



Assessment of Doubly Disadvantaged Neighborhoods by Healthy Living Environment Exposure

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Abstract

Good access to greenspace and healthy food has commonly been found to be positively associated with health outcomes, despite some studies finding no significant relationship between them. Examining inequalities in accessing greenspace and healthy food among different disadvantaged neighborhoods can help reveal the disadvantaged races/ethnicities in cities with a high level of residential segregation (i.e., population of the same race/ethnicity concentrated in the same neighborhoods). However, existing studies have mostly focused on measuring the inequalities in accessing either greenspace or healthy food alone, which can lead to the inaccurate depiction of disadvantaged neighborhoods in healthy living environments. Therefore, this paper aims at improving the assessment of doubly disadvantaged neighborhoods by considering accessibility to both greenspace and healthy food in the City of Chicago. Our results show that black-majority neighborhoods are the most doubly disadvantaged in terms of exposure to healthy living environments. This study can help guide policymakers to divert more resources towards the improvement of the urban environment for the most doubly disadvantaged neighborhoods.

Keywords greenspace · healthy food · doubly disadvantaged neighborhoods · Chicago

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Introduction

Easy access to greenspace and healthy food has been considered important components of healthy living environments. Studies have shown that greenspace is conducive to the improvement of both mental and physical health (Jennings & Bamkole, 2019; Larkin & Hystad, 2019). Further, access to healthy food is also indispensable for people to maintain a healthy diet, while people living in food deserts are prone to obesity, diabetes and other cardiovascular diseases (Testa et al., 2021; Richardson et al., 2017). Given the ongoing COVID-19 pandemic and various lockdown measures imposed by governments around the world, greenspace has been found to provide important outdoor venues for physical exercises (Venter et al., 2020). Besides, it has also been found that greenspace and physical exercises during the COVID-19 pandemic are conducive to relieving mental health issues such as stress, depression and anxiety (Heo et al., 2021; Li et al., 2022). Moreover, healthy food within walking distance enables socially disadvantaged people, who are more likely to be carless, to avoid taking public transport, which facilitates the spread of infectious diseases like COVID-19 due to its confined space (Shen et al., 2020).

Existing literature has characterized the inequalities among different neighborhoods and identified disadvantaged neighborhoods in terms of their greenspace exposure (Rigolon et al., 2018) and access to healthy food (Hilmers et al., 2012). Both greenspace exposure and access to healthy food have commonly been used as indicators for healthy living environments and health (in)equality (Broady and Meeks, 2015; De Vries et al., 2003; Larson et al., 2009; Maas et al., 2009). For instance, De Vries et al. (2003) explored the relationship between greenspace and health in the Netherlands and found that living in a green environment was related to better health outcomes. The positive association between living in a green environment and better health outcomes was found to be stronger for some socially disadvantaged groups including people with lower education levels and older adults. Maas et al. (2009) examined whether physician-assessed morbidity is related to greenspace in people's living environment in the Netherlands and revealed that the annual prevalence rate of 15 of the 24 disease clusters included in the study was lower in living environments with more greenspace in a 1 km radius from people's residences. The relationship was stronger for children and people with a lower socioeconomic status. Larson et al. (2009) revealed that US residents who had better access to supermarkets and healthy food tended to have healthier diets and lower levels of obesity, while residents from more socially disadvantaged backgrounds (i.e., low-income, minority) were most often adversely affected by poor access to supermarkets and healthy food. Broady and Meeks (2015) found that healthy food retailers within a half-mile of the residence were related to a lower level of obesity, while a higher percentage of the black population was associated with a higher level of obesity. Nevertheless, the Supplemental Nutrition Assistance Program (SNAP), which provided subsidies to lower-income individuals to purchase healthier food items, was found to be associated with lowering obesity levels. Although these studies have shown that greenspace and healthy food are important indicators of healthy environments, they have mainly studied greenspace exposure (Liu et al., 2021a; Song et al., 2021; You, 2016) and access to healthy food (Hu et al., 2020; Garcia et al., 2018; Walker et al., 2010) sepa-

rately. Meanwhile, little attention has been paid to those living in neighborhoods with poor access to both greenspace and healthy food, which can be considered as doubly disadvantaged neighborhoods (DDNs) in terms of healthy environment exposure.

This study seeks to measure exposure to healthy living environments by considering both greenspace and healthy food. This can help reveal the DDNs in terms of healthy environment exposure. In this paper, we adopt the two-step floating catchment area (2SFCA) method, which basically discounts the attraction of greenspace and healthy grocery by travel distance and competition from other people, to calculate the accessibility to greenspace and healthy grocery. Our study contributes to the understanding of the distribution of neighborhoods that are disadvantaged in terms of exposure to both greenspace and healthy food by race/ethnicity, which are integral components for developing a healthy living environment, especially in light of the COVID-19 pandemic.

Background

Greenspace is conducive to both physical and mental health (Jennings & Bamkole, 2019; Larkin & Hystad, 2019; Twohig-Bennett & Jones, 2018; Wolch et al., 2014). Astell-Burt et al. (2014) revealed that greenspace is related to higher physical activity and lower odds of having skin cancer based on survey data from more than 250,000 Australians (Astell-Burt et al., 2014). Demoury et al. (2017) uncovered that people living in greener areas have lower risks of prostate cancer in Montreal, Canada (Demoury et al., 2017). Richardson et al. (2013) found that greenspace is associated with better cardiovascular and mental health in New Zealand (Richardson et al., 2013). Ochiai et al. (2015) discovered that forest exposure can lead to lower blood pressure and an increase in relaxed and natural feelings in Nagano Prefecture, Japan (Ochiai et al., 2015).

Meanwhile, good access to healthy food has often been considered key to maintaining healthy diets, which in turn helps increase and maintain people's overall health. In comparison, living in food deserts has often been associated with a multitude of health issues such as obesity, diabetes and cardiovascular diseases. Testa et al. (2021) found that living in food deserts is associated with higher cardiovascular disease risk for people of low socioeconomic status in the United States (Testa et al., 2021). Richardson et al. (2017) revealed that the addition of healthy grocery retailers in food deserts reduces the risks of high cholesterol, arthritis and diabetes in Pittsburgh (Richardson et al., 2017). Schafft et al. (2009) uncovered a positive association between the percentage of school district population living in food deserts and the rate of school children overweight in Pennsylvania (Schafft et al., 2009). Nevertheless, some studies did not find a significant association between food deserts and obesity (Alviola et al., 2013; Fleischhacker et al. 2011; Ford and Dzewaltowski, 2010). Alviola et al. (2013) revealed no statistically significant association between the existence of food deserts and school district obesity rates in Arkansas. Ford and Dzewaltowski (2010) did not find a significant relationship between the limited spatial availability of grocery stores/supermarkets and obesity risk among low-income women, infants and children in Kansas. The inconsistency in the relationship between food deserts

and obesity in the existing literature could be due to the influence of other factors such as access to greenspace.

Since greenspace and healthy food are both relevant and conducive to health improvement, both can therefore be considered components of healthy environments. Nevertheless, despite the health benefits of both greenspace and healthy food, existing literature has mostly studied exposure inequality to greenspace (Liu et al., 2021a; Song et al., 2021; You, 2016) and healthy food (Hu et al., 2020; Garcia et al., 2020; Liu et al., 2022; Walker et al., 2010) separately. Specifically, in terms of greenspace, You (2016) found that neighborhoods of lower socioeconomic status have more limited access to greenspace in Shenzhen (You, 2016). Song et al. (2021) revealed that cities located in northern and northwestern China have higher greenspace exposure inequality than the rest of the country (Song et al., 2021). As for healthy food, Hu et al. (2020) found that neighborhoods with higher concentrations of elderly residents have lower accessibility to healthy food in Hangzhou (Hu et al., 2020). Garcia et al. (2020) showed that wealthier neighborhoods have substantially better access to organic food than low-income neighborhoods in Barcelona (Garcia et al., 2018).

Given the health benefits of both greenspace and healthy food, it is reasonable to assess exposure inequality to healthy living environments by considering both factors at the same time. Furthermore, although past studies have examined healthy living environments by considering access to greenspace (Liu et al., 2021a; Song et al., 2021; You, 2016) and healthy food (Hu et al., 2020; Garcia et al., 2018; Walker et al., 2010), these studies have examined them separately. To the best of our knowledge, few existing studies to date have assessed exposure to healthy living environments by considering greenspace and healthy food together. Therefore, this study aims at filling this gap by uncovering the DDNs in healthy living environment exposure through the integration of access to greenspace and healthy food.

Data and Methodology

Study Area and Data Sources

The study area for this research is the City of Chicago (hereafter “Chicago”), which is the third-largest city in the United States in terms of population (United States Census Bureau, 2018a). Chicago has been traditionally known as a city with high residential and economic segregation (Liu et al., 2021b). The western and southern parts of the city are predominantly resided by the lower-income black and Hispanic population; while the northern part of the city is mostly dwelled by the higher-income white population, as shown in Fig. 1, which uses the Jenks natural breaks classification scheme.

The neighborhood study unit in this research is set at the census tract level and the datasets are from the year of 2018. As of 2018, the study area consisted of 801 census tracts. In terms of the data sources, first of all, sociodemographic information (e.g., median personal income, race/ethnicity) is derived from the 2014–2018 American Community Survey (ACS) 5-year Estimates (United States Census Bureau, 2018b). The choice of the median personal income is based on that personal income has

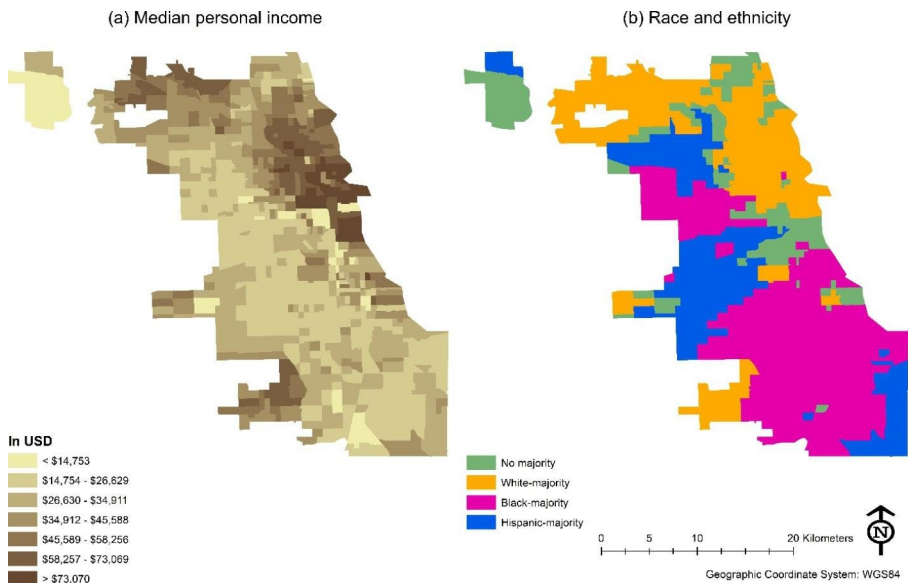


Fig. 1 Distribution of (a) median personal income; (b) race and ethnicity in Chicago in 2018

already been often used in previous health inequality studies (Biggs et al., 2010; Nwosu and Oyenubi, 2021; Ruger and Kim, 2006). Second, the area information on greenspace is obtained from the United States Census Bureau (United States Census Bureau, 2018c) and the area information on grocery stores comes from the Chicago Data Portal (City of Chicago, 2018). The grocery store data in our study were collected by the City of Chicago to measure food deserts and improve access to healthy food in the food deserts (Office of the Mayor, City of Chicago, 2013). Therefore, we consider this list of grocery stores as the ones selling healthy groceries. Third, the street network information is obtained from the Chicago Data Portal (City of Chicago, 2018). Finally, the 2018 social vulnerability index data at the census tract level is obtained from the Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry (CDC/ATSDR, 2018). The social vulnerability index is a composite score calculated based on 15 variables related to socioeconomic status, household composition and disability, minority status and language, as well as housing type and transportation (CDC/ATSDR, 2022).

Methodology

In this research, we use the normalized walking accessibility score to quantify the exposure to healthy living environments including greenspace and healthy food. Therefore, our study adopts the 2SFCA method to calculate the accessibility score to greenspace and grocery stores selling healthy food respectively. The adopted 2SFCA method (Luo & Whippo, 2012) accounts for the supply of and demand for greenspace and healthy food. Furthermore, we also incorporate the Gaussian distance decay function within the walking distance cut-off threshold. The choice of the Gaussian

function is because it helps reduce the bias from the uncertainty of catchment size (Chen & Jia, 2019). The two-step calculation is based on Eqs. (1) and (2).

$$E_j = \frac{M_j}{\sum_{o \in \{d_{oj} \leq T\}} P_o \times \text{EXP}\left(\frac{-d_{oj}^2}{\mu}\right)} \quad (1)$$

where E_j is the greenspace/grocery store area-to-population ratio for census tract j ; M_j is the area of greenspace/grocery store j ; P_o is the population in census tract o whose centroid is within the travel distance threshold from the centroids of greenspace j /the locations of grocery store j ; d_{oj} is the distance between the centroids of census tract o and centroids of greenspace j /the locations of grocery store j ; T is the travel distance threshold, which is set at 800 m. This walking distance threshold is determined based on the walking distance threshold commonly used in previous studies (Coombes et al., 2010; Van Dyck et al., 2009). μ is the Gaussian distance decay function parameter.

$$A_i = \sum_{j \in \{d_{ij} \leq T\}} E_j \quad (2)$$

where A_i is the integrated accessibility to greenspace/grocery store from census tract i ; d_{ij} is the distance between the centroids of census tract i and centroids of greenspace j /the locations of grocery store j ; T is the travel distance threshold, which is again set at 800 m. In addition, we have also performed Spearman's rank-order correlation analysis using multiple distance thresholds (500 m, 600 m, 700 m, 900 and 1000 m) to determine the impact of different travel distance thresholds on the accessibility results. As shown in Tables 1 and 2, the test results show that there is a significant correlation between the rank orders of healthy food/greenspace accessibility results based on different distance thresholds, which indicates that the different travel distance thresholds have no significant effect on the accessibility results in this case.

We then normalize the accessibility results in order to obtain the accessibility score for each census tract that can be more readily interpreted and compared. Afterward, we obtain the quartile values for healthy food and greenspace accessibility respectively and select the census tracts whose accessibility scores are below the first quartile.

Finally, we identify the census tracts whose accessibility scores are below the first quartile in terms of both healthy food and greenspace accessibility and consider these census tracts as meeting both of the study criteria for being doubly disadvantaged. In other words, these census tracts are considered to be DDNs with regard to healthy living environment exposure.

Table 1 Spearman’s rank-order correlation analysis results for healthy food accessibility based on different travel distance thresholds

		500 m	600 m	700 m	800 m	900 m	1000 m
Spearman’s rho	500 m Correlation Coefficient	1	0.873**	0.758**	0.697**	0.531**	0.603**
	Sig. (2-tailed)		3.166E-251	1.3839E-150	2.0837E-117	1.4215E-59	1.58105E-80
	N	801	801	801	801	801	801
600 m	Correlation Coefficient	0.873**	1	0.879**	0.805**	0.638**	0.700**
	Sig. (2-tailed)	3.166E-251		1.3259E-259	3.7342E-183	7.2727E-93	5.0483E-119
	N	801	801	801	801	801	801
700 m	Correlation Coefficient	0.758**	0.879**	1	0.899**	0.749**	0.794**
	Sig. (2-tailed)	1.3839E-150	1.3259E-259		3.8778E-288	9.5385E-145	4.3454E-175
	N	801	801	801	801	801	801
800 m	Correlation Coefficient	0.697**	0.805**	0.899**	1	0.888**	0.902**
	Sig. (2-tailed)	2.0837E-117	3.7342E-183	3.8778E-288		2.4534E-271	9.3187E-294
	N	801	801	801	801	801	801
900 m	Correlation Coefficient	0.531**	0.638**	0.749**	0.888**	1	0.932**
	Sig. (2-tailed)	1.4215E-59	7.2727E-93	9.5385E-145	2.4534E-271		0
	N	801	801	801	801	801	801
1000 m	Correlation Coefficient	0.603**	0.700**	0.794**	0.902**	0.932**	1
	Sig. (2-tailed)	1.58105E-80	5.0483E-119	4.3454E-175	9.3187E-294	0	
	N	801	801	801	801	801	801

** Correlation is significant at the 0.01 level (2-tailed).

Results and Findings

The exposure to healthy living environments is quantified by the levels of accessibility to greenspace and healthy food based on Eqs. (1) and (2). After obtaining the results, we render them in Fig. 2 for analysis. Figure 2 uses the Jenks natural breaks classification scheme.

As shown in Fig. 2(a), neighborhoods with higher healthy food accessibility are largely concentrated in the western and northern parts of the city. The southeastern part of the city generally has lower accessibility to healthy food. In comparison, as shown in Fig. 2(b), many neighborhoods with higher greenspace accessibility appear to be clustered in the southeastern part of the city. Meanwhile, the western and northern parts of the city do not have too many neighborhoods with higher greenspace accessibility. In general, as Fig. 2 indicates, the same neighborhoods do not necessarily have the same high level of accessibility to healthy food as greenspace.

Table 2 Spearman’s rank-order correlation analysis results for greenspace accessibility based on different travel distance thresholds

			500 m	600 m	700 m	800 m	900 m	1000 m
Spearman’s rho	500 m	Correlation Coefficient	1	0.897**	0.802**	0.726**	0.648**	0.596**
		Sig. (2-tailed)		7.2061E-285	9.0101E-181	5.8953E-132	1.67978E-96	4.68077E-78
		N	801	801	801	801	801	801
	600 m	Correlation Coefficient	0.897**	1	0.892**	0.812**	0.723**	0.675**
		Sig. (2-tailed)	7.2061E-285		4.0531E-278	1.0123E-188	2.8722E-130	1.2649E-107
		N	801	801	801	801	801	801
	700 m	Correlation Coefficient	0.802**	0.892**	1	0.905**	0.812**	0.759**
		Sig. (2-tailed)	9.0101E-181	4.0531E-278		5.4632E-299	1.2012E-188	2.6934E-151
		N	801	801	801	801	801	801
	800 m	Correlation Coefficient	0.726**	0.812**	0.905**	1	0.905**	0.853**
		Sig. (2-tailed)	5.8953E-132	1.0123E-188	5.4632E-299		1.1729E-299	6.0576E-228
		N	801	801	801	801	801	801
	900 m	Correlation Coefficient	0.648**	0.723**	0.812**	0.905**	1	0.952**
		Sig. (2-tailed)	1.67978E-96	2.8722E-130	1.2012E-188	1.1729E-299		0
		N	801	801	801	801	801	801
	1000 m	Correlation Coefficient	0.596**	0.675**	0.759**	0.853**	0.952**	1
		Sig. (2-tailed)	4.68077E-78	1.2649E-107	2.6934E-151	6.0576E-228	0	
		N	801	801	801	801	801	801

** . Correlation is significant at the 0.01 level (2-tailed).

Alternatively, we should note that there are some neighborhoods with similarly low levels of accessibility to both healthy food and greenspace. The neighborhoods whose accessibility scores are below the first quartile in terms of both healthy food and greenspace accessibilities are then identified as the DDNs. Afterward, we categorize the DDNs in terms of healthy living environments by considering both the accessibility to healthy food and greenspace and their associations with the majority race/ethnicity.

As shown in Fig. 3, most of the DDNs, which have low accessibility to both greenspace and healthy food, are black-majority neighborhoods located in the south and west of the city. In comparison, there are fewer Hispanic-majority and white-majority DDNs in the west and north of the city respectively. To further examine the attributes of the DDNs by race/ethnicity, we proceed to create Table 3.

As shown in Table 3, the number of black-majority DDNs ranks the highest and is much higher than other racial/ethnic majority doubly disadvantaged neighborhoods.

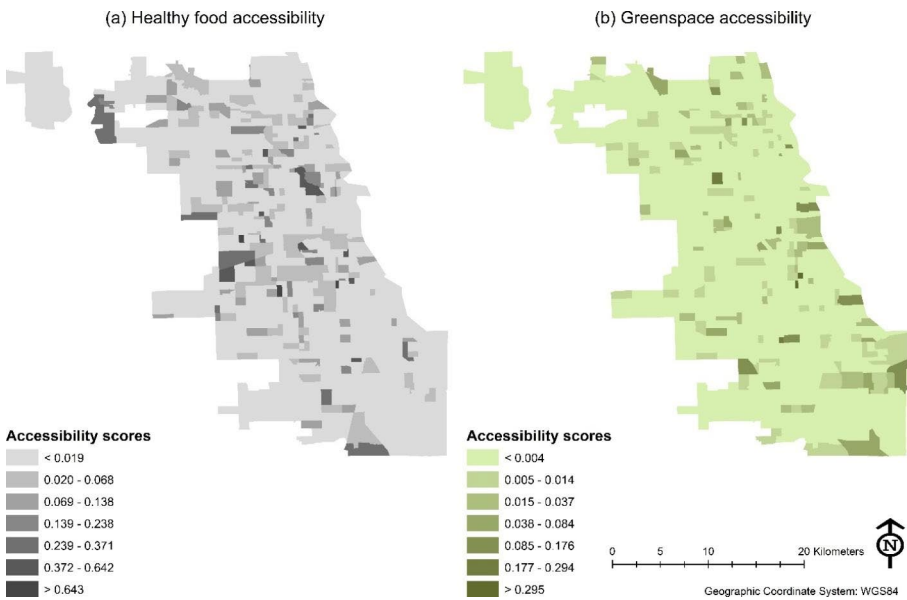
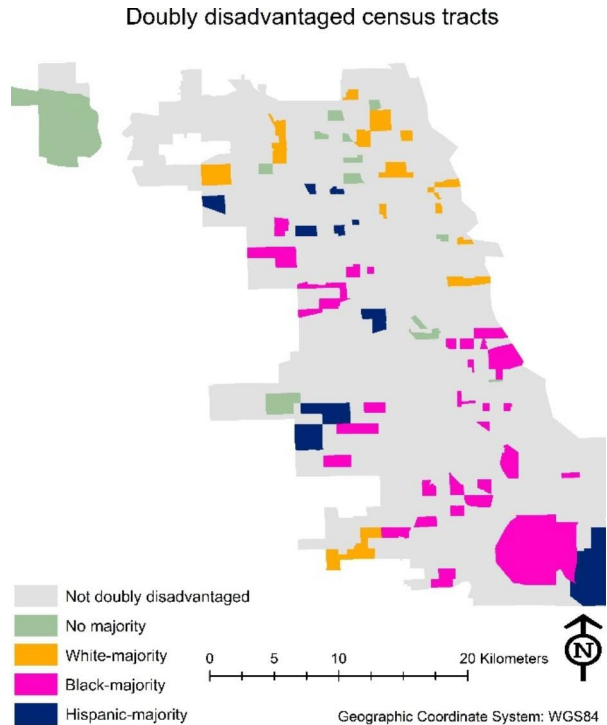


Fig. 2 Distribution of (a) healthy food accessibility; (b) greenspace accessibility in Chicago in 2018

Fig. 3 Distribution of doubly disadvantaged neighborhoods in healthy living environment exposure in Chicago in 2018



Specifically, the numbers of no-majority (14), white-majority (27) and Hispanic-

Table 3 Attributes of the doubly disadvantaged neighborhoods by race and ethnicity in Chicago in 2018

	Number of Doubly Disadvantaged Neighborhoods	Median Personal Income (in USD)	Median Carless Household Percentage	Median Social Vulnerability Index
No Majority	14	\$35,281.50	11.20%	0.560
White-Majority	27	\$61,797.00	15.00%	0.239
Black-Majority	46	\$26,803.00	18.10%	0.854
Hispanic-Majority	16	\$30,178.50	7.25%	0.838

majority (16) DDNs are 69.57%, 41.30% and 65.22% lower than the number of black-majority (46) DDNs respectively.

Furthermore, the median personal income of the black-majority DDNs is merely \$26,803, which ranks the lowest and is less than half of the median personal income for the white-majority DDNs. When it comes to the carless household attribute, the median carless household percentage for the black-majority DDNs is 18.10%, which ranks the highest and more than double that of the Hispanic-majority DDNs. Finally, in terms of the median social vulnerability index, the black-majority DDNs again rank at the top of all DDNs. A higher social vulnerability index indicates a higher level of social vulnerability and vice versa. Therefore, the median social vulnerability index for the black-majority DDNs shows that they have the highest level of social vulnerability.

In summary, among all the DDNs, the number of the black-majority ones is the most and far exceeds those of other racial/ethnic-majority DDNs. Moreover, the black-majority DDNs also have the lowest median personal income and the highest median carless household percentage. These results indicate that people from black-majority DDNs are more likely to live in poverty and carless households. As a result, they are less likely to improve their exposure to greenspace and healthy food by driving compared to their counterparts from no-majority, white-majority and Hispanic-majority DDNs.

Discussion and Conclusion

Our study conducts an assessment of the DDNs in healthy living environment exposure by considering both greenspace and healthy food. The results show that considering either greenspace or healthy food alone would lead to an inaccurate estimation of healthy living environment exposure since neighborhoods with higher greenspace exposure may have lower healthy food exposure, and vice versa.

By integrating both greenspace and healthy food into the measurement of healthy environment exposure, we manage to reveal the neighborhoods that are doubly disadvantaged in terms of exposure to both greenspace and healthy food. The findings show that far more black-majority neighborhoods are doubly disadvantaged compared to white-majority and Hispanic-majority neighborhoods. In addition to this, the black-majority DDNs also fare the worst in terms of median personal income and median carless household percentage.

Policymakers should therefore consider channeling more resources towards improving the accessibility to greenspace and healthy food, especially for the black-majority DDNs. Specific actions that can be taken include building more community parks and providing financial incentives for grocery stores selling healthy food. The opening of a major organic food retailer (i.e., Whole Foods) in 2016 in Englewood, which is a black-majority neighborhood in the south of Chicago, serves as a good example of improving residents' exposure to healthy food. Nevertheless, it should be noted by policymakers that DDNs are often low-income neighborhoods such as those in the south of the city. Thus, grocery stores selling affordable healthy food should be a major part of the incentive package provided to those willing to set up affordable grocery retailing businesses in the DDNs. Otherwise, the government could also offer grocery coupons to residents living in the DDNs to alleviate their financial burden in purchasing healthy food.

We acknowledge that there are some limitations to our study due to data availability. First of all, we only consider spatial access to healthy food in this study when food affordability is also an important factor for many low-income residents (Egbe et al., 2021; Ward et al., 2013). Second, besides the spatial dimension (e.g., travel distance), the temporal dimension of accessibility (e.g., opening hours of urban parks and grocery stores) can also affect people's accessibility to greenspace and healthy food (Chen & Clark, 2016; Xing et al., 2018). Therefore, future studies should explore the integration of spatiotemporal accessibility as well as affordability into the evaluation of disadvantaged neighborhoods in healthy living environment exposure.

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Data Availability All data used in this study are public data available on the web.

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