaction data. Moreover, the value is not intuitive to interpret (Guagliardo, 2004; Luo and Qi, 2009).

The 2SFCA method evaluates spatial accessibility to medical service supply in two steps:

Step 1:

$$R_j = \frac{S_j}{\sum_{k \in \{d_{kj} \le d_0\}} P_k}$$

For each primary care physician location j, we searched all population locations (k) that are within a threshold travel time (d_0) from catchment j, and compute the physician-to-population ratio R_j within the catchment area, where P_k is the population of census tract k whose centroid falls within the catchment j (i.e., $d_{kj} \le d_0$), S_j the total weight of physicians at location j, and d_{kj} the drive time between k and j.

Step 2:

$$A_i^F = \sum_{j \in \{d_{ij} \le d_0\}} R_j = \sum_{j \in \{d_{ij} \le d_0\}} \left(\frac{S_j}{\sum_{k \in \{d_{ij} \le d_0\}} P_k} \right)$$

For each population location i, search all physician locations (j) that are within the threshold travel time (d_0) from catchment area i, and sum up the R_j at these locations, where A_i^F represents the accessibility of population at centroid point i to physicians based on the 2SFCA method, R_j is the physician-to-population ratio at physician location j whose centroid falls within the catchment centered at population location i (i.e., $d_{ij} \le d_0$), and d_{ij} the travel time between i and j.

The first step calculates an initial physician-to-population ratio for each catchment defined by the travel time threshold, which determines how the physician resources are distributed to the population. The second step is to sum up the initial ratios within the catchment area to estimate the amount of resources that the population can get within the catchment. From the steps of 2SFCA method, we can see that the accessibility A_i^F represents the ratio between physician and population under travel time threshold.

Based on 2SFCA method, E2SFCA divides the catchment into several travel time zones and apply weights to the population locations to account for distance decay. The Gaussian function is adopted as the distance impedance function, because it performs better than other function (Wang, 2007):

$$R_j = \frac{S_j}{\sum_{k \in \{d_{kj} \le D_t\}} P_k \times W_t}$$

$$A_i^F = \sum_{j \in \{d_{ij} \le D_t\}} R_j \times W_t$$

The demand populations in Step 1 and the physician-to-population ratios in Step 2 are multiplied with same weight W_t, which is the weight of the tth travel time zone (D_t). The E2SFCA method not only derives the advantage of interpretability from 2SFCA but also solves the non-differentiating accessibility within the catchment problem. Moreover, the discretized weights capture the actual seeking care behavior better than the continuous gravity model, for people would not mind a few minutes of difference in driving time to seek care. The E2SFCA score is essentially a weighted physician-to-population ratio (Luo & Qi, 2009). The improvement of gravity model is summarized in the chart (Figure 1).

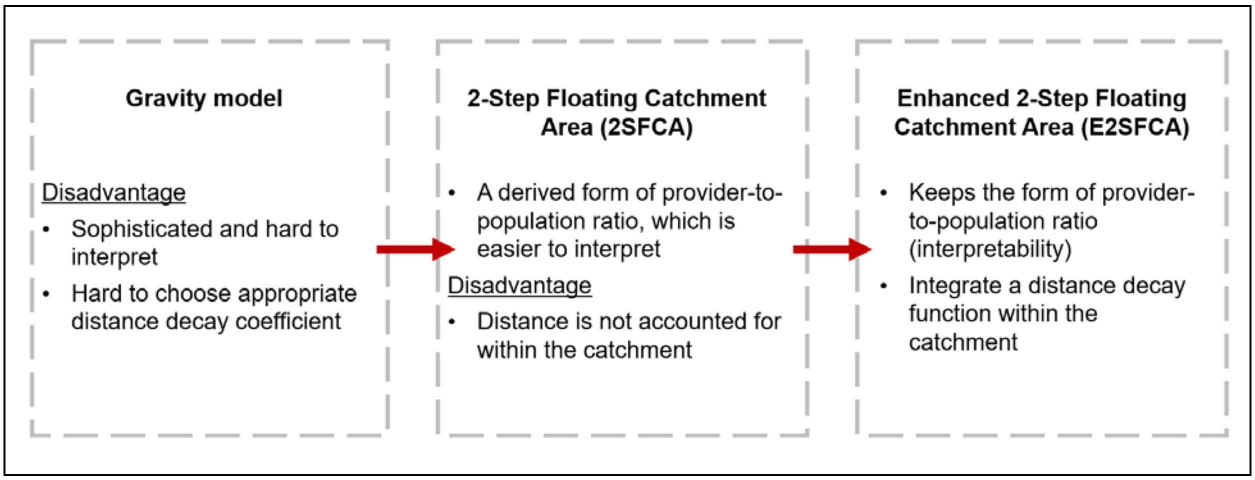

Figure 1: Improvement of gravity model

In this study, we assumed the average driving speed was 30 miles per hour for all types of roads in King County, and the driving time threshold was 30 minutes as recommended by previous studies (Lee, 1991). A Gaussian function with bandwidth 50 was used to assign weights. To make comparison easier, all E2SFCA score results were multiplied by 1,000, which represent the primary care physician per 1,000 adult residents.

Racial/Ethnic Disparity

To assess the difference in spatial accessibility among races/ethnicities, we first measured spatial accessibility by calculating the E2SFCA score for the population regardless of race/ethnicity for each census tract. Secondly, we calculated weighted mean E2SFCA score for each racial/ethnic group, where n was the total number of census tracts, and Pop_r the rth racial/ethnic population:

$$Weighted\ mean\ E2SFCA = \frac{\sum_i^n Pop_{ri} \times E2SFCA\ score_i}{\sum_i^n Pop_{ri}}$$

To assess trends in E2SCFA score differences between race/ethnic groups, we used Spearman's rank correlation coefficient method to test the correlation between E2SFCA score and percent population of each racial/ethnic group for all census tracts. This approach has been used previously (Xie, Q. & Lu, M., 2020).

All statistical analyses were performed in R Studio (R version 4.0.2). We used Network Analyst Extension of ArcGIS 10.6 to calculate travel times between centroid points and medical service sites. An ArcGIS add-in tool, USWFCA2, developed by Langford, Higgs and Fry (2015) was used to calculate E2SFCA scores. The projection for all data used in this study was State Plane (Zone: 5601 Washington State Plane North; FIPS Zone 4601; Datum: HPGN; Units: feet), which was the standard projection used by King County GIS Center.

Results

Descriptive statistics

There were 77,580 records with information of 10,873 primary care physicians in King County. After removing duplicate records and excluding locations outside King County, 35,945 records for 10,873 physicians were used for modeling. All records were successfully geocoded. A total of 794 medical service locations identified. Physicians mostly clustered in the cities of Seattle and Bellevue (Figure 2), which are the largest two municipalities in the county.

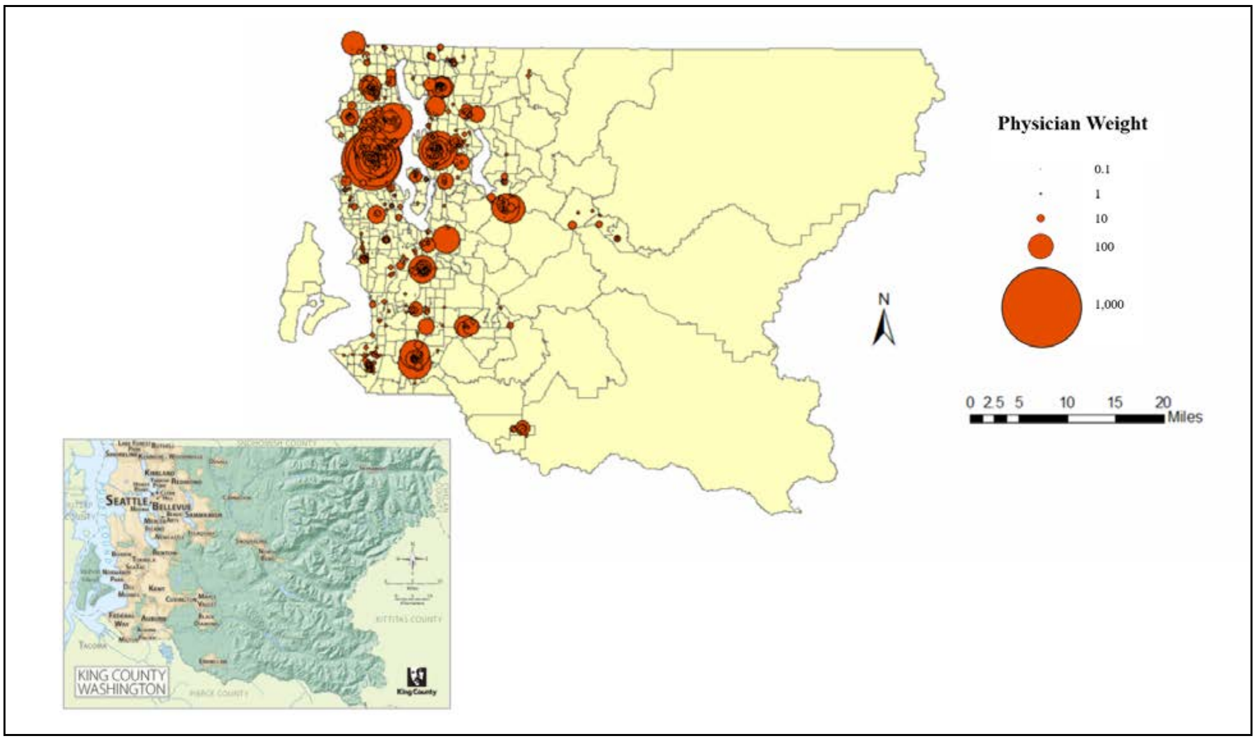

Figure 2: Primary care physicians weight sums and locations in King County, WA King County map reprinted from *King County Maps*, 2017, https://www.kingcounty.gov/about/region/maps.aspx

The ACS 5-year estimated population size in King County from year 2015 to 2019 was 2,195,502 people who lived in 398 census tracts. After excluding respondents who did not respond to race or ethnicity questions and those who reported more than one race (n=140,606), 2,076,490 people were included in our study. Population density was the highest in Seattle;

most of the other census tracts in King County had population densities lower than 8,000 people per square mile (Figure 3).

The dominant racial/ethnic group was non-Hispanic white (1,308,660 people, 63.0% of the County population), followed by non-Hispanic Asian (384,359, 18.5%), and Hispanic (212,241, 10.2%). Other groups comprised less than 10% of total population (Table 1).

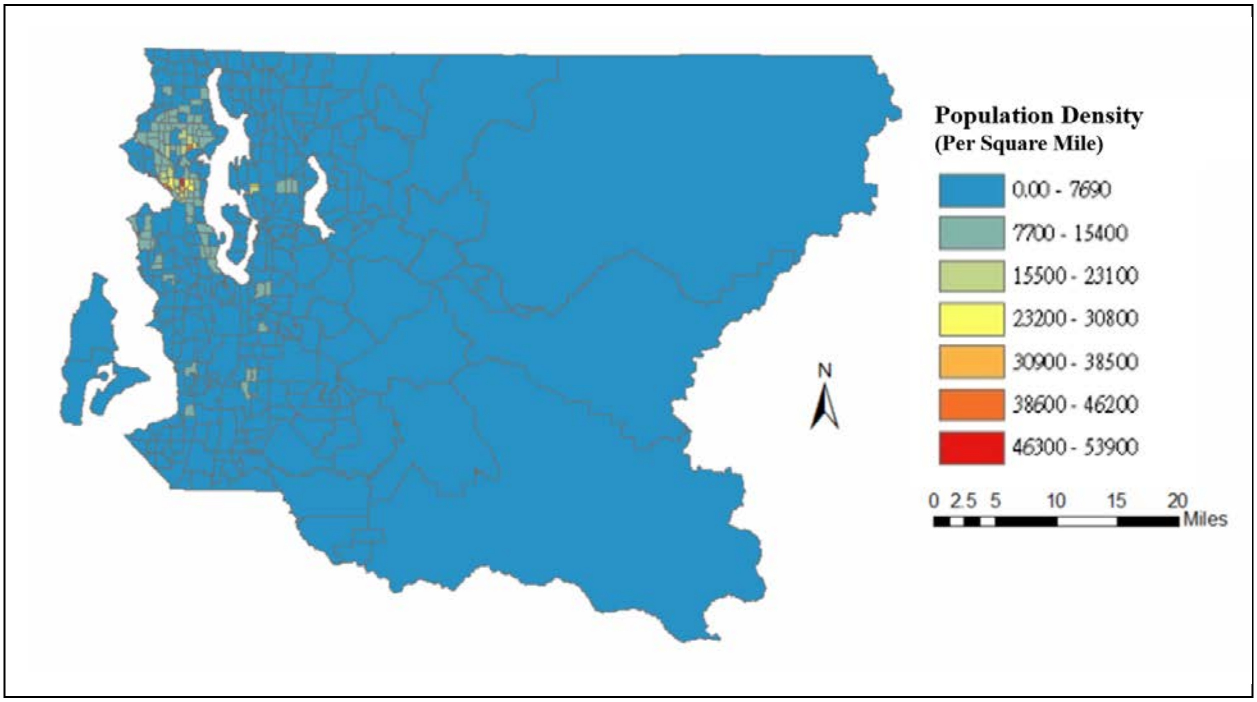

Figure 3: Population density by census tracts, King County, WA

Table 1: Population by race/ethnicity, King County, WA

Race/ Ethnicity	n	(%)
Hispanic	212,241	10.2
Non-Hispanic White	1,308,660	63.0
Non-Hispanic Black	137,919	6.6
Non- Hispanic American Indian and Alaska Native	10,965	0.5
Non-Hispanic Asian	384,359	18.5
Non-Hispanic Native Hawaiian and Pacific Islander	16,608	0.8

Other	5,738	0.3

The non-Hispanic white population and non-Hispanic American Indian and Alaska natives are more concentrated in the eastern region of the County. Non-Hispanic Black, Hispanic, and non-Hispanic Native Hawaiian and Pacific Islander populations clustered in South King County such as Kent and Federal Way, while non-Hispanic Asian located in Bellevue and Sammamish areas east of Lake Washington (Figure 4).

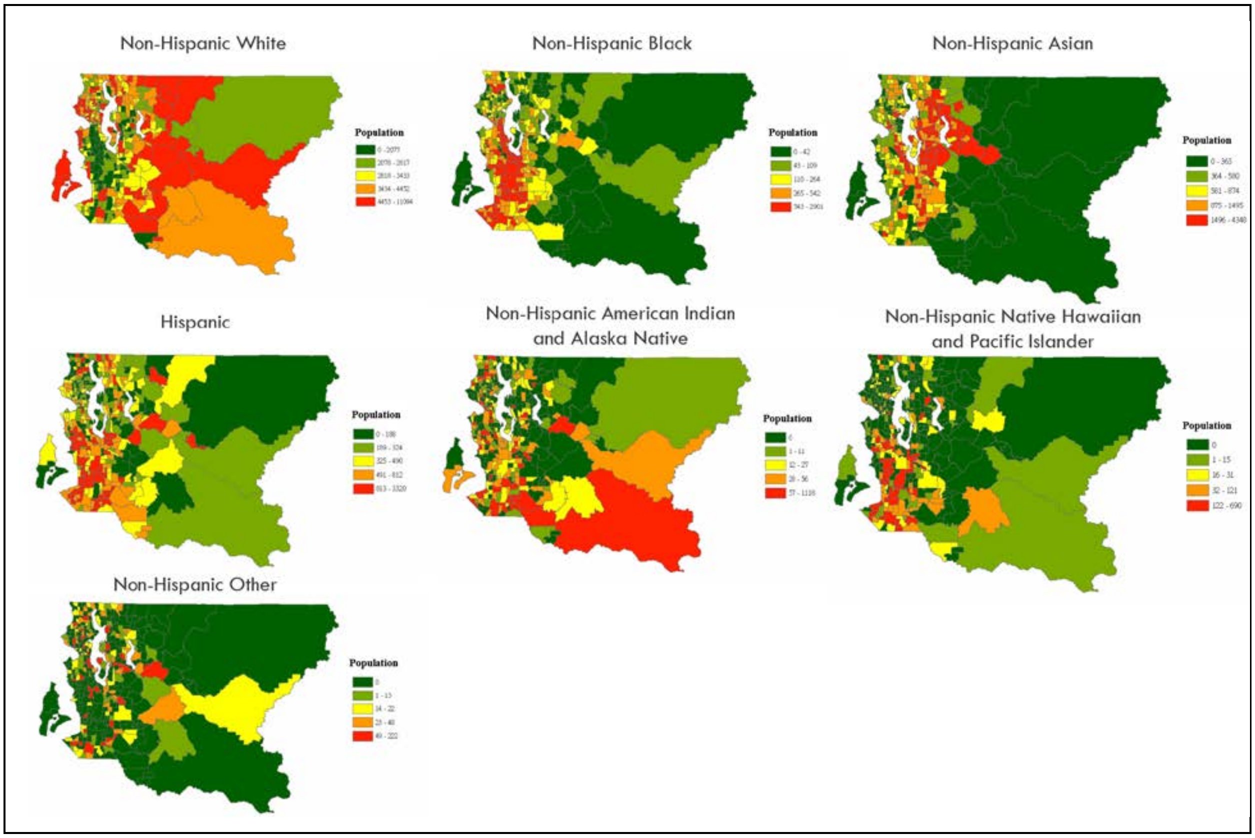

Figure 4: Spatial distribution of population by race/ethnicity, King County, WA

Spatial accessibility

The mean E2SFCA score for all census tracts was 3.795 (SD 2.291), indicating nearly 4 primary care physicians per 1000 residents. However, there was significant spatial variability in scores by tract (Figure 5). There was a right-skew to the score distribution: about 61% (n=243) of census tracts in King County had lower E2SFCA results than the mean score. Primary care physician accessibility was higher in Seattle and Bellevue areas, where both population and physician supply were higher.

Non-Hispanic White (mean 3.827, SD 2.374), non-Hispanic Black (mean 3.836, SD 2.147), and non-Hispanic Asian populations (mean 3.979, SD 2.138) had above average spatial accessibility to primary care physicians, whereas Hispanic (mean 3.341, SD 1.944) and non-Hispanic native Hawaiian and Pacific Islander populations (mean 2.778, SD 1.363) had lower spatial accessibility (Table 2).

The correlation between spatial accessibility and race/ethnicity concentration was weak across all groups (Table 3). Nevertheless, non-Hispanic Asian population proportion was positively correlated with spatial accessibility to primary care (Rho 0.193, $p<0.001$), while proportion of the population that reported Hispanic (Rho -0.186, $p<0.001$) or non-Hispanic native Hawaiian and Pacific Islander (Rho -0.172, $p<0.001$) race/ethnicity was negatively associated with spatial accessibility.

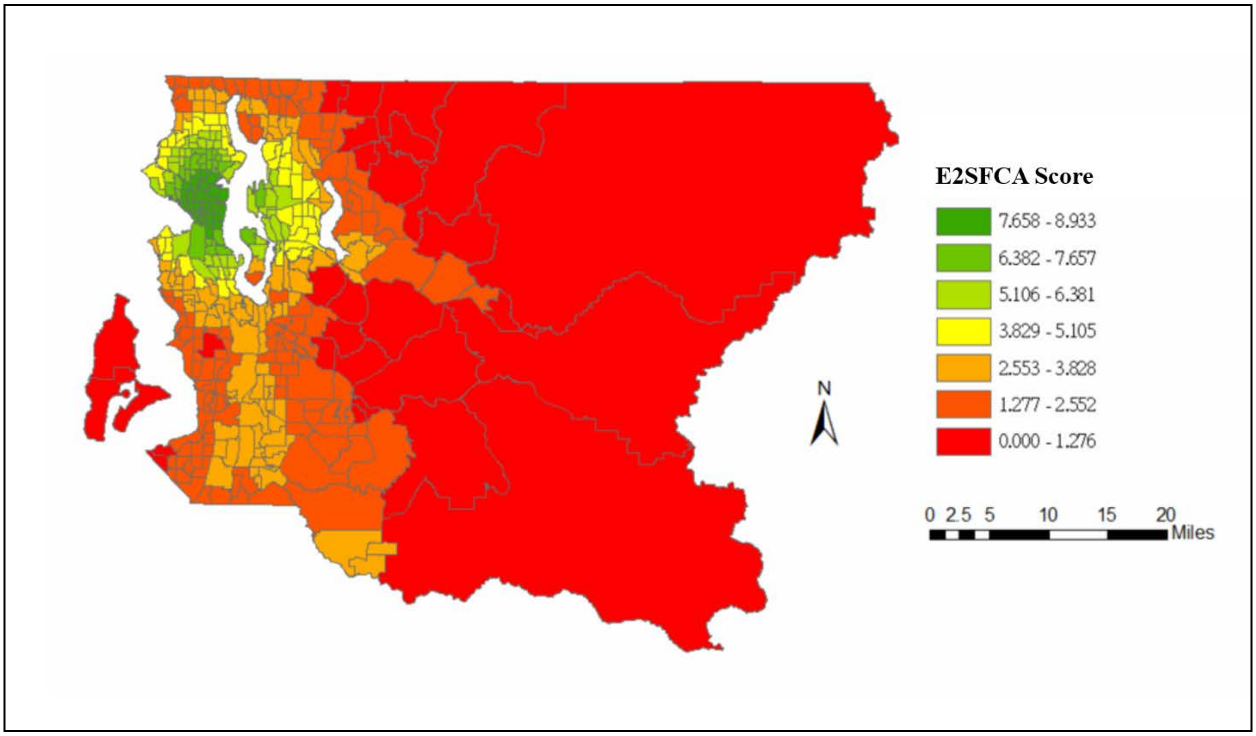

Figure 5: Spatial accessibility to primary care physicians in King County, WA by Enhanced 2-Step Floating Catchment Area method All scores were multiplied by 1,000

Table 2: Weighted Enhanced 2-Step Floating Catchment Area score by race/ethnicity

Population	Weighted mean E2SFCA Score (*1000)	Weighted SD[1]
Hispanic	3.341	1.944
Non-Hispanic White	3.827	2.374
Non-Hispanic Black	3.836	2.147
Non-Hispanic American Indian and Alaska Native	3.646	2.274
Non-Hispanic Asian	3.979	2.138

Non-Hispanic Native Hawaiian and Pacific Islander	2.778	1.363
Other	4.184	2.281

[1] SD: Standard Deviation

Table 3: Correlation between percent population and Enhanced 2-Step Floating Catchment Area score in each census tract by race/ethnicity

Race	Rho	p-value
Hispanic	-0.186	< 0.001
Non-Hispanic White	-0.002	0.97
Non-Hispanic Black	0.042	0.41
Non-Hispanic American Indian and Alaska Native	-0.022	0.66
Non-Hispanic Asian	0.193	< 0.001
Non-Hispanic Native Hawaiian and Pacific Islander	-0.172	< 0.001
Other	0.143	< 0.01

Discussion

Brief summary of results

We investigated spatial accessibility to primary care in King County, Washington. We found differences in spatial accessibility across census tracts; most census tracts had lower E2SFCA scores than the average. In addition, spatial accessibility to primary care varied by race/ethnicity of the population. Non-Hispanic Asians had greater spatial accessibility to primary care, whereas Hispanic and non-Hispanic Native Hawaiian and Pacific Islander populations had less accessibility to primary care services.

Interpretation

Spatial accessibility to primary care services was better for people living in urban areas in King County where hospitals and clinics clustered. These results are consistent with prior findings that residents of rural areas experience higher travel time to seek medical services (Chan et al., 2006; Onega et al., 2008; Wang et al., 2008; Wan et al., 2012).

The clusters of Non-Hispanic White population scatter around the whole county. Only some population gathered in area near medical centers such as central north King county near EvergreenHealth medical Center in Kirkland, Southwest area near Swedish Medical Center

Issaquah campus, and south King County. This might be the reason why we did not find significant correlation between E2SFCA score and non-Hispanic White group.

In King County, non-Hispanic Asians disproportionately live on the 'Eastside'– a swath of urbanized land comprising Bellevue, Kirkland, Redmond, and Sammamish to Issaquah east of Lake Washington. These locations are close to medical services in Bellevue and Issaquah. The non-Hispanic Black population in King county is clustered from the Central District south through Rainier Valley into Renton, and the northern part of this band has spatial accessibility to the First Hill cluster of primary care services while the south is close to the Valley Medical Center cluster (Figure 4). Therefore, we observed both groups having high spatial accessibility to primary care than average. By contrast, the Hispanic and Pacific Islander populations are more centered in south King County cities such as Kent, Federal Way, and Auburn, which are further from medical services (Figure 4).

Strengths

We used a newer, improved gravity model – E2SFCA -- to estimate spatial accessibility. The results can be interpreted as physician-to-population ratio adjusted for distance. Such gravity models improve on simple physician-to-population ratios within a spatial unit by incorporating distance impacts on demand and supply interactions and by bypassing the modifiable areal unit problem (Guagliardo, 2004). In Washington State, the government examines the primary care resources and distribution with physician to population ratio (Office of Financial Management, 2020), which may not be sufficient.

Our results are consistent with a study conducted in Texas that reported potential spatial accessibility to primary care physicians, Colorectal Cancer screening facilities, and oncologists varied among racial/ethnic groups. In Texas, Non-Hispanic Blacks and Asians had greater spatial accessibility to primary care services than other racial/ethnic groups (Wan et al., 2012). Another study showed that lower accessibility to pediatric providers was associated with a higher neighborhood percentage of Black children in urban areas (Guagliardo et al., 2004). However, our findings do not align with work from Philadelphia that reported the odds of being in a low-access to primary care area were greater for census tracts with a high proportion of Black people than in tracts with a low proportion of Black people (Brown et al., 2016). Future work should more deeply explore how historical structural racism, including exclusionary racial covenants and red-lining, affect current accessibility to care across cities. The findings from such work could directly inform restitution initiatives.

Limitations

Our findings should be interpreted in the light of several key limitations. First, spatial accessibility may not represent the key quantification of access to primary care. A person's insurance payer or lack thereof, health literacy, assigned providers, transportation options, and physician's primary language spoken are important factors that may affect people's decision on where to seek care. This type of information is sensitive and not easily obtained. Considering limited time and budget, we choose not to use hospital and insurance databases but census data. Census data can still provide useful information on the population and the distribution of groups of people in King County. Examining the geospatial accessibility to primary care can provide useful information to inform better primary care service delivery models.

Second, we used physicians' data to define primary care. Although these data do not include other types of primary care providers such as physician assistants and nurse practitioners.

Physicians are the most commonly sought primary care provider type (Benitez et al., 2015). Further, non-physician primary care providers in Washington State must work under licenses of primary care physicians.

Third, we used car driving time as the estimate for accessibility. However, people may not possess a car and car ownership is not randomly distributed across different races/ethnicities. About 94.4% of workers above age 16 years had one or more vehicles. In addition, 71.1% of them went to work by car, truck, or van, and 13.7% used public transportation. Therefore, we considered driving as the most common commuting methods for population in King County and assumed it was also true for people seeking primary care. However, we acknowledge that access to preferred transportation is likely not equally distributed across census tracts or races/ethnicities.

Fourth, we do not consider stop signs and traffic history when estimating driving time. Different types of roads may also have different speed limits. Although these may affect the accuracy of driving time estimation, they may not affect patients' decisions on where to seek care. These factors may have a bigger impact on emergency care but not primary care.

Fifth, the determination of travel time breaks is based on Gaussian decay function and traveling time threshold is set as 30 minutes for all areas, which might be conservative in defining the catchment size for primary care physicians. Empirical data such as patient survey are needed to decide appropriate time breaks and threshold.

Lastly, the study area is limited to King County. There are primary care locations that are near the border of the County. Populations that are near those locations are still pose demand for those primary care resources. Conversely populations inside King County that are close to the border can get primary care outside the border, too.

Implications

Distributing primary care resources to the population, especially for those in greatest need, is a vital function of a public health system. Investigating which areas and vulnerable groups lack accessibility to healthcare resources can inform government policies that might encourage medical organizations to locate in those areas, ensure adequate medical service delivery to key groups, or give travel compensation to a specific population or area. The results also provide information on medical service demands and capacity within an administrative area for local hospitals or clinics to change their operation strategies (e.g., staffing, open hours, patient panel limits).

In addition to primary care, there are other types of healthcare services we can investigate. For example, additional behavioral health professionals found to be needed in racial/ ethnic minority neighborhoods and rural areas to provide access to behavioral health services (Wielen et al., 2015). Improved spatial access to palliative care has the potential to reduce travel-times for patients and palliative care workers making home visits (Cinnamon et al., 2008). Understanding spatial accessibility to all resources and examining the difference between different races/ethnicities can help us achieve better health equity from various aspects.

Conclusion

Spatial accessibility to primary care services has regional and race/ethnic differences. Focusing on policies improving access for Hispanic and non-Hispanic native Hawaiian and Pacific Islander populations can help reduce the disparity in spatial accessibility to care.

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