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ORIGINAL PAPER

Spatial characteristics of food insecurity and food access in Los Angeles County during the COVID-19 pandemic

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Abstract

Food insecurity spiked in some U.S. regions during the COVID-19 pandemic, as did food access challenges. Concerns were raised that these food issues were more prominent in food deserts, or neighborhoods lacking access to a grocery store or supermarket. Using data collected from a representative sample of Los Angeles County adults between April and October 2020, this study examined relationships between self-reported food insecurity, perceived food access barriers, and residing in a food desert, and examined differences across key geographic regions of the county. There was little relationship between residing in a food desert and experiencing food insecurity. However, perceived grocery store closures/limited hours and not having access to a vehicle were commonly reported barriers to food access, which were associated with more food insecurity. These findings suggest that geographic disparities in food access impact food insecurity. Efforts to address food insecurity should center on achieving food justice and addressing disparities across geographic regions.

Keywords Food environment · Food access · Food justice · Food desert · Food insecurity · COVID-19

1 Introduction

Prior to the COVID-19 pandemic, approximately 1 in 10 U.S. households experienced food insecurity each year (Coleman-Jensen et al., 2021). Food insecurity is defined as not having "regular access to enough safe and nutritious food for normal growth and development and an active and healthy life," which may be due to unavailability of food or lack of resources (Food & Agriculture Organization of the United Nations, 2023). Examples of consistent risk factors

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for food insecurity in the United States (U.S.) include economic hardship, lower education, single parent households, and high food prices (Gundersen & Ziliak, 2014, 2018). Although federal food assistance often helps to alleviate food insecurity in U.S. households, some families receiving food assistance benefits continue to experience food insecurity, and many households with food insecurity are not enrolled in these programs (Andreyeva et al., 2015; Gundersen et al., 2019).

National data suggest that food insecurity rates did not change over recent years in the U.S., and remained around 10% across 2019, 2020, and 2021 (Coleman-Jensen et al., 2021). However, regional evidence shows that food insecurity did spike in the early months of the COVID-19 pandemic, at least in some areas of the U.S. (Wolfson & Leung, 2020). For example, the food insecurity rate in California was estimated to be 11% in the period 2016–2018 (Coleman-Jensen et al., 2021). In contrast, the proportion of L.A. County residents reporting past-week food insecurity reached 23% in April 2020 (de la Haye, Wilson, et al., 2021). Moreover, 34% of L.A. County residents reported experiencing food insecurity at some point between April and December 2020 (de la Haye, Miller, et al., 2021). It is possible that the staggering rates of food insecurity in 2020 in regions like L.A. County were due, in part, to barriers to food access resulting from pandemic-related changes in people's lives. This study seeks to explore the relationships between perceived and spatial barriers to food access and food insecurity during the early months of the COVID-19 pandemic in key geographic regions of L.A. County.

1.1 Food deserts, food access, and food insecurity before COVID-19

A "food desert" is a neighborhood lacking food access, or convenient access to a supermarket, large grocery store, or other retailers that sell affordable, healthy foods (Ghosh-Dastidar et al., 2017; Walker et al., 2010; Widener & Shannon, 2014). Much food desert research in the U.S. uses data from the U.S. Department of Agriculture (USDA) Economic Research Service (ERS) Food Access Research Atlas. The Food Access Research Atlas takes into account whether census tract areas include a high proportion of low-income residents and provide low access to supermarkets and large grocery stores. The Food, Conservation, and Energy Act of 2008 defines food deserts as communities that have both a low-income population and limited access to healthy food (Food, Conservation, and Energy Act of 2008, 2008).

Prior to the COVID-19 pandemic, several studies observed that living in a food desert was a significant barrier to healthy food availability and food access (Larsen & Gilliland, 2009; LeClair & Aksan, 2014). Living in a food desert was also perceived to be a barrier to accessing high-quality, healthy, and affordable foods (Dhillon et al., 2019; Mogil et al., 2021; Walker et al., 2011). Despite barriers to food access reported by those living in food deserts, there was little evidence prior to the pandemic that living in a food desert was associated with food insecurity (Thomas, 2010) or worse diet quality (Woodruff et al., 2020). However, as the early months of the pandemic brought many changes and limited mobility beyond one's home neighborhood (Robinette et al., 2021), there is reason to expect that living in a food desert may have had a more substantial impact on experiences of food insecurity, discussed more in the next section.

1.2 Food insecurity and food access during COVID-19

During the early months of the COVID-19 pandemic, several studies showed increased rates of food insecurity in specific regions or populations in the U.S. (de la Haye, Wilson, et al., 2021; Dubowitz et al., 2021; Fang et al., 2022; Mui et al., 2022). Historically, access to food outlets has not been a strong driver of food insecurity (Gundersen & Ziliak, 2014, 2018; Thomas, 2010). However, individuals who experienced food insecurity during the pandemic were more likely than those who were food secure to report challenges in finding enough food to buy, and indicated visiting more stores than usual in order to find food (Niles et al., 2020; Reimold et al., 2021). Below, we explore three potential reasons why barriers to food access may have been related to increased food insecurity during the pandemic.

First, restrictions to grocery store capacity and hours may have complicated individuals' food access. Many regions in the U.S. with high COVID-19 infection rates enforced policies to limit virus transmission that impacted individuals' mobility and their potential access to grocery stores and other food outlets (Jingnan, 2020; Tyko, 2020). For example, L.A. County facilitated social distancing by mandating reductions in grocery store capacity to 50% in March 2020, 20% in December 2020, and 50% in March 2021, with normal operations resuming in June 2021 (de la Haye, Wilson, et al., 2021). Grocery store hours were sometimes drastically reduced in order to thoroughly clean, disinfect, and restock (Jingnan, 2020). Some grocery stores were temporarily closed at the beginning of the pandemic (de la Haye, Wilson, et al., 2021; Tyko, 2020). In L.A. County, there were additional temporary closures in June 2020 due to local protests of the murder of George Floyd (de la Haye, Wilson, et al., 2021). Further, several grocery stores closed permanently after the City of L.A. passed a measure requiring grocery stores to pay workers an additional $5/hour for four months in 2020 (Juarez, 2021). It has been hypothesized that such grocery store closures and other food supply disruptions may have negatively impacted people's ability to access healthy food, as well as their food consumption patterns (Leddy et al., 2020).

Second, transportation challenges that emerged during the pandemic may have posed an additional barrier to food access. Prior to the pandemic, research conducted by the USDA showed that most Americans drove their own vehicles to the grocery store (Ver Ploeg et al., 2012). Further, those without access to a vehicle tended to be driven to the grocery store by family or friends (Ver Ploeg et al., 2012). Getting rides from family and friends may have been more difficult during the pandemic, when social distancing was recommended to prevent COVID-19 transmission. Grocery delivery services did expand their home deliveries during the pandemic (Gilligan, 2022). However, low-income populations—who are at the greatest risk of food insecurity—were less likely to use these services (de la Haye, Wilson, et al., 2021), likely due to not being able to cover the cost or not having a secure location for deliveries.

Third, the pandemic may have created geographic challenges in food access and food insecurity, because of underlying structural and social inequities that are barriers to healthy food access. These barriers are concentrated among specific populations and neighborhoods, and are central to struggles for food justice, which "places access to healthy, affordable, culturally appropriate foods in the contexts of institutional racism, racial formation, and racialized geographies" (Alkon & Norgaard, 2009). One recent study focusing on residents of two predominantly Black, lower-income, food desert neighborhoods in Pittsburgh, PA found that food insecurity increased in the early weeks of the pandemic (March–May 2020; Siddiqi et al., 2021). The results of this study raised additional questions, including whether findings would generalize to larger and more diverse regions such as L.A. County, and whether living in a food desert was associated with worse food insecurity during the pandemic compared to not living in a food desert.

1.3 The current study

The current study sought to better understand the relationships between food deserts, food access, and food insecurity during the COVID-19 pandemic through a case study of L.A. County, California. L.A. County is a large, predominantly urban landscape that is home to more than 10 million residents who are ethnically and socioeconomically diverse. We investigated food insecurity and food access at two spatial scales: (a) L.A. County as a whole; and (b) three Service Planning Area (SPA) groups. While L.A. County is geographically divided into eight SPAs for public health planning and governance, we combined SPAs that are geographically adjacent and demographically similar into three SPA groups to maintain robust sample sizes. Additionally, as the USDA uses census tracts to define food deserts, we also incorporated census tracts, which are commonly used to define "neighborhoods" in public health research in the U.S. (Liese et al., 2018; Martz et al., 2021; Moise, 2020).

Specifically, the current study seeks to explore the spatial characteristics of food insecurity and food access during the COVID-19 pandemic by addressing the following research questions:

1. What were the rates of food insecurity, perceived food access barriers, and food desert status across key geographic regions of L.A. County during the early months of the COVID-19 pandemic?
2. (a) Were *barriers to food access*—specifically, living in a census tract-level food desert, and experiencing limited food access due to store closures/hours or transportation—associated with food insecurity in key geographic regions of L.A. County during the early months of the COVID-19 pandemic? And (b) did *perceived barriers to food access*—i.e., reports of limited food access due to store closures/hours or limited personal transportation—worsen (moderate) the effect of living in a food desert on food insecurity?

2 Materials and methods

2.1 Study area

This study focused on L.A. County, the most populous county in the U.S. As an example of the diversity within the county, Fig. 1 shows the median household income, by census tract, in L.A. County. Of the county's 2,343 census tracts, 23% (545 census tracts) were classified as low-income / low-access *food deserts* by the USDA as of 2019. Further, L.A. County experienced substantial socioeconomic hardship because of the COVID-19 pandemic, with unemployment increasing from 5% in February 2020 to 19% in May 2020 (FRED Economic Data, 2020). For these reasons, L.A. County was a prime study area to examine food insecurity and food access during the COVID-19 pandemic.

2.2 Data sources

2.2.1 Survey data

Our L.A. County survey was conducted as part of the Understanding Coronavirus in America tracking survey (henceforth: COVID-19 tracking survey; Kapteyn et al., 2020). The COVID-19 tracking survey was implemented through the Understanding America Study (UAS; Alattar et al., 2018), a nationally representative panel survey that includes approximately 1,800 adult residents of L.A. County and has been running since 2014. Panel recruitment

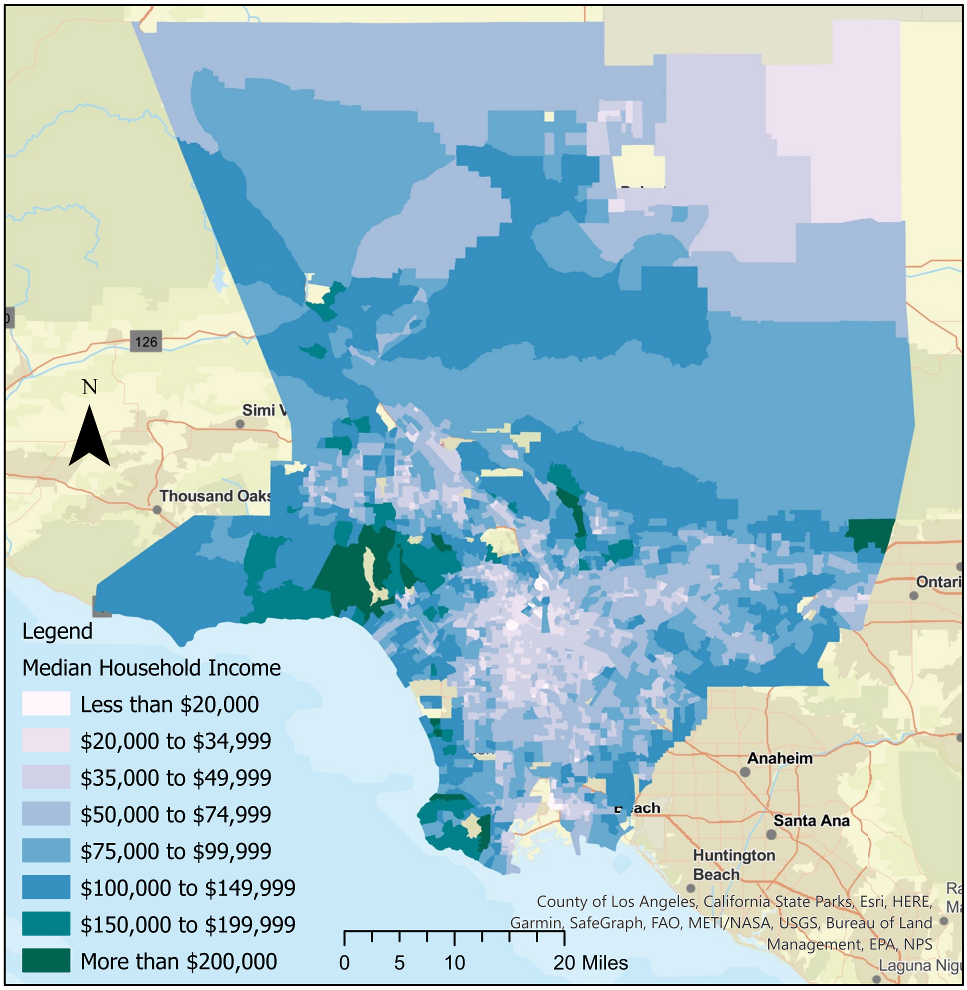

Fig. 1 *A choropleth map of Los Angeles County census tract-level median household income. Note.* Median household income data were obtained from the 2015-2019 American Community Survey 5-year estimates; census tract shapefile was obtained from the U.S. Census Bureau TIGER/Line shapefiles website (https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html). Please refer to the online edition for a color version of this figure

takes place using address-based sampling. Surveys are completed online; individuals with no Internet access and/or no access to a computer or tablet are provided equipment for the duration of the study, and participants are compensated by the minute. Survey weights are developed to ensure that the L.A. County data are representative of the county's total adult population in terms of age, gender, race/ethnicity, and educational attainment (Understanding America Study Weights, 2017).

In addition to L.A. County as a whole, we consider smaller geographic regions within the county. We combined L.A. County's eight SPAs into three SPA groups. Specifically, we grouped SPAs that were geographically adjacent and were similar in terms of race/ethnicity, education, or other demographics (see Fig. 2): SPA Group A includes the Antelope Valley, San Gabriel, and Metro L.A. SPAs; SPA Group B includes the San Fernando, West L.A., and South Bay SPAs; and SPA Group C includes the East and South L.A. SPAs. Survey weights were created by the UAS team for the COVID-19 tracking survey to ensure survey data were representative of each of these three SPA groups. Because sample sizes within the eight individual SPAs were too small to compute survey weights for the eight individual SPAs, we focused on these three SPA groups.

For the COVID-19 tracking survey, L.A. County residents were surveyed twice a month starting in March 2020. Topics included COVID-19 infections, vaccination beliefs and behaviors, employment status, and mental health (Kapteyn et al., 2020). The current study includes five survey waves, from April through October 2020, in which L.A. County participants were asked questions about food insecurity and food access. We excluded participants who did not complete: (i) at least one of three biweekly surveys from April to May 2020, which assessed past-week food insecurity, and (ii) both the July and October surveys that asked about past-month food insecurity. The resulting study sample was demographically similar to the full L.A. County UAS panel, except that more participants in the study sample had Bachelor's degrees or higher education (37.2% compared to 27.7%), and fewer participants in the study sample were renting their primary residences (45.7% compared to 55.9%).

Fig. 2 *A map showing Service Planning Area (SPA) groups utilized in analyses, L.A. County, California; the SPA groups include Group A (Antelope Valley, San Gabriel, and Metro SPAs), Group B (San Fernando, West L.A., and South Bay SPAs), and Group C (South and East L.A. SPAs). Note*. Service planning area shapefile was obtained from the County of Los Angeles Geohub (https://geohub.lacity.org/datasets/e9134f735c0c473d8156f4703a687ce9_4/explore). Please refer to the online edition for a color version of this figure

A total of 906 L.A. County participants were included in the study sample.

Food insecurity was measured with two items from the Food Insecurity Experiences Scale (FIES) that have the strongest factor loadings for moderate and severe food insecurity (Cafiero et al., 2018): "Did you eat less than you thought you should because of a lack of money or other resources?" (yes/no; assessing *moderate* food insecurity); and "Did you go without eating for a whole day because of a lack of money or other resources?" (yes/no; assessing *severe* food insecurity). On the April and May surveys, these items referred to the past 7 days, so as to capture the rapidly changing circumstances early in the COVID-19 pandemic. On the July and October surveys, these items referred to the past 30 days, so as to capture a longer time period of the ongoing COVID-19 pandemic. A participant was considered to have experienced *any food insecurity* (1) if they indicated moderate or severe food insecurity on any of the five surveys. If a participant did *not* indicate moderate or severe food insecurity on any of the five surveys, that participant was coded as experiencing *no food insecurity* (0).

Participants also responded to several questions about perceived barriers to food access on the July survey: *Limited food access due to store closures/hours* was a dichotomous variable based on the question, "Did you have difficulty getting food because food stores were closed or had limited hours?" (yes = 1; no = 0). *Limited food access due to transportation* was a dichotomous variable based on the question, "Did you have challenges getting food because you didn't have a car or personal transportation?" (yes = 1, no = 0). These questions were included only on the July survey for the L.A. County sample.

Demographic covariates were risk factors commonly associated with food insecurity, which were measured every three months in the COVID-19 tracking survey. These demographics included sex (male or female); age range (18–30, 31–40, 41–50, 51–64, 65 and over); race/ethnicity (Hispanic, non-Hispanic Black, non-Hispanic white, non-Hispanic Asian, or other); educational attainment (high school diploma/GED or less, some college, Bachelor's degree or more); employment status (currently working, unemployed, retired, disabled, other); household income relative to the federal poverty line

[FPL] (< 100% of FPL, 100–200% of FPL, 200–300% of FPL, 300 + % of FPL); number of children in the household; and housing tenure (whether a participant rented or owned their primary residence).

2.2.2 USDA ERS food desert classifications

Contextual data about census tract-level food deserts came from the USDA ERS Food Access Research Atlas (USDA Economic Research Service, 2019). Food deserts were operationalized by the USDA using two strategies. The first strategy defined food deserts in terms of *having low access to a supermarket*, based on the 2019 Trade Dimensions TDLinx directory of supermarkets, supercenters, and large grocery stores (USDA Economic Research Service, 2020):

(i) A census tract was defined as a food desert with *low access at 1 and 10 miles* if at least 33% of the tract's population lived more than 1 mile (in urban areas) or more than 10 miles (in rural areas) from the nearest supermarket, supercenter, or large grocery store.
(ii) A census tract was defined as a food desert with *low access at ½ and 10 miles* if at least 33% of the tract's population lived more than ½ mile (in urban areas) or more than 10 miles (in rural areas) from the nearest supermarket, supercenter, or large grocery store.

The second strategy defined food deserts in terms of *being low income and having low access to a supermarket.* Using data from the 2014–2018 American Community Survey 5-year estimates, a census tract was defined as *low income* if it had one or more of the following: (a) a poverty rate of 20% or more; (b) a median family income less than 80% of the median family income for the entire state; or (c) a metropolitan census tract with a median family income less than 80% of the median family income for the surrounding metropolitan area. Then, considering both income and access:

(i) A census tract was defined as a food desert with *low income and low access at 1 and 10 miles* if it was categorized as low income and also met the definition for low access at 1 and 10 miles.
(ii) A census tract was defined as a food desert with *low income and low access at ½ and 10 miles* if it was categorized as low income and also met the definition for low access at ½ and 10 miles.
(iii) A census tract was defined as a food desert with *low income and low access using vehicle access and at 20 miles* if the census tract was categorized as low income and met one additional criterion: either (a) at least 100 residences had no reported vehicle access and were located more than ½ mile from the nearest supermarket, supercenter, or large grocery store; or (b) at least 33% of the population lived more than 20 miles from the nearest supermarket, supercenter, or large grocery store, regardless of vehicle access.

Low-access and combination low-income / low-access indicators were examined in the current study.

2.3 Analytic approach

Indicators from the USDA ERS Food Access Research Atlas were linked with the survey data based on each survey respondent's census tract of residence. Analyses implemented to answer each research question are detailed in the sub-sections below.

What were the rates of food insecurity, perceived food access barriers, and food desert status across key geographic regions of L.A. County during the early months of the COVID-19 pandemic?

Responses from the COVID-19 tracking survey were aggregated for all of L.A. County and for each SPA group. Survey weights developed for L.A. County, and for each SPA group, were incorporated to compute representative descriptive statistics. We also computed sociodemographic profiles of the populations of L.A. County and each SPA group using survey weights.

Were barriers to food access—specifically, living in a census tract-level food desert, and experiencing limited food access due to store closures/hours or transportation—associated with food insecurity in key geographic regions of L.A. County during the early months of the COVID-19 pandemic?

Initial bivariate comparisons of food access barriers and food insecurity were conducted by computing unweighted descriptive statistics of food access indicators among participants who did and did not experience food insecurity between April and October 2020. Comparisons were made for L.A. County overall, and within each SPA group.

Next, logistic regression analyses were used to determine whether barriers to food access predicted food insecurity, with *food insecurity* as the dichotomous outcome in all models. Starting with data from the full L.A. County sample, five unadjusted models were examined, with each model including one food desert indicator as the predictor of interest (i.e., *low access at 1 and 10 miles*; *low access at ½ and 10 miles*; *low-income and low-access at 1 and 10 miles*; *low-income and low-access at ½ and 10 miles*; *low-income and low-access using vehicle access and at 20 miles*) (results not shown). Two additional unadjusted models were examined: the first included *limited food access due to store closures/hours* as the predictor, the second included *limited food access due to transportation* as the predictor (results

Table 1 Weighted descriptive statistics from the COVID-19 Tracking Survey characterizing the total population residing in L.A. County overall and three SPA groups within L.A. County

Characteristics of total population	L.A. County Total: *N* = 912 %/Mean (95% CI)	Antelope Valley, San Gabriel, Metro L.A. (SPA Group A; Fig. 2): *N* = 294 %/Mean (95% CI)	San Fernando, West L.A., South Bay (SPA Group B; Fig. 2): *N* = 400 %/Mean (95% CI)	South and East L.A. (SPA Group C; Fig. 2): *N* = 190 %/Mean (95% CI)
Demographics				
Sex:				
Female	49.6 (45.5, 53.6)	51.3 (44.5, 58.1)	47.6 (40.8, 54.4)	50.9 (43.1, 58.7)
Male	50.4 (46.4, 54.5)	48.7 (41.9, 55.5)	52.4 (45.6, 59.2)	49.1 (41.3, 56.9)
Age category:				
18 to 30	20.7 (17.3, 24.1)	17.2 (11.9, 22.4)	17.8 (12.2, 23.3)	20.9 (15.4, 26.4)
31 to 40	23.2 (19.8, 26.6)	24.0 (18.5, 29.4)	16.4 (11.9, 20.9)	19.7 (13.8, 25.6)
41 to 50	16.3 (13.4, 19.2)	15.2 (9.9, 20.4)	18.7 (13.4, 24.1)	20.8 (15.0, 26.7)
51 to 64	21.5 (18.3, 24.8)	21.9 (16.1, 27.7)	26.2 (20.5, 31.9)	27.1 (19.3, 34.9)
65 and over	18.3 (15.2, 21.5)	21.8 (16.4, 27.2)	20.9 (14.7, 27.7)	11.4 (6.4, 16.4)
Race/ethnicity:				
Hispanic	44.6 (40.6, 48.7)	40.3 (33.6, 47.0)	26.6 (20.3, 33.0)	64.4 (57.1, 71.8)
Non-Hispanic Black	8.1 (5.9, 10.4)	2.7 (0.3, 5.2)	11.1 (6.4, 15.8)	17.4 (11.6, 23.3)
Non-Hispanic white	30.7 (27.2, 34.2)	28.3 (22.9, 33.6)	47.7 (40.8, 54.5)	12.0 (6.6, 17.4)
Non-Hispanic Asian	14.3 (11.6, 17.1)	22.0 (16.1, 28.0)	8.4 (5.0, 11.8)	4.8 (2.6, 7.0)
Other	2.2 (1.1, 3.4)	6.7 (2.0, 11.3)	6.2 (3.4, 8.9)	1.3 (0.0, 2.7)
Educational attainment:				
High school diploma/GED or less	38.5 (34.2, 42.8)	38.9 (31.4, 46.5)	24.1 (16.5, 31.8)	53.5 (46.0, 61.0)
Some college	24.3 (21.3, 27.2)	27.0 (21.9, 32.1)	31.7 (25.7, 37.6)	29.8 (23.6, 36.0)
Bachelor's degree or more	37.2 (33.6, 40.9)	34.1 (28.6, 39.6)	44.2 (37.6, 50.8)	16.7 (12.7, 20.7)
Employment status as of October 2020:				
Currently working	47.2 (43.2, 51.2)	46.4 (39.7, 53.1)	54.3 (47.4, 61.2)	43.7 (36.2, 51.3)
Unemployed	19.8 (16.4, 23.3)	18.0 (12.3, 23.7)	15.7 (10.6, 20.8)	22.9 (16.0, 29.7)
Retired	13.7 (10.9, 16.5)	18.1 (13.0, 23.3)	12.2 (7.7, 16.7)	11.0 (4.9, 17.2)
Disabled	4.7 (2.9, 6.5)	3.2 (9.4, 19.1)	4.8 (1.2, 8.4)	7.5 (3.2, 11.7)
Other	14.6 (11.7, 17.5)	14.2 (9.4, 19.1)	13.0 (8.7, 17.4)	14.9 (10.0, 19.8)
Household income:				
< 100% of FPL	20.7 (17.1, 24.3)	17.1 (11.7, 22.5)	11.9 (7.0, 16.7)	26.3 (19.5, 33.1)
100–200% of FPL	20.3 (16.8, 23.7)	24.0 (17.7, 30.4)	14.0 (9.2, 18.8)	24.9 (18.2, 31.5)
201–300% of FPL	14.8 (11.8, 17.8)	15.1 (10.1, 20.1)	10.8 (6.5, 15.1)	22.1 (14.3, 29.9)
> 300% of FPL	44.2 (40.2, 48.2)	43.7 (37.1, 50.3)	63.3 (56.5, 70.1)	26.7 (20.4, 33.0)
Household:				
Have children in the household	37.4 (33.5, 41.4)	30.5 (23.9, 37.1)	34.3 (27.7, 40.8)	46.1 (38.4, 53.7)
Have children under 5 in the household	7.5 (5.4, 9.6)	6.6 (2.5, 10.7)	6.3 (3.5, 9.1)	9.3 (5.2, 13.5)
Renting primary residence	45.7 (41.7, 49.7)	43.4 (36.8, 50.1)	42.7 (35.9, 49.6)	45.0 (37.4, 52.7)
Experienced any food insecurity April-Oct. 2020	28.9 (25.1, 32.7)	26.9 (20.6, 33.1)	23.4 (17.1, 29.6)	43.2 (30.4, 56.1)
Food Access				
Limited food access due to (July 2020):				
Store closures/ hours	9.2 (6.8, 11.7)	8.6 (4.0, 13.1)	6.8 (2.6, 11.0)	11.1 (6.7, 15.5)
Transportation	6.7 (4.6, 8.9)	6.7 (3.1, 10.3)	5.6 (2.1, 9.0)	7.8 (4.3, 11.3)
Reside in a food desert:				

Table 1 (continued)

Characteristics of total population	L.A. County Total: $N=912$ %/Mean (95% CI)	Antelope Valley, San Gabriel, Metro L.A. (SPA Group A; Fig. 2): $N=294$ %/Mean (95% CI)	San Fernando, West L.A., South Bay (SPA Group B; Fig. 2): $N=400$ %/Mean (95% CI)	South and East L.A. (SPA Group C; Fig. 2): $N=190$ %/Mean (95% CI)
Low access at 1 mile for urban areas	13.5 (10.6, 16.5)	17.7 (12.4, 23.1)	15.4 (10.4, 20.4)	3.1 (1.1, 5.1)
Low access at ½ mile for urban areas	59.8 (55.7, 63.9)	62.9 (56.5, 69.3)	58.9 (52.1, 65.8)	56.7 (49.1, 64.3)
Low income + low access at 1 mile for urban areas	3.0 (1.8, 4.2)	5.8 (3.0, 8.6)	1.5 (0.0, 2.9)	2.1 (0.3, 3.8)
Low income + low access at ½ mile for urban areas	25.3 (21.7, 28.9)	26.2 (20.3, 32.2)	15.8 (10.3, 21.4)	43.8 (36.2, 51.5)
Low income + low vehicle access	7.1 (4.7, 9.4)	6.5 (3.3, 9.7)	5.6 (1.7, 9.6)	10.9 (6.1, 15.8)

CI confidence interval, *FPL* federal poverty level

not shown). Finally, adjusted logistic regression models were fit, with each model including one perceived barrier to food access and one food desert indicator, in order to avoid collinearity between predictors of interest. In these adjusted models, covariates were added into the model using a stepwise approach; details about model specification and model fit are included in Online Resource 1. In addition to the predictors of interest, the best-fitting models included five covariates: age group, race/ethnicity, educational attainment, employment status, and income relative to FPL.

Next, to examine whether perceived barriers to food access and living in a food desert predicted food insecurity in key geographic regions of L.A. County, data were disaggregated by SPA group. Seven unadjusted logistic regression models, as described above, were examined for each SPA group (results not shown). Adjusted logistic regression models specific to each SPA group were then fitted using a stepwise approach, as described in Online Resource 1. The best-fitting models for all three SPA groups included four covariates: age group, educational attainment, employment status, and income relative to FPL. The best-fitting models for SPA Group A additionally included race/ethnicity. Survey weights were not included in any logistic regression models.

Did perceived barriers to food access—i.e., experiencing limited food access due to store closures/hours or limited personal transportation—worsen (moderate) the effect of living in a food desert on food insecurity?

The adjusted logistic regression models representing L.A. County and each SPA group were expanded to analyze interactions between perceived barriers to food access and food desert status in predicting food insecurity. Ten interaction terms were tested in each model, one at a time, including interactions between *limited food access due to store closures/hours* and each of the five USDA food desert indicators, and interactions between *limited food access due to transportation* and each of the five USDA food desert indicators. Survey weights were not included in any logistic regression models.

2.3.1 Robustness checks

To examine the robustness of our results, we recoded food insecurity as a continuous variable. Participants were grouped into four categories based on whether they reported moderate and/or severe food insecurity in April/May, July, and October: reported food insecurity at no waves, one wave, two waves, or three waves. All analyses were repeated using this continuous indicator of number of waves of reported food insecurity, and using ordinary least squares regression models in place of logistic regression models; results are presented in Online Resource 2.

3 Results

3.1 Rates of food insecurity, food access barriers, and demographic characteristics

Weighted descriptive statistics are presented in Table 1. In the full L.A. County sample, about three in ten (28.9%) participants experienced food insecurity at any time between April and October 2020. Less than one-tenth (9.2%) of participants reported limited food access due to store closures/hours, and 6.7% reported limited food access due to transportation. The proportion of participants living in food deserts ranged from 3.0% living in food deserts defined as low income and low access at 1 and 10 miles, to 59.8% living in food deserts defined as

Table 2 Unweighted rates of food access barriers among those experiencing food insecurity and those experiencing no food insecurity from April–October 2020, for L.A. County overall and three SPA groups within L.A. County

	L.A. County Total: $N=906$		Antelope Valley, San Gabriel, Metro L.A (SPA Group A; Fig. 2): $N=352$		San Fernando, West L.A., South Bay (SPA Group B; Fig. 2): $N=284$		South and East L.A (SPA Group C; Fig. 2): $N=266$	
	Food insecure ($n=233$) %/Mean (95% CI)	Food secure ($n=673$) %/Mean (95% CI)	Food insecure ($n=81$) %/Mean (95% CI)	Food secure ($n=271$) %/Mean (95% CI)	Food insecure ($n=59$) %/Mean (95% CI)	Food secure ($n=225$) %/Mean (95% CI)	Food insecure ($n=91$) %/Mean (95% CI)	Food secure ($n=175$) %/Mean (95% CI)
Limited food access due to (July 2020):								
Store closures/hours	17.2 (12.3, 22.1)	4.8 (3.1, 6.4)	13.8 (6.0, 21.5)	4.8 (2.2, 7.4)	15.3 (5.8, 24.7)	3.1 (0.8, 5.4)	22.0 (13.3, 30.6)	6.9 (3.1, 10.6)
Transportation	18.1 (13.1, 23.1)	1.8 (0.8, 2.8)	16.3 (8.0, 24.5)	1.8 (0.2, 3.5)	16.9 (7.1, 26.8)	1.3 (0.0, 2.8)	20.9 (12.4, 29.4)	2.3 (0.0, 4.5)
Reside in a food desert:								
Low access at 1 mile for urban areas	12.1 (7.9, 16.4)	13.9 (11.2, 16.5)	18.5 (9.9, 27.2)	18.5 (13.8, 23.1)	16.9 (7.1, 26.8)	15.1 (10.4, 19.8)	3.3 (0.0, 7.0)	5.1 (1.8, 8.4)
Low access at ½ mile for urban areas	54.5 (48.1, 61.0)	63.0 (59.4, 66.7)	50.6 (39.5, 61.7)	64.9 (59.2, 70.7)	54.2 (41.1, 67.3)	63.1 (56.8, 69.5)	58.2 (47.9, 68.6)	60.0 (52.7, 67.3)
Low income + low access at 1 mile for urban areas	7.4 (4.0, 10.8)	4.0 (2.5, 5.5)	14.8 (6.9, 22.7)	7.7 (4.5, 11.0)	5.1 (0.0, 10.9)	1.3 (0.0, 2.8)	2.2 (0.0, 5.3)	1.7 (0.0, 3.7)
Low income + low access at ½ mile for urban areas	34.6 (28.5, 40.8)	24.6 (21.3, 27.9)	30.9 (20.6, 41.1)	25.5 (20.2, 30.7)	22.0 (11.1, 32.9)	12.9 (8.5, 17.3)	46.2 (35.7, 56.6)	38.3 (31.0, 45.6)
Low income + low vehicle access	10.0 (6.1, 13.8)	7.7 (5.7, 9.8)	4.9 (0.1, 9.8)	7.0 (4.0, 10.1)	8.5 (1.2, 15.8)	3.6 (1.1, 6.0)	15.4 (7.8, 22.9)	14.3 (9.0, 19.5)

CI confidence interval

low access at ½ and 10 miles. Table 1 also summarizes these characteristics within each SPA Group. SPA Group C—including the East and South L.A. SPAs—had the largest proportion of participants who experienced food insecurity (43.2%), a significantly larger proportion compared to SPA Group B (23.4%)—which includes the San Fernando, West L.A., and South Bay SPAs. SPA Group C also had the largest proportion of participants who reported limited food access due to store closures/hours (11.1%) and transportation (7.8%), though these proportions were not significantly different from the other SPA groups. The proportion of participants living in food deserts did not vary significantly across SPA groups. The demographics of participants in the full L.A. County sample and in each SPA group are also summarized in Table 1.

3.2 Rates of perceived food access barriers and food desert status among those who did and did not experience food insecurity

In L.A. County, significantly larger proportions of individuals who experienced food insecurity reported that they had limited food access due to store closures/hours (17.2%) or transportation (18.1%) compared to individuals who reported no food insecurity (4.8% and 1.8%, respectively; see Table 2). Perceived barriers to food access

Table 3 Results from one logistic regression model—an example of the ten logistic regression models conducted–testing if food insecurity from April–October 2020 is predicted by barriers to food access and living in a food desert, for L.A. County overall and three SPA groups within L.A. County

Predictor	L.A. County Total: *N* = 912, *n* = 233 with any food insecurity Odds Ratio (95% CI)	Antelope Valley, San Gabriel, Metro L.A. (SPA Group A; Fig. 2): *N* = 294, *n* = 81 with any food insecurity Odds Ratio (95% CI)	San Fernando, West L.A., South Bay (SPA Group B; Fig. 2): *N* = 400, *n* = 59 with any food insecurity Odds Ratio (95% CI)	South and East L.A (SPA Group C; Fig. 2): *N* = 190, *n* = 91 with any food insecurity Odds Ratio (95% CI)
Age Group:				
18–30	2.94 (1.22, 7.11)*	1.08 (0.28, 4.15)	13.96 (1.54, 126.70)*	2.91 (0.44, 19.41)
31–40	3.21 (1.35, 7.63)*	2.36 (0.67, 8.25)	8.59 (0.96, 77.30)	2.82 (0.43, 18.62)
41–50	3.08 (1.28, 7.42)*	2.68 (0.73, 9.77)	8.14 (0.92, 72.28)	2.02 (0.30, 13.47)
51–64	2.12 (0.91, 4.98)	1.38 (0.41, 4.69)	3.97 (0.44, 36.14)	2.92 (0.44, 19.41)
(Ref = 65 +)				
Race/Ethnicity:[a]				
Hispanic	1.39 (0.87, 2.23)	2.13 (0.98, 4.64)	–	–
Non-Hispanic Black	1.43 (0.73, 2.83)	5.58 (0.87, 35.85)	–	–
Non-Hispanic Asian	1.32 (0.70, 2.47)	1.65 (0.66, 4.10)	–	–
Other	2.04 (0.86, 4.85)	1.32 (0.24, 7.36)	–	–
(Ref = Non-Hispanic white)				
Education:				
High school diploma/GED or less	1.52 (0.91, 2.54)	1.31 (0.55, 3.08)	3.01 (0.94, 9.65)	1.05 (0.43, 19.41)
Some college	1.71 (1.13, 2.59)*	1.10 (0.54, 2.24)	3.11 (1.41, 6.83)	1.75 (0.81, 3.75)
(Ref = Bachelor's degree or more)				
Employment:				
Disabled	2.98 (1.34, 6.66)*	8.76 (1.75, 43.92)*	9.26 (1.47, 58.46)*	0.85 (0.26, 2.78)
Other	1.23 (0.75, 2.00)	2.06 (0.92, 4.61)	0.72 (0.25, 2.11)	0.95 (0.41, 2.19)
Retired	0.38 (0.12, 1.15)	0.59 (0.14, 2.54)	N/A	0.19 (0.02, 2.01)
Unemployed	1.50 (0.94, 2.40)	1.68 (0.76, 3.70)	0.66 (0.24, 1.85)	2.60 (1.11, 6.09)*
(Ref = Working)				
Income Relative to FPL:				
< 100% of FPL	4.06 (2.39, 6.91)*	5.18 (2.08, 12.92)*	1.78 (0.54, 5.80)	6.44 (2.49, 16.68)*
100–200% of FPL	3.05 (1.88, 4.97)*	3.07 (1.36, 6.92)*	4.30 (1.57, 11.77)*	4.05 (1.66, 9.88)*
201–300% of FPL	2.74 (1.63, 4.62)*	4.15 (1.78, 9.64)*	1.93 (0.63, 5.94)	3.33 (1.25, 8.93)*
(Ref = > 300% of FPL)				
Barrier to food access predictor:				
Limited food access due to store closures/hours	2.97 (1.67, 5.27)*	2.57 (0.93, 7.11)	3.61 (0.91, 14.32)	4.16 (1.62, 10.66)*
Food desert predictor:				
Low access at 1 mile for urban areas	1.04 (0.60, 1.81)	0.95 (0.42, 2.13)	1.15 (0.41, 3.22)	3.06 (0.69, 13.57)

Covariate effects were similar for all ten logistic regression models tested in this analysis. This specific logistic regression model was randomly selected, and full results of this model are included here, as an example

CI confidence interval, *FPL* federal poverty level

*Significant confidence interval, $p < 0.05$

[a]Race/Ethnicity excluded from models representing SPA Group B and SPA Group C due to non-significance in model fitting

Table 4 Odds ratios from logistic regression models testing if barriers to food access and living in a food desert (using five different definitions) predict food insecurity from April–October 2020, for L.A. County overall and three SPA groups within L.A. County

Predictor of interest	L.A. County Total: $N=912$, $n=233$ with any food insecurity Odds Ratio (95% CI)	Antelope Valley, San Gabriel, Metro L.A. (SPA Group A; Fig. 2): $N=294$, $n=81$ with any food insecurity Odds Ratio (95% CI)	San Fernando, West L.A., South Bay(SPA Group B; Fig. 2): $N=400$, $n=59$ with any food insecurity Odds Ratio (95% CI)	South and East L.A (SPA Group C; Fig. 2): $N=190$, $n=91$ with any food insecurity Odds Ratio (95% CI)
Model 1A:				
Limited food access due to store closures/hours	2.97 (1.67, 5.27)*	2.57 (0.93, 7.11)	3.61 (0.91, 14.32)	4.16 (1.62, 10.66)*
Low access at 1 mile for urban areas	1.04 (0.60, 1.81)	0.94 (0.42, 2.13)	1.15 (0.41, 3.22)	3.06 (0.69, 13.57)
Model 1B:				
Limited food access due to store closures/hours	3.01 (1.69, 5.35)*	2.36 (0.85, 6.59)	3.47 (0.88, 13.65)	3.99 (1.57, 10.14)*
Low access at ½ mile for urban area	0.77 (0.55, 1.10)	0.43 (0.23, 0.80)*	1.71 (0.81, 3.63)	0.94 (0.52, 1.72)
Model 1C:				
Limited food access due to store closures/hours	2.93 (1.64, 5.20)*	2.41 (0.86, 6.78)	3.59 (0.90, 14.23)	4.07 (1.60, 10.37)*
Low income + low access at 1 mile for urban areas	1.35 (0.58, 3.14)	1.37 (0.45, 4.12)	1.20 (0.09, 15.32)	4.03 (0.53, 30.43)
Model 1D:				
Limited food access due to store closures/hours	3.00 (1.69, 5.33)*	2.54 (0.92, 7.01)	3.16 (0.79, 12.68)	3.98 (1.57, 10.07)*
Low income + low access at ½ mile for urban areas	0.86 (0.58, 1.28)	0.69 (0.35, 1.36)	2.24 (0.90, 5.76)	0.75 (0.40, 1.41)
Model 1E:				
Limited food access due to store closures/hours	2.95 (1.66, 5.23)*	2.57 (0.93, 7.10)	3.15 (0.79, 12.57)	3.98 (1.55, 10.17)*
Low income + low vehicle access	1.30 (0.70, 2.43)	0.77 (0.27, 2.24)	3.02 (0.64, 14.25)	1.89 (0.66, 5.39)
Model 2A:				
Limited food access due to transportation	6.36 (3.04, 13.30)*	5.18 (1.45, 18.47)*	7.02 (1.42, 34.76)*	11.29 (2.78, 45.79)*
Low access at 1 mile for urban areas	1.11 (0.63, 1.93)	1.06 (0.48, 2.37)	1.04 (0.36, 3.02)	3.03 (0.69, 13.24)
Model 2B:				
Limited food access due to transportation	6.20 (2.97, 12.94)*	4.65 (1.26, 17.14)*	8.62 (1.65, 45.12)*	10.62 (2.67, 42.22)*
Low access at ½ mile for urban area	0.83 (0.58, 1.18)	0.45 (0.24, 0.83)*	1.98 (0.90, 4.34)	0.99 (0.54, 1.82)
Model 2C:				
Limited food access due to transportation	6.42 (3.07, 13.45)*	5.16 (1.45, 18.39)*	7.10 (1.43, 35.18)*	11.44 (2.80, 46.79)*
Low income + low access at 1 mile for urban areas	1.64 (0.71, 3.79)	1.62 (0.56, 4.68)	1.31 (0.10, 16.63)	4.49 (0.59, 34.19)
Model 2D:				
Limited food access due to transportation	6.32 (3.02, 13.21)*	5.13 (1.43, 18.41)*	8.09 (1.54, 42.39)*	10.72 (2.69, 42.70)*
Low income + low access at ½ mile for urban areas	0.91 (0.61, 1.35)	0.70 (0.35, 1.38)	2.60 (1.03, 6.59)*	0.76 (0.40, 1.45)
Model 2E:				
Limited food access due to transportation	6.57 (3.13, 13.77)*	5.13 (1.43, 18.37)*	8.26 (1.61, 42.27)*	11.37 (2.85, 45.33)*
Low income + low vehicle access	1.54 (0.82, 2.88)	0.87 (0.30, 2.51)	4.25 (0.90, 19.94)	2.27 (0.81, 6.42)

The pairs of predictors in this table were tested in separate logistic regression models including covariates as described in the text; covariate odds ratios and p-values were similar in all models to those displayed in Table 3

CI confidence interval

*Significant confidence interval, $p<0.05$

also differed by food security status within SPA groups. In SPA Groups B and C, significantly larger proportions of participants who experienced food insecurity reported limited food access due to store closures/hours (15.3% in SPA Group B; 22.0% in SPA Group C) compared to participants who reported no food insecurity (3.1% in SPA Group B; 6.9% in SPA Group C). In all three SPA groups, significantly larger proportions of participants who experienced food insecurity reported limited food access due to transportation (16.3% in SPA Group A; 16.9% in SPA Group B; 20.9% in SPA Group C) compared to participants who were food secure (1.8% in SPA Group A; 1.3% in SPA Group B; 2.3% in SPA Group C). Food desert status did not differ significantly between those who did and did not experience food insecurity, in L.A. County or any of the SPA groups.

3.3 The relationships between living in a food desert, perceived barriers to food access, and food insecurity in L.A. County

Because effects of covariates were similar across ten adjusted logistic regression models, full results from just one of these adjusted models are shown in Table 3 as an example, including results pertaining to L.A. County and the three SPA groups. Table 4 shows odds ratios corresponding to the predictors of interest in all models (i.e., perceived food access barriers and food desert indicators), again including results pertaining to L.A. County and the three SPA groups.

Considering L.A. County as a whole, food insecurity was not significantly associated with any of the food desert indicators, but it was associated with perceived food access barriers. Regardless of which food desert indicator was included in the model, the odds of experiencing food insecurity were at least 2.9 times greater among individuals who reported limited food access due to store closures/hours, and at least 6.2 times greater among individuals who reported limited food access due to transportation (see Table 4 for all odds ratios and 95% confidence intervals).

When examining findings for each SPA group, food desert indicators were again mostly not significant predictors of food insecurity, whereas perceived food access barriers were significant in most models, regardless of which food desert indicator was included. In SPA Group C, the odds of food insecurity were at least 4.0 times greater among individuals who reported limited food access due to store closures/hours; however, the odds of food insecurity in SPA Groups A and B were not significantly related to store closures/hours. In all three SPA groups, transportation significantly predicted food insecurity, but the size of the effect notably differed. Specifically, the odds of experiencing food insecurity were at least 4.6 times greater among individuals in SPA Group A, at least 7.0 times greater among individuals in SPA Group B, and at least 10.6 times greater among individuals in SPA Group C who reported limited food access due to transportation.

Lastly, in models that tested if perceived barriers to food access worsened (moderated) the relationship between living in a food desert and food insecurity, we found no evidence of an interaction. Specifically, none of the interactions of food desert status with limited food access due to store closures/hours or limited food access due to transportation were significantly associated with food insecurity.

3.4 Robustness checks

Our robustness checks showed that, regardless of how we defined food insecurity, the barriers to food access due to store closures/hours or due to transportation were significantly associated with food insecurity (see Online Resource 2). The one exception occurred in SPA Group B, where food insecurity was not associated with store closures/hours (see Online Resource 2). Additionally, regardless of how we defined food insecurity, living in a food desert was not associated with food insecurity, and did not moderate the relationship of store closures/hours or transportation with food insecurity.

4 Discussion and conclusions

Food insecurity in L.A. County spiked in the early months of the COVID-19 pandemic (de la Haye, Miller, et al., 2021). This study examined spatial differences in this food insecurity surge across L.A. County, while exploring how food insecurity was associated with geographic barriers to food access such as living in a food desert, store closures or limited hours, or having no personal transportation. Food insecurity rates differed across geographic regions in L.A. County, with the highest rate in the region of East and South L.A, also referred to as SPA Group C. L.A. County residents were significantly more likely to report food insecurity if they also perceived limited food access because of food store closures or limited hours. This finding also held within East and South L.A, or SPA Group C. Residents of L.A. County and each SPA group were also more likely to report food insecurity if they lacked personal transportation. Although many individuals who experienced food insecurity resided in food deserts, living in a food desert was not associated with food insecurity. Additionally, perceived barriers to food access such as store closures or limited hours and having no transportation did not significantly worsen the effect of living in a food desert on food insecurity.

Living in a food desert has traditionally been associated with perceptions of limited access and availability of healthy and perishable foods (Dhillon et al., 2019; Larsen & Gilliland, 2009; LeClair & Aksan, 2014; Mogil et al., 2021; Walker et al., 2011). However, living in a food desert does not necessarily predict food insecurity or diet quality (Thomas, 2010; Woodruff et al., 2020), likely for two main reasons. First, food insecurity is consistently associated with low household income, household poverty, high costs of living, high food prices, single parent households, and less educational attainment (Gundersen & Ziliak, 2018)—which are individual-level factors rather than neighborhood-level factors. Second, living in a food desert may not be associated with food insecurity in the U.S. due to widespread access to low-cost fast food, including in food deserts (Powell et al., 2007).

In the current study, we also found that living in a food desert was unrelated to food insecurity. However, it is possible that we found no relationship between living in a food desert and experiencing food insecurity because we used the USDA definition of "food deserts." The USDA definition is intentionally focused on access to supermarkets, supercenters, and large grocery stores within one's home neighborhood, as smaller food retailers tend to be more expensive and may not stock all foods needed for a healthy diet (Glanz et al., 2007; Liese et al., 2007; USDA Economic Research Service, 2009). Neighborhoods designated as food deserts by the USDA may have small grocery stores, corner stores, farmers' markets, and restaurants that make food more accessible to local residents (Joassart-Marcelli et al., 2017; Short et al., 2007). Moreover, living in a food desert may not reflect where people actually shop for groceries; they may frequent stores near their workplace or child's school, rather than stores close to home (Cannuscio et al., 2013; Shannon & Christian, 2017).

We do present robust evidence that perceived barriers to food access—specifically, food store closures or reduced hours, and lack of personal transportation—were associated with food insecurity between April and October 2020. These findings held among individuals living inside and outside of food deserts. Perceived barriers to food access may better reflect the challenges that people experienced during the COVID-19 pandemic, as compared to the concept of food deserts. Overall, these findings, along with the broader literature (Bonanno & Li, 2015; Cantor et al., 2020; Ma et al., 2016), suggest that policymakers may need to improve grocery access to address food security. Potentially, in addition to federal food assistance (Andreyeva et al., 2015; Gundersen et al., 2019), extended grocery store hours, transportation interventions, enhanced public transit options, and/or free grocery delivery services may help to alleviate food insecurity.

Of note, the region of East and South L.A. (SPA Group C) had the highest rates of food insecurity, which were driven by multiple barriers to food access in addition to poverty and other covariates. This region of L.A. County is largely comprised of residents with lower incomes and communities of color, and has seen less investment than other areas. Research across the U.S. has shown that disinvestment and redlining are associated with limited healthy food access, and likely food insecurity (Mayorga et al., 2022; Miller et al., 2021; Shaker et al., 2022; Singleton, 2022). As such, our results reflect an underlying struggle for food justice. Such a broad institutional and structural problem is unlikely to be completely resolved by simplistic approaches, such as opening a supermarket (Ghosh-Dastidar et al., 2017). Rather, addressing a struggle for food justice requires a multi-faceted approach involving multiple stakeholders, including residents, community-based organizations, local government, researchers, and funders (Wekerle, 2004), who work together to address multiple dimensions of food access. For example, potential policy solutions may include food retailers, farmers' markets (Larsen & Gilliland, 2009), access to culturally appropriate foods (e.g., ethnic markets; Alkon & Norgaard, 2009), addressing institutionalized racism that impacts household and community resources and food access, and other actors and food touch-points.

5 Limitations and future research

Like any research endeavor, this study is not without limitations. First, the results of this study may not be generalizable beyond L.A. County because UAS measures on food access and store closures were only available for L.A. County and not for the entire U.S. sample. Second, the COVID-19 tracking survey was designed to be representative of L.A. County, not of the eight individual SPAs that comprise L.A. County. Third, food access was reported as perceived by participants, and not objectively measured. Fourth, due to concerns about survey costs and respondent burden, we only included questions about perceived barriers to food access on one wave of the COVID-19 tracking survey, and we were only able to ask two food insecurity items from the 8-item FIES. Considering a broader view of food insecurity that includes availability, accessibility, utilization, stability, and sustainability (Berry et al., 2015) in future work may provide deeper insights that can inform policy and programming for promoting food justice.

Lastly, food desert indicators, such as those published by the USDA in 2019, may not have reflected the rapid changes to the food environment during the COVID-19 crisis. Additionally, we did not have other information beyond the spatial proximity of food access, and the USDA does not provide indicators of access to smaller food retailers. Moving forward, incorporating a wider variety of data sources, including regularly updated, relatively novel datastreams (e.g., Yelp; Google; cellphone mobility data) will likely provide more comprehensive and timely characterizations of the actual food environment. Frequently implemented panel surveys will also continue to be useful to represent individuals' experiences of food access and their local food environments. Additional types of data, such as public transit data, walkability data, and more comprehensive self-reported survey data about transportation, could provide important insights regarding transportation-related food access.

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Author contribution M.S. Livings: conceptualization, methodology, formal analysis, writing (original draft, review & editing), visualization. J. Wilson: conceptualization, methodology, writing (original draft, review & editing), visualization, supervision. S. Miller: conceptualization, formal analysis, writing (review & editing). W. Bruine de Bruin: conceptualization, methodology, writing (original draft, review & editing), supervision. K. Weber: conceptualization, writing (review & editing). M. Babboni: conceptualization, writing (review & editing). M. Xu: conceptualization, writing (review & editing). K. Li: conceptualization, writing (review & editing). K. de la Haye: conceptualization, methodology, writing (original draft, review & editing), supervision.

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Data availability Understanding America Study data are publicly available and may be accessed by request at the following website: https://uasdata.usc.edu/index.php. Food desert data from the USDA Economic Research Service are publicly available and may be accessed at the following website: https://www.ers.usda.gov/data-products/food-access-research-atlas/

Declarations

Conflict of interest None of the authors have employment, financial, or non-financial conflicts of interest to disclose.

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