Health & Place 89 (2024) 103315

Contents lists available at ScienceDirect

Health and Place

journal homepage: www.elsevier.com/locate/healthplace

WEIRD and non-consensual food deserts and swamps: A scoping review of operational definitions

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ARTICLE INFO

Keywords:
Food environment
Food retail
Food access
Food availability

ABSTRACT

The aim of the present study was to critically analyze operational definitions of food deserts and food swamps included in empirical studies published in peer-reviewed journals. A scoping review was conducted following the recommendations of the Joanna Briggs Institute and PRISMA Extension for Scoping Reviews. A search of the scientific literature was performed on August 2023 to identify empirical studies including operational definitions of food deserts and/or food swamps in three databases: Scopus, PubMed, and Scielo. A total of 932 scientific articles were identified in the three databases, from which 157 articles, published between 2002 and 2023, were included in the review. The included studies were mainly conducted in WEIRD (Western, Educated, Industrialized, Rich and Democractic) countries. They presented a total of 107 operational definitions of food deserts and 30 operational definitions of food swamps. Large heterogeneity in the operational definitions of food deserts and food swamps was found. Published studies differed in all the elements of the operational definitions analyzed in the present work. Results stress the need for standardization and the development of more objective and multivariate continuous measures of physical food accessibility that reflect the complexity of modern food environments globally. A series of recommendations to advance food environment research are derived.

1. Introduction

Malnutrition in all its forms and non-commnicable diseases continue to be one of the most important public health problems worldwide (FAO, 2023). The food systems, defined as "*the entire range of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption and disposal of food products that originate from agriculture, forestry or fisheries, and parts of the broader economic, societal and natural environments in which they are embedded*" (FAO, 2018) have been identified as one of the key underlying causes of this situation (Swinburn et al., 2019; Brouwer et al., 2020; Hawkes et al., 2020). In the last decades, food systems have shifted towards the production of low-cost ultra-processed products based on a limited number of commodities, failing to provide enough healthy, safe, affordable and sustainable foods (Swinburn et al., 2019; Popkin, Corvalan and Grummer-Strawn, 2020).

Food environments are one of the three core elements of food systems. They can be defined as the physical, economic, political, and sociocultural context through which consumers interact with the food system to obtain, prepare, consume and discard food (HLPE, 2017). Availability and physical access are two of the dimensions of the food environment that influence food choice and eating habits (Sawyer et al., 2021; Konapur et al., 2022). Availability refers to the food supply, whereas physical accessibility refers to the location of food retail outlets and ease of reaching that location considering distance, travel time, and/or cost (Penchansky and Thomas, 1981; Caspi et al., 2012).

Two concepts have been widely used in the literature to describe food availability and physical access in specific areas: food deserts and food swamps. The concept of food deserts emerged in the mid-1990s to describe areas where residents do not have physical access to healthy foods (Beaumont et al., 1995; Cummins and Macintyre, 2002). The concept of food swamps is more recent and responds to the shift of the

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https://doi.org/10.1016/j.healthplace.2024.103315
Received 18 March 2024; Received in revised form 2 July 2024; Accepted 5 July 2024
Available online 15 July 2024

food supply chain towards the production of ultra-processed products high in nutrients associated with non-communicable diseases. It refers to areas with "excessive" access to unhealthy foods (Cooksey-Stowers, Schwartz and Brownell, 2017; Hager et al., 2017; Garg et al., 2023). Despite debate around the concepts, a large number of studies have reported that living in a food desert or food swamp is associated with an increased risk of obesity and non-communicable diseases (Cooksey-Stowers, Schwartz and Brownell, 2017; Hager et al., 2017; Garg et al., 2023). However, other studies have found no or small associations (Fitzpatrick, Greenhalgh-Stanley and Ver Ploeg, 2019; Key et al., 2023). In addition, empirical evidence to support the causal effect of living in a food desert or a food swamp on nutrition and health outcomes is still limited (Zhen, 2021).

One of the potential motives underlying non-consensual results is the lack of methodological standardization (Beaulac et al., 2009; Caspi et al., 2012; Ver Ploeg, Dutko and Breneman, 2015; Gebremariam et al., 2017; Titis, Procter and Walasek, 2022). Previous reviews have reported heterogeneity in the approaches used for measuring food availability and physical access (Charreire et al., 2010; Ver Ploeg, Dutko and Breneman, 2015; Gebremariam et al., 2017; Titis et al., 2022). However, to the authors' knowledge, no study has performed a systematic assessment of the operational definitions of food deserts and food swamps. An operational definition can be regarded as an explicit, unambigious and detailed explanation of the conditions necessary for identifying an area as a food desert or a food swamp (Winne, 2023). Operational definitions of food deserts and food swamps are expected to include detailed conditions about the types of outlets regarded as source of (un)healthy foods, specifications on how to calculate physical access to the outlets, and the thresholds of physical access used to classify areas as deserts or swamps.

In this context, the aim of the present study was to critically analyze operational definitions of food deserts and food swamps included in empirical studies published in peer-reviewed journals. Results are expected to provide insights to refine and standardize methodological approaches for assessing physical access to food and its effects on health and wellbeing. This is particularly relevant to advance food environment research in emerging countries, where studies on the topic are still scarce (Turner et al., 2018, 2020; Blake et al., 2021; Karanja et al., 2022). So far, most of the studies on the topic have been conducted in WEIRD (Western-Educated-Industrialized-Rich-Democratic) countries (Muthukrishna et al., 2020; Turner et al., 2020). Therefore, the operational definitions commonly used in the literature may not be applicable in non-WEIRD settings (Turner et al., 2018). In the present work, special focus is placed on Latin America and the Caribbean, one of the world's most unequal regions (United Nations Development Programme, 2023). In terms of food security and nutrition, the region faces relevant challenges related to the availability and access to healthy diets (FAO, 2024). In 2022, the prevalence of food insecurity was 39%, whereas obesity affected 24.2% of the adult population (FAO, 2024).

2. Methods

The scoping review was conducted following the recommendations of the Joanna Briggs Institute (Peters et al., 2020) and PRISMA Extension for Scoping Reviews (PRISMA-ScR) guidelines (Tricco et al., 2018). This type of review is recommended for identifying and analyzing concepts and mapping the available evidence (Munn et al., 2018). The guiding question for the scoping review was: What operational definitions of food deserts and food swamps have been used in the scientific literature? The population of the scoping review was empirical studies, published in peer-reviewed journals, assessing the retail food environment and/or analyzing its influence on behavioral and/or health outcomes. The concepts were operational definitions of food deserts and food swamps, whereas the context was both WEIRD and non-WEIRD countries.

2.1. Search strategy

A search of the scientific literature was performed to identify scientific studies including operational definitions of food deserts and/or food swamps in three databases: Scopus, PubMed, and Scielo. The databases were selected to cover the scientific literature across health, behavioral and social sciences globally with special emphasis on Latin America and the Caribbean. The search was completed on August 2023 using the following specific terms in English: "food desert" or "food swamp". The decision to use a narrow search strategy based on two specific terms was made considering that the scoping review was specifically focused on operational definitons of food deserts and food swamps. It was hypothesized that studies reporting such definitons would include an explicit reference to food deserts or food swamps in the title, abstract or keywords.

2.2. Inclusion criteria

Only empirical studies published in peer-reviewed scientific journals and written in English, Spanish or Portuguese were included. Commentaries, editorials, and reviews were excluded. All included studies had to present a detailed operational definition of food deserts and/or food swamps. Thus, studies missing key methodological details for the identification of food deserts or food swamps were excluded.

2.3. Study selection

One of the authors conducted the literature search in the selected databases and imported the resultant records into Mendeley. Duplicates were removed. The screening of title and abstracts was performed against the inclusion and exclusion criteria by two independent researchers to evaluate eligibility. All articles referring to food deserts, food swamps or the characterization of the physical food environment, regardless of their specific objective, were retained. Discrepancies between the two researchers were solved by a third researcher.

Full-text screening was performed by two independent researchers. Reasons for exclusion were documented and discrepancies were solved by a third researcher, who provided a tie-breaking vote.

2.4. Data extraction

Data extraction was focused on the operational definitions of food deserts and/or food swamps. It was performed on an Excel spreadsheet using a template developed by one of the authors. The following data were extracted: authors, publication year, country where data were collected, operational definition of food desert, operational definition of food swamp. Given the focus of the review, information about other variables not related to the definiton of food deserts and/or food swamps was not extracted. For example, the outcome measures of studies analyzing associations between the food environment and health variables were not extracted.

The data was then synthethised using inductive coding to address the research question. The following elements of the definitions were analyzed: measure, food outlets regarded as healthy, food outlets regarded as unhealthy, other food outlets included in the definition, unit of analysis for the identification of food deserts and/or food swamps, unit of measurement of distance (m or km), type of distance used to measure proximity to food outlets (e.g., Euclidean or network distances), cut-off criterion or thresholds to identify food deserts and/or food swamps, and other conditions included in the definition.

3. Results

The PRISMA flow chart describing the review process is shown in Fig. 1. A total of 932 scientific articles were identified in the three databases, from which 201 were duplicate. After title and abstract

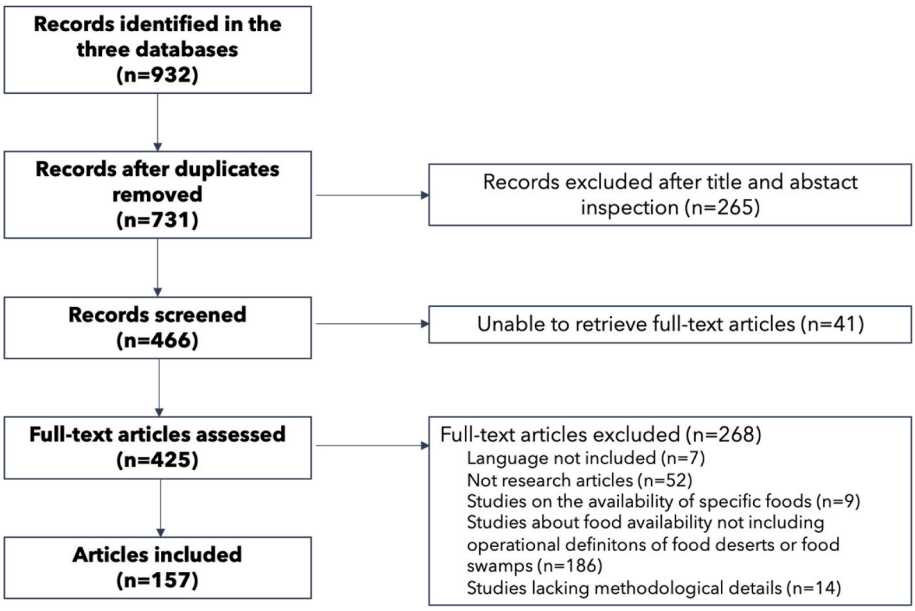

Fig. 1. PRISMA flow diagram for the selection of articles included in the scoping review.

inspection, 265 records were removed, giving as a result 466 articles to be screened in full-text. However, the authors did not have access to the full text of 41 articles. From the 425 articles assessed for eligibility, 268 were excluded. The main reasons for exclusion were the lack of inclusion of an operational definition of food deserts or food swamps (n = 186), and not being research articles (n = 52) (Fig. 1). In addition, 14 articles were excluded because they lacked methodological details in the operational definition of food deserts and/or food swamps. A total of 157 articles were included in the review.

3.1. Description of the included studies

The first study including an operational definition of food deserts dates from 2002. The number of studies including operational definitions of food deserts and/or food swamps has increased over time and at least one study has been published every year from 2011 (Fig. 2). The last decade (2013–2023) represents 81% of the studies included in the review.

Most of the studies included in the review were counducted in WEIRD countries (n = 146), whereas only 11 (7%) were conducted in non-WEIRD countries (Fig. 2). Table 1 of the Supplementary Materials shows the list of WEIRD and non-WEIRD countries where the studies reporting definitions of food deserts and food swamps included in the review were conducted. The United States of America is the country where most studies were conducted (n = 118, 75%), followed by Canada (n = 14, 9%). Other WEIRD countries where studies were counducted include Slovak Republic (n = 5), The Netherlands (n = 2), Australia (n = 1), Belgium (n = 1), Germany (n = 1), New Zealand (n = 1) and the United Kingdom (n = 1). Studies in non-WEIRD countries are more recent, dating from 2016. Brazil is the non-WEIRD country with the largest number of studies (n = 6), followed by Mexico (n = 2), China (n = 1), Guatemala (n = 1), Iran (n = 1), Japan (n = 1), and Korea (n = 1). Ony 9 of the 157 studies (5.7%) were conducted in the region of Latin American and the Caribbean.

3.2. Operational definitions of food deserts

Operational defintions of food deserts were included in 146 studies, published between 2002 and 2023. The great majority of the studies (n = 136, 93%) were conducted in WEIRD countries (USA n = 112, Canada n = 13, Slovak Republic n = 5, The Netherlands n = 2, Australia n = 1 Belgium n = 1, Germany n = 1, United Kingdom n = 1) and only 10 (7%) were conducted in non-WEIRD countries (Brazil n = 4, Mexico n = 2, China n = 1, Iran n = 1, Japan n = 1, Korea n = 1).

The included studies presented a total of 107 different operational definitions of food deserts (Table 1). All the definitions included a measure of the physical availability of or physical access to food outlets selling healthy foods. However, they largely differ in all their key elements, as summarized in Fig. 3a.

A wide range of stores were regarded as healthy food outlets, being

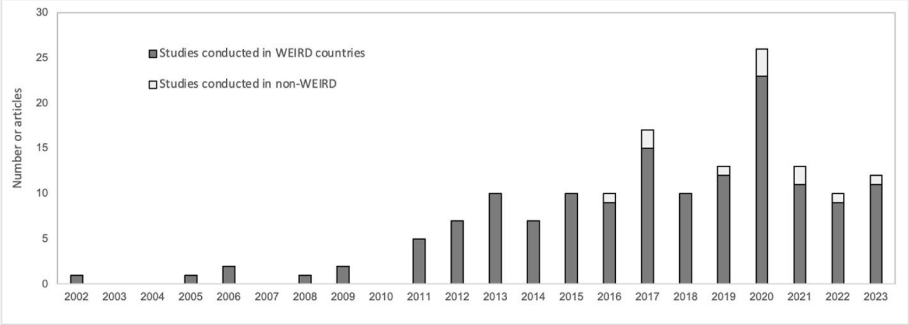

Fig. 2. Number of articles included in the scoping review per year and type of country.
Note: WEIRD stands for Western Educated Industrialized Rich and Democratic.

Table 1
Operational definitions of the food deserts included in the studies.

Type of measure	Measure	Healthy food outlets	Distance or time to healthy food outlet	Conditions related to household income	Other conditions	Unit of analysis	Type of distance	Country	Reference
Density of healthy food outlets	No healthy food outlet within the unit of analysis	Supermarkets, large grocery stores, warehouse clubs, fruit and vegetable markets	Within the unit of analysis and 800 m buffer around the boundary	–	–	Census tract	Euclidean distances	USA	(Ma et al., 2013; Liese et al., 2014; Sohi et al., 2014; Santorelli and Okeke, 2017; A. M. Testa, 2019; A. Testa, 2019; Testa and Jackson, 2019; Fortin-Miller et al., 2021; Testa et al., 2021)
		Grocery store	Within the unit of analysis	–	–	Town	–	USA	Campbell et al. (2020)
		Supermarkets	Census tract and a buffer zone of 800m from the tract boundary	–	–	Census tract	Euclidean distance	USA	(Amin, Badruddoza and McCluskey, 2021)
	Less than one healthy food outlet per square kilometer	Grocery stores	–	Highest quintile of households under the poverty line	–	Census tract	–	USA	Semple and Giguere (2018)
	Number of healthy food outlets lower than the average of rural counties (3.8)	Supermarkets, retail grocery stores	Within the unit of analysis	–	–	County	–	USA	Morton et al. (2005)
	Number of healthy food outlets within the unit of analysis in the lower quartile	Supermarkets (offering a full range of grocery items and at least ten employees)	1000 m from the population weighted average distance of all the postal codes within the neighborhood boundaries	Percentage of low-income households above city median	Residents aged 65 years and older above city median Households without automobile above the city median	Neighborhood	Network distance	Canada	(Smoyer-Tomic et al., 2006)
		Supermarkets and larger grocery stores, fruit and vegetable markets, warehouse clubs	Within the unit of analysis	–	–	ZIP codes	Network distance	USA	Potluri et al. (2020)
		Seafood shops, fruits and vegetables establishments	Within the unit of analysis	–	–	Neighborhoods		Brazil	Andretti et al. (2023b)
	Number of healthy food outlets in the lower tertile	Fish and seafood shop, fruits and vegetables shops, butchers, supermarkets, grocery stores	Within the unit of analysis	–	–	Municipalities		Brazil	Victor et al. (2023)
	Number of healthy food outlets (continuous measure)	Supermarkets, larger grocery stores, produce stores	Within the census tract and a buffer zone of half a mile from the tract boundary	–	–	Census tract	Euclidean distance	US	Cerceo et al. (2023)
	No healthy food outlet per 1000 residents within the unit of analysis	Club stores, supercenters, grocery stores (excluding "superettes")	Within the unit of analysis	–	–	ZIP codes	–	USA	Allcott et al. (2020)
	Number of healthy food outlets per 10,000 inhabitants in the lower quartile	Public establishments for food security, fresh product store, butcher shop, fish market	Within the unit of analysis	–	–	Census tract	–	Brazil	Honório et al. (2021)
	Number of healthy outlets per 10,000 inhabitants (continuous measure)	Open-air organic/ agroecological food markets, supermarkets	Within the unit of analysis	–	–	Regional administration (subdivision of municipalities	–	Brazil	(Grilo, Menezes and Duran, 2022)

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Table 1 (*continued*)

Type of measure	Measure	Healthy food outlets	Distance or time to healthy food outlet	Conditions related to household income	Other conditions	Unit of analysis	Type of distance	Country	Reference
						according to geographical position and history of occupation)			
Coverage of healthy food outlets	No healthy food outlets within a distance threshold	Supermarkets, greengrocers, butchers	2.5 km	–	Located in collection districts with a percentage of households without car over 15.8% (top quartile for the region)	Residential dwellings	Euclidean distances	Australia	O'Dwyer and Coveney (2006)
		Supermarkets	1000 m by foot or 10-min bus ride without transfers combined with 500 m walk	–	–	Blocks	Network distances	Canada	Larsen and Gilliland (2008)
		Supermarkets	800 m	–	–	ZIP-code	Euclidean distances	USA	(Walker, Butler, *et al.*, 2011; Walker, Fryer, *et al.*, 2011)
		Supermarkets	1600 m	Located in census tracts where >40% of the population live in households with income <200% poverty threshold		Homes	Euclidean distances	USA	Hamrick and Hopkins (2012)
		Superstores, wholesalers, warehouses, grocery stores	400 m (urban) 2.4 km (rural)	–	–	Migrant and seasonal farmworkers labor camps	Euclidean distances	USA	Grauel and Chambers (2014)
		Supermarkets, community gardens, farmers' markets	1000 m from the centroid	Lower quintile of median income	Lower quintile of car access Higher quintile of population density	Neighborhood	Network distance	Canada	(Wang, Qiu and Swallow, 2014)
		Supermarkets, supercenters	4 km	–	–	Dissemination areas (smallest geographic areas for which census data are disseminated)	Network distances	Canada	(Luan, Law and Quick, 2015)
		Large retail food stores	3.2 km from the centroid	–	–	Block groups	Network distance	USA	(Jaskiewicz, Block and Chavez, 2016)
		Supermarket	1600 m (16 km for rural)	Located in low-income block groups (median household income ≤ US$28,273 or > 20% of the population below the poverty line)	–	Private residences	Euclidean distances	USA	Thomsen et al. (2016)
		Affordable stores selling fresh, diverse and high-quality food products among the four groups of the Canadian food guide (4 fruits and vegetables, 10 meat and alternatives, 6 grain products, 5 milk and alternatives)	16 km (rural)	Within communities in the 5th quintile of deprivation index		Households	Network distances	Canada	Lebel et al. (2016)

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Table 1 (*continued*)

Type of measure	Measure	Healthy food outlets	Distance or time to healthy food outlet	Conditions related to household income	Other conditions	Unit of analysis	Type of distance	Country	Reference
		(resulting from a field audit)							
		Stores selling all types of staple foods (manioc flour, beans, bread) and at least five different types of fruit or vegetable, and at least three sources of animal protein (tinned beef, meat on the bone, chicken, or eggs).	250 m (equivalent to a 5-min walk)	–	–	Households	Network distances	Brazil	(Davies, Frausin and Parry, 2017)
		National chain grocery store (large full-service grocery stores)	500 m from the dissemination block centroid	Lowest income quintile	–	Dissemination blocks	Geodesic distances	Canada	Slater et al. (2017)
		National chain grocery store (large full-service grocery stores), full-service grocery stores (large, local grocery stores offering a good selection of self-serve fruits and vegetables), fresh meat and dairy products at reasonable prices, as assessed by local health dietitians involved in the study)	500 m from the dissemination block centroid	Lowest income quintile	–	Dissemination blocks	Geodesic distances	Canada	Slater et al. (2017)
		Supermarkets	1000 m	–	–	Blocks	Euclidean, and Network distances	Slovak Republic	Bilková et al. (2017)
		Chain supermarkets, large grocery stores	1600 m	Poverty rate higher than 20%	–	Block, census blocks, census tracts	Euclidean distances	USA	Bao and Tong (2017)
		Supermarkets	1.2 km	–	–	Homes	Euclidean distances	USA	Schwartz et al. (2018)
		Small scale fixed food retailers (butcher shop, poultry shop, fish shop, greengrocer, dried chilies and seeds), public market, Tianguis and wheels market, supermarket	1000 m (for markets and supermarkets) 500 m for stores selling animal proteins or fruits and vegetables	–	–	100 m × 100 m grid	Euclidean distances	Mexico	(González-Alejo, Frejomil and Rosales-Tapia, 2019)
		Grocery store, farmer's market, full service/sit-down restaurant	1.6 km (8 km in rural areas)	–	–	Homes	Self reported distance	USA	Cooksey Stowers et al. (2020)
		Department stores, supercenters, large supermarkets, marketplace/shopping malls, special stores for organic foods, discount chains, farmers' markets	500 m	–	–	100 m × 100 m grid	Euclidean distances	Korea	Kim et al. (2020)

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Table 1 (*continued*)

Type of measure	Measure	Healthy food outlets	Distance or time to healthy food outlet	Conditions related to household income	Other conditions	Unit of analysis	Type of distance	Country	Reference
		Department stores, supercenters, large supermarkets, marketplace/shopping malls, special stores for organic foods, discount chains, farmers' markets, small grocery stores, arcade/shopping centers, local grocery stores, convenience stores	**500 m**	**–**	**–**	**100 m × 100 m grid**	**Euclidean distances**	**Korea**	**Kim et al. (2020)**
		Supermarkets	1600 m (urban) 16 km (rural)	>20% of the population below poverty	–	Census blocks	Network distance	USA	Chenarides et al. (2021)
		Supermarkets	400 m	Neighborhood median household income ≤185% Federal poverty line	>40% of the households in the neighborhood have no vehicle Average Healthy Food Availability Index for supermarkets and corners stores in the neighborhood is ≤ 9.5 (out of 27)	Family childcare homes	Euclidean distances	USA	Francis et al. (2022)
		Supermarkets	1 km	Median household income in the lowest two deciles	Bus stop: no bus stop within 500 m walking distance where people can take the bus to the supermarket Senior citizens: number of people older than 65 in the lowest two deciles Walkability: in the lower two deciles	Residential areas (1000 m walking distance buffer around the geometric center of gravity of all residential addresses within a census tract)	Walking/ road distances	Belgium	Smets, Cant and Vandevijvere (2022)
		Supermarkets	1 km	Low socio-economic status	–	Block	Network distances	Mexico	Reyes-Puente et al. (2022)
		Supermarkets, grocery stores, farmers' market, community kitchens, food pantries	800 m	–	–	Residential addresses	Euclidean distances	USA	Figueroa et al. (2023)
		Supermarkets	1600 m	–	–	Census tract	Euclidean distances	USA	Coyle et al. (2023)
	Number of healthy food outlets within the distance threshold in the lower quartile	Supermarkets and larger grocery stores, fruit and vegetable markets, warehouse clubs	Driving distance of 1 km around the unit of analysis	–	–	Dialysis units	Network distance	USA	Potluri et al. (2020)
	Lack of service areas around healthy food outlets	Multiple/co-op stores	500 m	High Carstairs indices of multiple deprivation	–	Areas within the city	Euclidean distances	UK	Clarke et al. (2002)
		Supermarkets, superstores, large grocery stores	16 km (rural)	–	–	Census block	Euclidean distance	USA	Hubley (2011)

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Table 1 (*continued*)

Type of measure	Measure	Healthy food outlets	Distance or time to healthy food outlet	Conditions related to household income	Other conditions	Unit of analysis	Type of distance	Country	Reference
		Supermarkets (stores run by national or regional chains selling a broad selection of foods)	1600 m	–	–	Areas within the city	Network distance	USA	Jiao et al. (2012)
		Supermarket chain stores, convenience stores, ethnic markets, independently owned food marts	800 m	–	–	Areas within the city	Euclidean distances	USA	Johns, Dixon and McHan (2013)
		Supercenters, supermarkets/ convenience stores with more than 5 employees	800 m	–	–	Areas within the city	Network distance	USA	Chen and Clark (2013)
		Supermarkets, large grocery stores (>50 employees), farmers' market	1000 m (urban) 16 km (rural tracts)	–	–	Areas within the state	Euclidean distances (urban) Network distances (rural)	USA	Sage, McCracken and Sage (2013)
		Grocery stores. markets, and health food stores	2000 m	–	–	Areas within the city	Network distance	Canada	Newbold et al. (2013)
		Discount supermarkets, ethnic stores, specialty food stores (e.g., stores selling meat, fish and seafood, fruit and vegetable markets)	1000 m	Disadvantaged areas based on socioeconomic and demographic factors (e.g., population, employment, income, vulnerable groups)	–	Areas within the neighborhood	Euclidean	Canada	(Behjat, Koc and Ostry, 2013)
		Supermarkets, community gardens, farmers' markets	1000 m from the centroid	Low income	High population density Low car access	Neighborhoods	Network	Canada	(Wang, Qiu and Swallow, 2014)
		Major grocery stores	800 m	Poverty rate higher than 20%	–	Areas within the city	Euclidean distances	USA	LeClair and Aksan (2014)
		Large and small grocery stores selling good quality (exclusion of stores with deficiencies according to the State Veterinary and Food Administration of the Slovak Republic), diverse (exclusion of stores selling less than 10% of the average proportion of foods in the basic food basket), and non-expensive foods (stores where the price of the food basket was 10% higher than average were excluded)	1000 m (car driven distance)	–	–	Areas within the city	Network distance	Slovak Republic	Križan et al. (2015)
		Green retailers (stores that sell fruits and vegetables)	800 m	–	–	Areas within the city	Network distance	USA	Chen and Clark (2016)

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Table 1 (*continued*)

Type of measure	Measure	Healthy food outlets	Distance or time to healthy food outlet	Conditions related to household income	Other conditions	Unit of analysis	Type of distance	Country	Reference
		Supermarkets, chain supermarkets, ethnic specialty food markets, fruit and vegetable markets, Women, Infant and Children (WIC), farmers markets	800 m for residents living in households without vehicle and 5-min drive for residents living in households with vehicle (urban areas) or 800 m for residents living in households with vehicle (rural areas)	Household income ≤185% of the federal poverty threshold	–	Neighborhoods	Network distance	USA	(Mohammadi, Mohammadian and Thill, 2017)
		Supermarkets, grocery stores	1000 m	–	–	Residential buildings	Network distances	Japan	Ikejima (2019)
	Less than 2 service areas around healthy food outlets	Supermarkets, local grocery stores	1000 m for residents in households without vehicle and 10-min drive for residents living in households with vehicle	Bottom quartile of median household income	Top quartile of population density	Neighborhood	Network distance	Canada	(Yang, Wang and Qiu, 2020)
	Service areas around healthy food outlets in the lower quantile	Supermarkets, grocery stores	1000 m	–	–	Neighborhood	Network distance	Canada	(Yang, Qiu and Tu, 2022)
		Supermarkets, supercenters, large grocery stores	8 km (urban) 16 km (rural)	–	–	Homes	Euclidean distances	USA	(Mishra, Sharma and Pani, 2023)
	Lack of service areas around healthy food outlets based on travel time	Supermarkets (stores run by national or regional chains selling a broad selection of foods)	10 min by walking, bicycling, driving or public transport	–	–	Areas within the county	Network distance	USA	Jiao et al. (2012)
		Supermarkets and other grocery and convenience stores, supercenters,	10 min drive (rural) Access to bus service within 5 miles of the city center (rural)	–	–	Areas within the State	Network distance	USA	Mulangu and Clark (2012)
		Large grocery stores	10 and 15 min (rural)	–	–	Areas within the municipality	Network distance	Slovak Republic	Bilková and Križan (2015)
		Full-service supermarket, grocery store, fruit store and market, vegetable store and market, seafood market	30 min (walking) 20 min (public transit) 15 min (bicycle) 10 min (private car)	Percentage of unemployed people >4.1%	Percentage of people with degree lower than middle school >65.6%	Community	Road network distance	China	Su et al. (2017)
		Grocery stores, supermarkets, hypermarkets	15 min walking	–	–	Basic settlement units	Network distances	Slovak Republic	Trembošová and Jakab (2021)
		Supermarkets, discounters	15 min travel time (foot, bicycle or car) and ≥33% of the population has travel times ≥15 min (rural) Potentially perceived food deserts: <15 min and >33% of the population experience (rural)	–	–	250 m × 250 m grids	Street network distances	Germany	Neumeier and Kokorsch (2021)
Proximity to the closest healthy food outlet	Average distance to closest healthy food outlet (continuous measure)	Full-service grocery store	Average distance weighted by number of households without vehicle	–	–	Block groups	Network distance	USA	Widener, Metcalf and Bar-Yam (2012)
	Distance to the closest healthy food outlet in the top quartile	Supermarkets (offering a full range of grocery items and at least ten employees)	Population weighted average distance of all the postal codes within the neighborhood boundaries	Percentage of low-income households above city median	Residents aged 65 years and older above city median Households without automobile above city median	Neighborhood	Network distance	Canada	(Smoyer-Tomic et al., 2006)

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Table 1 (*continued*)

Type of measure	Measure	Healthy food outlets	Distance or time to healthy food outlet	Conditions related to household income	Other conditions	Unit of analysis	Type of distance	Country	Reference
	Distance to the closest healthy food outlet larger than the threshold	Supermarkets, greengrocers, butchers	2.5 km average distance weighted by population density	Poverty rate in the higher quartile	Percentage of population aged 65 years and more in the higher quartile	Residential dwellings (distances calculated at the level of blocks)	Euclidean distances	Australia	(Lamb, Brand and Sparks-Ibanga, 2012)
		Supermarkets and other grocery stores (except convenience stores) larger than 2500 square feet	16 km (rural)	–	Low vehicle access in the higher quartile	Census tract	Network distances	US	McEntee and Agyeman (2010)
		Affordable stores selling fresh, diverse and high-quality food products among the four groups of the Canadian food guide (4 fruits and vegetables, 10 meat and alternatives, 6 grain products, 5 milk and alternatives) (resulting from a field audit)	16 km (rural)	Within communities in the 5th quintile of deprivation index	–	Households	Network distances	Canada	Lebel et al. (2016)
		Large retail food stores	3.2 km	–	–	Block groups	Network distance	USA	(Jaskiewicz, Block and Chavez, 2016)
		Stores selling all types of staple foods (manioc flour, beans, bread) and at least five different types of fruit or vegetable, and at least three sources of animal protein (tinned beef, meat on the bone, chicken, or eggs).	250 m (equivalent to a 5-min walk)	–	–	Households	Network distances	Brazil	(Davies, Frausin and Parry, 2017)
		National chain grocery store (large full-service grocery stores)	500 m from the dissemination block centroid	Lowest income quintile	–	Dissemination blocks	Geodesic distances	Canada	Slater et al. (2017)
		National chain grocery store (large full-service grocery stores), full-service grocery stores (large, local grocery stores offering a good selection of self-serve fruits and vegetables), fresh meat and dairy products at reasonable prices, as assessed by local health dietitians involved in the study)	500 m from the dissemination block centroid	Lowest income quintile	–	Dissemination blocks	Geodesic distances	Canada	Slater et al. (2017)
		Supermarkets	0.4 km	Median household income is ≤ 185% of	>30% of households have no vehicle available	Census block group	Walking distance measure	US	(Hager et al., 2017; Misiaszek, Buzogany and Freishtat, 2018)

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Table 1 (*continued*)

Type of measure	Measure	Healthy food outlets	Distance or time to healthy food outlet	Conditions related to household income	Other conditions	Unit of analysis	Type of distance	Country	Reference
				the Federal Poverty threshold	Quality and quantity of foods available: Healthy Food Availability Index score between 0 and 8·7				
		Supermarket, grocery stores	1600 m	>20% of the population under the poverty line	–	Census tract	Population weighted Euclidean distance	USA	Bao et al. (2020)
		Supermarkets, grocery stores, fruit and vegetable stores	1000 m (urban) 16 km (rural)	5th quintile of deprivation index	–	Residential units, aggregated in dissemination areas (smallest geographic areas for which census data are disseminated)	Road network distances	Canada	Robitaille and Paquette (2020)
		Full-service grocery store (selling fresh meat and poultry, produce and fruit, dry and packaged foods, dairy, and frozen foods)	800 m	>20% of the population under the poverty line	Weighted average of distance from the census block to the food outlet and population of the census block	Census tracts	Euclidean distances	USA	Bao et al. (2020)
	Average distance to the three nearest healthy outlets larger than the threshold	Grocery stores, fruit and vegetable sources	16 km (rural)	–	–	Individual address points	Network distances	Canada	(Sadler, Gilliland and Arku, 2011)
	Self-reported distance to healthy food outlet larger than the threshold	Supermarkets	800 m (urban) 16 km (rural)	–	–	Homes	Self-reported	USA	James et al. (2022)
	99% or more of the address points far from healthy food outlets	Full-service grocery store	1000 m	Socioeconomic distress index (calculated based on low educational attainment, incidence of low income, lone parenthood, and unemployment) in the higher two quintiles	–	Census block groups	Network distances	US	(Sadler, Gilliland and Arku, 2013)
	Travel time to closest healthy food outlet larger than the threshold	Large grocery stores	10 and 15 min (rural) from the centroid of the unit of analysis	–	–	Municipality	Network distance	Slovak Republic	Bilková and Križan (2015)
Proximity to a food desert	Distance to a food desert closer than the threshold	–	400 m	–	–	Family childcare homes	Euclidean distances	USA	Francis et al. (2022)
Coverage and proximity	Distance to the closest healthy food outlet in the higher quartile and number of healthy food outlets in the lower quartile	Supermarkets (grocery chains, warehouse club stores, supercenters), farmers' markets	1 km from the community centroid	Median household income in the lower quintile	–	Communities	Network distances	Canada	Lu and Qiu (2015)

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Table 1 (*continued*)

Type of measure	Measure	Healthy food outlets	Distance or time to healthy food outlet	Conditions related to household income	Other conditions	Unit of analysis	Type of distance	Country	Reference
Coverage, density, and proximity	High proximity, high density of supermarkets, and mean distance to three outlets of different chains	Supermarkets	1000 m	Housing prices below the median	Percentage of native Dutch people below the median	100 × 100 m grid	Network distances	The Netherlands	Helbich et al. (2017)
	Clustering of units of analysis based on average distance to supermarket, number of supermarkets in the buffer area, and average distance to the three nearest from different chains	Supermarket chains	1000 m from the centroid	Housing prices	Percentage of native Dutch people	100 × 100 m grids	Network distance	The Netherlands	Helbich and Hagenauer (2017)
Proportion of the population with low access to healthy food outlets	Proportion of the population living far from a healthy outlet (continuous measure)	Supermarket	1600 m (urban) 16 km (rural)	–	–	Neighborhood	Euclidean distances	USA	(Liese et al., 2018; Choi et al., 2021)
		Supermarket, supercenter, or large grocery store	800 m (urban) 16 km (rural)	–	–	Census tract	Euclidean distances	USA	Wood et al. (2023)
		Supermarkets, grocery stores	1600 m 16 km (rural)	Median household income ≤200% of the federal poverty threshold	–		County	USA	Bevel et al. (2023)
	More than 33% of the population living far from a healthy food outlet	Grocery store (including a fresh produce department)	1600 from the centroid of the block for urban (16 km for rural)	Median household income <80% of the statewide income or >20% of the population with incomes below poverty level	–	Block groups	Euclidean distance	USA	Alviola et al. (2013)
		Supermarkets	1600 from the centroid of the block for urban (16 km for rural)	Median household income <80% of the statewide median income or >20% of the population below poverty level or	–	School districts	Euclidean distances	USA	(Alviola, 2013 Nayga and Thomsen, 2013)
	At least 500 people or 33% of the population lives far from a healthy food outlet	Supermarkets, supercenters, large grocery stores (annual revenue over USD 2 million and containing all the major food departments)	1.6 km (urban) 16 km (rural)	–	–	Census tract	Euclidean distances	USA	(Hipp and Chalise, 2015; Suarez et al., 2015; Pike et al., 2017; Wu et al., 2017; Gailey and Bruckner, 2019; Hamidi, 2020; Fong et al., 2021; Delk et al., 2022; McCullough et al., 2022; Livings et al., 2023)
			800 m (urban) 16 km (rural)	–	–	Census tract	Euclidean distances	USA	(Delk et al., 2022; Livings et al., 2023)
			1.6 km (urban) 16 km (rural)	Median household income ≤80% of the median income in the surrounding area or ≥20% of the population with	–	Census tract	Euclidean distances	USA	(Andrews, Bhatta and Ploeg, 2013; Frndak, 2014; Hardin-Fanning and Gokun, 2014; Liese et al., 2014, 2018; Sohi et al., 2014; Block and Subramanian, 2015; Daepp, 2015; Shannon et al.,

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Type of measure	Measure	Healthy food outlets	Distance or time to healthy food outlet	Conditions related to household income	Other conditions	Unit of analysis	Type of distance	Country	Reference
				incomes below poverty level					2015; Bohannon and Henry, 2016; Chen, Jaenicke and Volpe, 2016; Fitzpatrick, Greenhalgh-Stanley and Ver Ploeg, 2016, 2019; Strome et al., 2016; Dakkak W, 2017; Santorelli and Okeke, 2017; Chai, Fan and Wen, 2018; Fan et al., 2018; Gray et al., 2018; Ma et al., 2018; Fossi et al., 2019; Gbenro, Brace and Matthews, 2019; Kelli et al., 2019; Morris et al., 2019; Schupp, 2019; Barboza-Salerno, 2020; Goodman, Thomson and Landry, 2020; McKey, Kim and Seo, 2020; Sinclair, 2020; Tipton et al., 2020; Tong et al., 2020; Woodruff et al., 2020; Corbera-Hincapie et al., 2021; Lee and Caine-Bish, 2021; Madzia et al., 2021; Moughames et al., 2021; Smith et al., 2021; Gebrehiwot et al., 2022; Livings et al., 2023; Lloyd et al., 2023; Phillips et al., 2023; Sisk et al., 2023; Tanoh and Hashemi-Beni, 2023)
			800 m (urban) 16 km (rural) (calculated at the level of 500 × 500 m grids)	Median household income ≤80% of the median income in the surrounding area or ≥20% of the population with incomes below poverty level	–	Census tract	Euclidean distances	USA	(Bohannon and Henry, 2016; Santorelli and Okeke, 2017; Brace, Moore and Matthews, 2020; Isokpehi et al., 2020; Jettner and Secret, 2020; Banner et al., 2021; Crimarco et al., 2022; Livings et al., 2023; Tanoh and Hashemi-Beni, 2023)
			1.6 km (urban) 32 km (rural) (calculated at the level of 500 × 500 m grids)	Median household income ≤80% of the median income in the surrounding area or ≥20% of the population with incomes below poverty level	–	Census tract	Euclidean distances	USA	(Santorelli and Okeke, 2017; Brace, Moore and Matthews, 2020; Isokpehi et al., 2020; Tanoh and Hashemi-Beni, 2023)
			800 m (urban when the condition for car applies) or 32 km (regardless of vehicle access)	Median household income ≤80% of the median income in the surrounding area or ≥20% of the population with	≥100 households without vehicle	Census tract	Euclidean distances	USA	(Robinson et al., 2016; Santorelli and Okeke, 2017; Isokpehi et al., 2020; Livings et al., 2023; Tanoh and Hashemi-Beni, 2023)

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Table 1 (*continued*)

Type of measure	Measure	Healthy food outlets	Distance or time to healthy food outlet	Conditions related to household income	Other conditions	Unit of analysis	Type of distance	Country	Reference
				incomes below poverty level					
		Supermarkets, large grocery stores, warehouse clubs, fruit and vegetable markets	1600 m (urban) 16 km (rural)	Median household income ≤80% of the median income in the surrounding area or ≥20% of the population with incomes below poverty level	–	Census tract	Euclidean distances	USA	Ma et al. (2013)
		Supermarket, supercenter or large grocery store	1.6 km (urban) 16 km (rural)	≥20% poverty rate or median household income ≤80% median income	≥100 households have no access to a vehicle	Census tract	Euclidean distances	US	(Wilde, Llobrera and VerPloeg, 2014)
		Supermarket, grocery store	1.6 km (urban) 16 km (rural)	≤200% of the Federal Poverty threshold		County	Euclidean distances	US	(Cooksey-Stowers, Schwartz and Brownell, 2017)
	More than 30% of the population lives far from a healthy food outlet	Supermarket	1.6 km	Household income < USD 30,000 per year High poverty rate (criterion not specified)	Car ownership: without car access	Census tract	Euclidean distances	USA	Almalki et al. (2021)
	More than 50% of the population does not have access to a healthy food outlet	Supermarket	1 km	Poverty rate in the higher quartile	Percentage of population over 65 years old in the higher quartile or percentage of households lacking automobile access in the higher quartile	Census tracts (distance calculated at the level of blocks)	Euclidean distances	USA	(Leete, Bania and Sparks-Ibanga, 2012)
		Grocery stores (>50 employees)	16 km (from the population weighted centroid) or 24 km (for zip codes that fall along an interstate highway)	–	–	School districts (distance calculated over zip-codes)	Euclidean distances	USA	(Schafft, Jensen and Clare Hinrichs, 2009)
Food desert index	Number of healthy food outlets (1–3) + proportion of healthy bodegas of all bodegas (1–3) + proportion of fast-food restaurants from all restaurants (1–3)	Supermarkets, healthy bodegas (selling 7 or more healthy products - apples, oranges, bananas, skim and low-fat milk, water, tomatoes, carrots, leafy greens, 100% juice- according to an in-store survey)	400 m	–	–	Block groups	Euclidean distances	USA	Gordon et al. (2011)
	Clustering of areas based on proximity to closest healthy food outlet, number of food outlets within a distance threshold, average distance to three closest supermarket and social deprivation	Supermarket	1000 km	Poverty rate	Percentage of population over 65 years old Households lacking automobile access	Census tracts (distance calculated at the level of blocks)	Population weighted Euclidean distances	USA	(Leete, Bania and Sparks-Ibanga, 2012)

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Table 1 (*continued*)

Type of measure	Measure	Healthy food outlets	Distance or time to healthy food outlet	Conditions related to household income	Other conditions	Unit of analysis	Type of distance	Country	Reference
	Index calculated based on distance to the grocery store and other variables above 1 standard deviation above the mean	Full-service grocery stores		Per capita income Median household income Median income whites Median income blacks Percentage of adults under poverty level Percentage children under poverty line Percentage of workforce unemployed	Distance to nearest bus stop Elite-impoverished composite Comfortable-distressed Population mean Population density Percentage white Percentage black Percentage Hispanic Median age Percentage married Percentage households occupied by renters Percentage households with no car Average cars per household Percentage divorced Percentage single Average commute time Median housing value Percentage of housing is trailers Percentage high school dropouts Percentage of adults who are college graduates Population change from 2000 to 2009 Percentage uninsured Percentage obese Percentage hypertensive Percentage high cholesterol Percentage diabetes	Census block	Euclidean distances	USA	Larson et al. (2013)

large retail stores, particularly supermarkets (n = 68) and grocery stores (n = 61), the most common. Some definitions described specific characteristics supermarkets and grocery stores must have to be regarded as healthy food stores: selling a full range of grocery items (n = 10), annual revenue over 2 million dollars (n = 6), minimum number of employees (ranging from 5 or 50, n = 5), run by national or regional chains (n = 6), having a fresh produce departament (n = 2), or having an area over 2500 square feet (n = 1). A few studies (n = 6) identified healthy food outlets by conducting field audits to evaluate the availability of specific foods or used secondary databases of food availability on food stores. Two of the studies included food prices as an additional criterion, identifying healthy food outlets as those who sold healthy foods at an affordable price.

Food deserts were identified considering units of analysis of very different size, ranging from residential addresses, to grids of different area (e.g., 100 m × 100 m), to towns (Table 1). Census tracts, blocks or groups of blocks, and areas within a geographical region (city, county, neighborhood, municipality, state) were the most common geographical units, being included in 23, 21, and 14 definitions, respectively.

Operational definitions were grouped in 11 main types of approaches to measure the physical availability of or physical access to healthy food outlets. A first group of definitions were based on the density of healthy food outlets within a specified geographic area (Table 1). Three definitions regarded areas with no healthy food outlets as food deserts but differed in the type of stores regarded as indicators of the availability of healthy foods. Two definitions regarded food deserts as areas with less than one healthy food outlet per square kilometer or 1000 inhabitants. The other defitinions based on density identified food deserts using relative criteria based on the distribution of the data across units of analysis, considering the lower tertile, the lower quartile or areas with a density of healthy food outlets below average.

The largest proportion of definitions (n = 52) were based on the coverage of healthy food outlets, i.e., the number of healthy food outlets accessible within a pre-specified travel distance or time. Twenty eight definitions created buffered areas around the centroid of the units of analysis, ranging in radius from 250 m to 4 km in urban setings and from 4 km to 16 km in rural areas according to Euclidean or network distances. The definitions mainly considered walking distances, although some regarded driving as the main transportation mode. Five definitions also included public transport (Table 1). The most frequently applied criteria for identifying food deserts in these definitions was lack of a healthy food outlet within the buffered area, whereas one of the definitions used a relative criterion based on the lower quartile of the number of healthy food outlets within the buffered area. The other 24 definitions based on coverage created service areas around healthy food outlets, ranging in distance between 500 m and to 22 km in urban settings and 8 km–16 km in rural settings (measured using Euclidean or network distances), or a travel time ranging between 10 and 30 min. The lack of service areas within the geographic unit of analysis was the most common criterion to identify food deserts. However, one study considered 2 service areas as threshold and two studies used the lower quartile of the number of service areas as cut-off criterion.

Proximity to the closest healthy food outlet was considered in 18 definitions (Table 1). One study used the average distance to the closest healthy food outlet as a continuous variable, whereas two studies regarded areas with average distances in the top quartile as food deserts. These three studies used weighted distances considering population density or the number of household without vehicle. Eleven definitions regarded geographic areas as food deserts if the distance to the closest healthy food outlet was larger than a distance threshold ranging from 250 m to 3.2 km in urban settings or 16 km in rural settings. One definition used the average distance to the three nearest healthy food outlets, whereas another definition based on proximity measures used travel times, setting 10 and 15 min as thresholds for the identification of rural food deserts. Furthermore, one definition identified food deserts based on the percentage of the address points within a census block group located farther than 1 km from a healthy food outlets. Three types of distances were used for the calculations: Euclidean, network or self-reported distances in a survey.

One of the studies also considered proximity to a food desert, identified as such areas located closer than 400 m to a food desert based on coverage of healthy food outlets. In addition, three definitions combined proximity to a healthy food outlet with other measures such as coverage and/or density (Table 1).

Another group of definitions were based on the proportion of the population within a geograpic area with low access to healthy food outlets. Low access was measured based on a distance theshold that ranged between 800 m and 32 km for urban areas and between 16 km and 32 km for rural areas (measured using Euclidean distances). Three definitions calculated the percentage of population with low access to a healthy food outlet, whereas the majority set thresholds for the identification of food deserts ranging from 30% to 50%. The most frequently used threshold was at least 500 people or 33% of the population in the census tract, which corresponds to the definition of the United States Department of Agriculture (USDA).

The final set of definitions were proposed by three studies, which calculated food desert indexes using a series of variables related to the physical availability of healthy food outlets (Table 1). Two of the studies incorporated socioeconomic variables of the areas in the construction of the index. The identification of food deserts was based on the distribution of the data.

A major difference among the operational definitions of food deserts was whether indicators of socioeconomic vulnerability were included or not (Table 1). Fifty eight definitions only referred to physical availability, whereas the remaining 49 included requirements on additional indicators for the identification of food deserts. Requirements related to household income were the most common (n = 47), whereas two studies only included requirements on vehicle ownership.

A total of 47 operational definitions included requirements on household income, poverty rate, and/or other indicators of the socioeconomic status of the units of analysis (deprivation indexes, socioeconomic status index, socioeconomic distress index, unemployment, or housing prices). Heterogenity in the cut-off criteria for the definition of food deserts was identified (Table 1). The criterion included in the USDA definition of food deserts was the most commonly used by the studies: census tracts where median household income is equal or lower than 80% of the median income in the surrounding area or 20% of the population or more with household incomes below poverty level.

Nineteen of the 47 definitions imposed additional socioeconomic requirements for areas identified as food deserts (Table 1). Fifteen introduced requirements on vehicle ownership, six on the percentage of the population over 65 years old, three on population density, two on proximity to a bus stop, one on neighborhood walkability, and one on educational level. One of the studies relying on the calculation of a food desert index included a wide range of socioeconomic indicators (Table 1).

3.3. Operational definitions of food swamps

A total of 26 studies included an operational definition of food swamps, published from 2015 onwards. Nineteen studies were conducted in WEIRD countries (USA n = 12, Canada n = 5, Belgium n = 1, New Zealand n = 1), whereas the reamining 7 were conducted in non-WEIRD Latin American countries (Brazil n = 5, Guatemala n = 1, and Mexico n = 1).

A total of 30 operational definitions of food swamps were reported by the 26 studies. Definitions were highly heterogeneous, as no two studies used the exact same definition (Table 2). A summary of the key elements included in the definitions of food swamps is shown in Fig. 3b.

Although all the studies identified food swamps based on the absolute or relative physical availability of or physical access to unhealthy food outlets, the types of stores regarded as unhealthy outlets widely

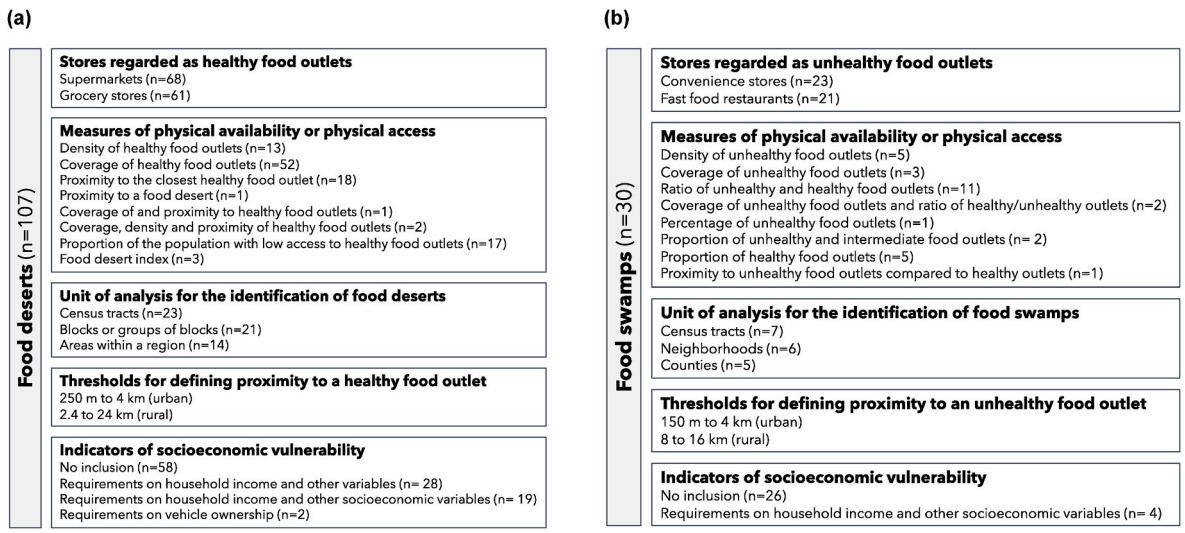

Fig. 3. Summary of the main elements of the operational descriptions of (a) food deserts and (b) food swamps reported in the studies included in the review and described in Tables 1 and 2

differed. The majority of the studies considered convenience stores (n = 23) and fast food restaurants (n = 21) as unhealthy food outlets. Fewer studies have included small grocery/corner stores (n = 6), candy shops (n = 6), bars (n = 5), as well as other types of stores, including behind-glass corner stores, snack bars, pubs, canteens or supercenters (Table 2).

Food swamps were identified at the level of widely different units of analysis, from homes to municipalities, using seven main approaches to measure the availability of unhealthy food outlets: density of unhealthy food outlets, coverage of unhealthy food outlets, ratio/proportion of unhealthy food outlets, and proximity to unhealthy food outlets.

Five studies used definitions based on density, considering the absolute number of unhealthy food outlets or the number per 10,000 inhabitants in a specific area (buffer areas around homes or schools, neighborhoods, census tracts, and municipalities). Arbitrary cut-off points have been used for identifying food swamps based on density. Three studies regarded areas with 4 or more unhealthy food outlets as food swamps, although they have worked with areas of very different size (250 m buffer areas around schools, 400 m buffer areas around homes, and neigbhborhoods) (Table 2). The other two studies using density measures relied on relative cut-off points, regarding areas in the top quartile or top tertile of the distribution of the number of unheahtly food outlets per 10,000 inhabitants as food swamps.

Coverage measures were used to identify food swamps in three definitions. The number of service areas around unhealthy food outlets in the neighborhood were calculated considering a 1000 m network distance from the outlets. One definition used a pre-defined cut-off criterion to categorize neigborhoods as food swamps, whereas the other two studies considered the top quartile of the distribution as cut-off point.

Operational definitions involving the comparison between the number of unhealthy and healthy outlets within a specified area were the most frequent (Table 2). Nine studies used the ratio between unhealthy and healthy food outlets within a specified area, one study relied on the percentage of unhealthy and healthy food outlets, two studies identified food swamps based on the proportion of unhealthy and intermediate food outlets, whereas five studies calculated the proportion of healthy food outlets. Nine of the studies only calculated continuous food swamp measures, whereas the other seven used absolute arbitrary or relative cut-off points to identify food swamps. Finally, one study conducted in Mexico used promixity measures, defining food swamps as blocks with a shorter distance to unhealthy food outlets (convenience stores) than to any other type of outlet.

Two of the definitions considered both the number of service areas around unhealthy food outlets and the ratio between service areas around healthy and unhealthy food oulets. For service areas, the threshold was based on the top quartile, whereas for ratio it was based on the median.

The inclusion of socioeconomic indicators for the identification of food swamps was not common. Only four definitions introduced requirements related to socioeconomic characteristics of the areas regarded as food swamps. One of the definitions required food swamps to be areas of low household income and high popuation density, another definition only included a requirement for low income and the third imposed the requirement of low household income and high percentage of black and brown minorities. In addition, one of the definitions based on the ratio between unhealthy and healthy food outlets adjusted the values for population density and income.

4. Discussion

Results from the present work showed that most studies including operational definitions of food deserts or food swamps have been conducted in WEIRD countries. Few studies were conducted in the majority world, i.e., emerging countries in Asia, Africa, Latin America and the Caribbean where most of the worlds' population live (Khan et al., 2022). Therefore, the definitions may not accurately reflect the characteristics of the food environment and the food purchasing habits of citizens from non-WEIRD countries. This suggests that refinements to the operational definitions may be needed to advance food environment research globally, as highlighted by Turner et al., (2018).

Large heterogeneity in the operational definitions of food deserts and food swamps was found (c.f., Fig. 3). Published studies largely differed in all the elements of the operational definitions analyzed in the study, suggesting that they regarded different areas as food deserts and/or food swamps. As summarized in Fig. 3, considerable differences among studies were found in the measures of physical availability or physical access, the definition of (un)healthy food outlets, the unit of analysis for the identification of food deserts and food swamps, the thresholds for defining proximity to a food outlet, the type of distance, as well as in the inclusion of additional conditions related to socio-economic characteristics of the areas. Heterogeneity in the definitions was found among studies conducted in both WEIRD and non-WEIRD countries. Lack of standardization hinders the comparability across studies and can contribute to the lack of consensus regarding the influence of the food environment on health outcomes. Similar results have been reported by previous studies analyzing measures of food availability and physical

Table 2
Operational definitions of the food swamps included in the studies.

Type of definition	Measure	Unhealthy food outlets	Healthy food outlets	Other food outlets	Unit of analysis	Distance	Type of distance	Cut-off criteria	Other conditions	Country	Reference
Density of unhealthy food outlets	Number of unhealthy food outlets in a specific area	Convenience stores, behind-glass corner store, small grocery/ corner store	–		Homes	400 m	Euclidean distances	≥4		USA	Hager et al. (2017)
		Snack bars, small grocery stores, candy shops	–		Schools	250 m	Euclidean distances	≥4		Brazil	Peres et al. (2021)
		Convenience stores, snack bars, grocery stores, candy stores	–	–	Neighborhoods	Within the unit of analysis	–	≥4		Brazil	Andretti et al. (2023b)
	Number of unhealthy food outlets per 10,000 inhabitants	Pubs, snack bars, candy shops	–		Census tracts	Within the unit of analysis	–	>Top quartile		Brazil	Honório et al. (2021)
		Convenience stores, snack bars, candy shops, bars, canteens	–		Municipality	Within the unit of analysis	–	>Top tertile	–	Brazil	Victor et al. (2023)
Coverage of unhealthy food outlets	Number of service areas around unhealthy food outlets in a specified area	Convenience stores, fast food restaurants	–		Neighborhoods	1000 m	Network distance	≥20	Bottom quartile of median household income Top quartile of population density	Canada	(Yang, Wang and Qiu, 2020)
		Convenience stores, fast food restaurants	–	–	Neighborhoods	1000 m	Network distance	>23 (top quartile)		Canada	(Yang, Qiu and Tu, 2022)
		Convenience stores, fast food restaurants	–	–	Neighborhoods	1000 m	Network distance	> top quartile		Canada	(Tu et al., 2022)
Ratio of unhealthy and healthy food outlets	Number of unhealthy food outlets/Number of healthy food outlets	Fast food/limited-service establishments, convenience stores	Supermarkets, grocery stores		County	Within the unit of analysis	–	–	–	USA	(Cooksey-Stowers, Schwartz and Brownell, 2017)
		Fast food/limited-service establishments, convenience stores, supercenters	Supermarkets, grocery stores, specialty stores (e.g., produce markets, delis), and permanent farmers' markets		County	Within the unit of analysis	–	–	–	USA	(Cooksey-Stowers, Schwartz and Brownell, 2017)
		Fast food/limited-service establishments, convenience stores	Supermarkets, grocery stores, specialty stores (e.g, produce markets, delis), and permanent farmers' markets, supercenters		County	Within the unit of analysis	–	–	–	USA	(Cooksey-Stowers, Schwartz and Brownell, 2017)
		Fast food/take-away outlets, convenience stores (bakery, confectionary, dairy shops, service stations)	Supermarkets, fruit and vegetable stores		Census area units	Within the unit of analysis	–	≥0.9		New Zealand	Sushil et al. (2017)
		Fast food restaurants	Grocers		Zip-code	Within the unit of analysis	–		Adjusted for population	USA	Phillips and Rodriguez (2019)

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Table 2 (*continued*)

Type of definition	Measure	Unhealthy food outlets	Healthy food outlets	Other food outlets	Unit of analysis	Distance	Type of distance	Cut-off criteria	Other conditions	Country	Reference
									density and average disposable income and standardized (values range between 0 and 10)		
		Fast food outlets, convenience stores	Supermarkets, grocery stores, fruit and vegetable shops		Residential units, aggregated at the level of dissemination areas (smallest geographic areas for which census data are disseminated)	1000 m reticular zone in urban areas and 16000 in rural areas	Network distances	>4		Canada	Robitaille and Paquette (2020)
		Fast food restaurants, corner stores	Supermarkets, farmers' markets		Schools	150 m	Euclidean distances	≥3.89 (mean across counties in the US)		Guatemala	(Chew, Moran and Barnoya, 2020)
		Convenience stores, dollar stores, and restaurants	Supermarkets, grocery stores, meat markets, farmers' markets, community gardens, farm road stands, food parties		Census tracks	Within the unit of analysis	–	>1		USA	Almalki et al. (2021)
		Fast food restaurants	Open-air organic/ agroecological food markets, supermarkets		Regional administration (subdivision of municipalities according to geographical position and history of occupation)	Within the unit of analysis	–	> median of the municipality (0.332)	Average income of the head of household < the median of the municipality (R $2275) or percentage of black and brown minorities > the median of the municipality (26.9%)	Brazil	(Grilo, Menezes and Duran, 2022)
		Fast food restaurants, convenience stores	Grocery stores, farmers' markets		County	Within the unit of analysis	–	–		USA	Bevel et al. (2023)
		Takeout, convenience stores	Supermarkets		Census tract	1600 m from the tract centroid	Euclidean distances	>4		USA	(Coyle et al., 2023)
Coverage of unhealthy food outlets and ratio of healthy/ unhealthy outlets	Number of service areas around unhealthy food outlets in a specified area and ratio between service	Convenience stores, fast food restaurants	Supermarkets, grocery stores	–	Neighborhoods	1000 m	Network distance	Service areas > top quartile Ratio < median		Canada	(Tu et al., 2022)
		Convenience stores, fast food restaurants	Supermarkets, grocery stores	–	Neighborhoods	1000 m	Network distance	Service areas > top quartile Ratio < median	Low-income rate above the city median	Canada	(Tu et al., 2022)

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Table 2 (*continued*)

Type of definition	Measure	Unhealthy food outlets	Healthy food outlets	Other food outlets	Unit of analysis	Distance	Type of distance	Cut-off criteria	Other conditions	Country	Reference
	areas around healthy and unhealthy food outlets										
Percentage of unhealthy food outlets	100x(Number of unhealthy food outlets)/ (Number of heathy food outlets + Number of unhealthy food outlets)	Fast food restaurants, convenience stores	Grocery stores, full-service restaurants		County	Within the unit of analysis	–	–	–	USA	Phillips and Rodriguez (2020)
Proportion of unhealthy and intermediate food outlets	(Number of unhealthy outlets per square mile + Number of intermediate outlets per square mile)/ Number of all outlets per square mile	Carry-out restaurants, fast food chain restaurants, convenience stores, small grocers/corner stores, unhealthy specialty stores (e.g., candy stores, ice cream parlors), dollar stores, pharmacy chain stores, gas station chains	Healthy specialty stores (e.g., fruit and vegetable markets, fish and seafood market), superstores (e.g., wholesale clubs), supermarkets	Intermediate outlets: full-service restaurants and mixed-specialty stores (e.g., gourmet food stores, juice shops)	Community statistical areas	Within the unit of analysis	–	–		USA	Mui et al. (2017)
		Carry-out restaurants, fast food chain restaurants, convenience stores, small grocers/corner stores, general merchandise stores, unhealthy specialty stores, dollar stores, pharmacy chain stores, gas station chains	Healthy specialty stores, superstores, supermarkets	Intermediate outlets: full-service restaurants and mixed-specialty stores	Community statistical areas	Within the unit of analysis	–	–		USA	(Mui, Gittelsohn and Jones-Smith, 2017)
Proportion of healthy food outlets	100xNumber of healthy food outlets/(Number of heathy food outlets + Number of unhealthy food outlets)	Fast food restaurants, convenience stores	Supermarkets, supercenters		Dissemination areas (smallest geographic areas for which census data are disseminated)	4 km from the centroid of the dissemination area	Road network distances	>0 and < 10	–	Canada	(Luan, Law and Quick, 2015)
		Fast food restaurants, small grocery stores, convenience stores	Supermarket and other grocery stores (except convenience stores), warehouse stores, fruit and vegetable markets		Census tract	Within the tract and a buffer zone of half a mile from the tract boundary	Euclidean distances	>0 and ≤ 9.09 (median)		USA	(Amin, Badruddoza and McCluskey, 2021)

(*continued on next page*)

Table 2 (*continued*)

Type of definition	Measure	Unhealthy food outlets	Healthy food outlets	Other food outlets	Unit of analysis	Distance	Type of distance	Cut-off criteria	Other conditions	Country	Reference
		Fast food restaurants, small grocery stores, convenience stores	Supermarkets, larger grocery stores, produce stores		Census tract	Within the census tract and a buffer zone of half a mile from the tract boundary	Euclidean distances	≥1 and ≤ 4		USA	Cerceo et al. (2023)
	Number of healthy food outlets/(Number of healthy food outlets + Number of unhealthy food outlets)	Fast food, grillroom/ shaorma, delivery, café/restaurant, pancakes, butcher, flans, chocolate, tobacco, drugstore, candy store, warehouse, ice-cream parlor, gas station, night shop, disco, sex/party clubs, theme park, amusement hall, party center, casino, billiard/pool, indoor playground, bowling, zoo, video store, cinema, theater, go cart, amusement/ other, ice skating track, climbing hall, laser game, ski track, swimming pool, sauna	Greengrocer, fish, on farm store, nuts, biostore		Residential areas (1000 m walking distance buffer around the geometric center of gravity of all residential addresses within a census tract)	Within the unit of analysis	Walking/ road distances	–		Belgium	(Smets, Cant and Vandevijvere, 2022)
	Self-reported number of healthy food outlets participants nearby/Self-reported number of healthy and unhealthy food outlets nearby	Supercenter/club stores, convenience/ corner stores, fast-food/limited service establishments, gas stations with foods	Grocery store, farmer's market, full service/sit-down restaurant		Homes	1.6 km (8 km in rural areas)	Self-reported distance	>0 and ≤ 0.368 (median)		USA	Cooksey Stowers et al. (2020)
Proximity to unhealthy food outlets compared to healthy food outlets	Shorter radial distance to unhealthy food outlets/Shorter radial distance to any other type of food outlet	Convenience stores	Supermarkets	Grocery store, corner shop, general store. fresh fruit and vegetable store; red-meat store, poultry store; fish and seafood store; Seeds, spices, and food grains store	Blocks	–	Network distance	>1	–	Mexico	Reyes-Puente et al. (2022)

access (Charreire et al., 2010; Ver Ploeg, Dutko and Breneman, 2015; Gebremariam et al., 2017; Titis, Procter and Walasek, 2022). In the following sub-sections, results for the key elements of the operational definitions of food deserts and food swamps are discussed, and recommendations to advance food environment research are provided.

4.1. Food retail outlets regarded as proxy for healthy and unhealthy foods

Operational definitions of food deserts and food swamps are based on the location of food retail outlets, regarded as proxy for the availability of healthy or unhealthy foods. Most studies assume that large retail stores, such as supermarkets, supercenters and full-service grocery stores, are sources of healthy foods. This criterion overlooks the relevance of other types of outlets selling healthy foods, such as small stores and farmers' markets, which may be particularly relevant in low-income settings and non-WIERD countries (Valdez et al., 2012; Battersby and Crush, 2014; Bridle-Fitzpatrick, 2015; Crush et al., 2019; Metoyer et al., 2022; Farah et al., 2023). In addition, although supermarkets may represent the most frequent source of healthy foods in specific settings, they have also been identified as a major source of unhealthy foods, both in WEIRD (Mackay et al., 2021; Mackenbach et al., 2022; Petimar et al., 2023; Vandevijvere et al., 2023) and non-WEIRD countries (Khonje et al., 2020; Machín et al., 2020; Meza-Hernández et al., 2020; Phulkerd et al., 2023). The rise of supermarkets in emerging regions, such as Asia and Latin America and the Caribbean, has been associated with the nutrition transition and increased consumption of ultra-processed products (Popkin and Reardon, 2018; Huse et al., 2022). In this sense, a recent study has reported a positive association between the increase in supermarket density in Mexican cities and higher blood pressure among adults with undiagnosed hypertension (Armendariz et al., 2022).

Convenience stores and fast-food restaurants have been regarded as stores mostly selling unhealthy foods. Most of the definitions consider both outlets selling packaged foods and prepared foods, whereas others only consider one of the two types of outlets. Convenience stores are not the only type of food outlet where unhealthy packaged foods can be purchased, as discussed above. Regarding fast food restaurants, studies have shown that the nutritional quality of the available foods is not necessarily worse than those offered in full-service restaurants (Auchincloss et al., 2014; Robinson et al., 2018; Liu et al., 2020).

4.2. Measures of access to healthy and unhealthy food outlets

The operational definitions of food deserts and food swamps of the studies included in the literature review have used measures of both availability (e.g., density) and access (e.g., coverage) to food outlets selling healthy and unhealthy foods. For food deserts, access measures based on the distance to the closest healthy retail outlet are the most frequent. These measures are most appropriate to analyze the difficulties experienced by citizens to access to adequate and healthy food. However, it is worth highlighting that no single measure is expected to fully describe the accessibility of food outlets, as previously highlighted by Apparicio et al. (2007) and Charreire et al. (2010).

Food swamps are a relatively new concept, and no operational definition has been used more than once in the scientific articles included in the scoping review. Areas with excessive access to unhealthy foods have been identified based on both absolute, i.e., access to unhealthy food outlets, and relative measures, i.e., relative access to healthy and unhealthy food outlets. These two measures capture different characteristics of the food environment.

4.3. Unit of analysis for the identification of food deserts and food swamps

Another key difference among the operational definitions of food deserts and food swamps was related to the size of the unit of analysis used for the identification of food deserts and food swamps, which ranged from individual households to towns. The consideration of large units of analysis may underestimate the difficulties faced by individual households within the area (Widener, 2018). In addition, restricting the analysis of food access to specific areas may underestimate physical access to food outlets due to boundary effects (Chen, 2017). Despite methodological challenges, food access measures should attempt to consider individual households as units of analysis or at least consider the percentage of households within an area, as currently done by the USDA definition. This approach has already been used by several authors (Lebel et al., 2016; Davies, Frausin and Parry, 2017; Mishra, Sharma and Pani, 2023). Spatial contexts beyond residences deserve further consideration to capture the characteristics of the food environment around other places where people conduct daily activities, such as workplaces and schools (Burgoine and Monsivais, 2013; Andretti et al., 2023a).

4.4. Thresholds for defining proximity to a food retail outlet

The operational definitions of food deserts and food swamps have used a wide range of thresholds for defining proximity to food retail outlets. Some of the studies have relied on purely relative thresholds selected based on the distribution of the data. However, this approach does not ensure that citizens living in the identified areas actually have inadequate access to healthy foods or excessive access to unhealthy food, as previously highlighted by Ver Ploeg et al. (2015).

On the other hand, absolute thresholds to define proximity are largely inconsistent. Some studies have used arbitrary thresholds, whereas others refer to behavioral data to identify central measures of distance or time travelled by consumers when making their food purchases. Studies exploring citizens' perception and food purchase patterns can largely contribute to the definition of objective and context-appropriate criteria to define proximity to retail outlets. In addition, research on how different thresholds influence conclusions regarding the influence of physical access on dietary and health outcomes may contribute to advance food environment research. For example, Iizaka et al. (2020) reported that participants living less than 300 m from the nearest supermarket were more likely to eat fruits almost every today compared to those living 500 m or more.

Different thresholds have been considered for different transportation modes. Although most studies only consider walking distances, others have considered travelling distances for cars, or public transport. Measures based on travel time from individual households to food outlets for different modes of transportation may improve the ecological validity of food access measures. Similarly, walking time measures would benefit from the consideration of walkability and criminality indexes, particularly in low-income settings (Kim and Park, 2020; Lee and Contreras, 2021; Tobin et al., 2022).

4.5. Inadequate physical access to food limited to socioeconomic vulnerable areas

A major difference across operational definitions of food deserts, and to a lower extent, across definitions of food swamps, is related to the inclusion of indicators of socioeconomic vulnerability. Approximately half of the operational definitions of food deserts and four definitions of food swamps were restricted to socioeconomic vulnerable areas. This approach may underestimate the impact of physical access to food in the dietary patterns of other population groups, including low-income populations living in medium-income areas (Ver Ploeg et al., 2012). Citizens not having physical access to healthy food may require additional interest, motivation, and resources to eat healthily, regardless of their income. However, vulnerable populations may have fewer resources to overcome the barriers imposed by physical access to food compared to non-vulnerable populations and therefore may be disproportionately affected. Analyzing the moderating effect of socioeconomic vulnerability on the influence of physical access on dietary and health

outcomes seems a promising way forward. In this sense, Jiao et al. (2012) evaluated physical access to food independently from socio-economic indicators and subsequently presented results for vulnerable populations living in food deserts.

4.6. Recommendations for food environment research

Results from the present work enable to derive a series of key recommendations to advance food environment research. The large number of definitions of food deserts and food swamps available in the literature stresses the need for standardization. Operational definitions of food deserts and food swamps adapted to the context and based on the purchasing habits of citizens in different regions of the world are needed. Such definitions should take into account the complexity of modern food environments, characterized by a wide range of different food outlets selling foods that substantially differ in their healthfulness (Winkler et al., 2020). This may require moving away from the identification of specific types of food outlets as proxy of the availability of healthy and unhealthy foods. Alternative approaches may consider the influence of different types of food outlets on dietary and health outcomes (Recchia et al., 2022) or the consideration of outlets selling specific food groups (Bao et al., 2020). Although this approach may be the most reliable, it requires store audits and therefore may not be feasible for studying food environments at the level of large areas.

The complexity of modern food environments also requires the incorporation of multivariate continuous measures of physical food accessibility. A multivariate and standardized approach is needed to measure access to healthy and unhealthy food outlets. The selection of standardized measures could be informed by qualitative research on how citizens conceptualize physical access to food and make their decisions on where to buy (Mcentee, 2009). Understanding citizens' behaviors regarding the means of transportation most frequently used to purchase food items could contribute to the development of context-based indicators and thresholds of proximity. In the specific case of food swamps, additional research is still needed to identify which measures of access to unhealthy food better predicts behavioral and health outcomes.

All the studies included in the present review have focused on physical food outlets. However, the widespread use of cell phones and social networks, together with the accelerated development of digital food delivery platforms, enable access to a wider range of outlets (Granheim et al., 2022). Food delivery platforms can increase food access by extending the coverage of available outlets in the physical food environment (WHO European Office for the Prevention and Control Noncommunicable diseases, 2021). For this reason, future research should include the digital food environment for the identification of food deserts and food swamps.

4.7. Strengths and limitations

The main strengths of the present work are its novelty and methodological rigor. As far as it can be ascertained, it is the first to provide a systematic and critical analysis of operational definitions of food deserts and food swamps. The review followed international recommendations for conducting and reporting scoping reviews, which increases the reliability of the findings. Based on the results, a series of recommendations to advance food environment research were derived.

The study is not free of limitations. The literature search was performed using only two specific terms: "food deserts" and "food swamps". Although this narrow search strategy was justified due to the focus on operational definitions, the use of broader search terms such as "retail food environment" or "food accessibility" could have led to a larger number of studies. Similarly, the consideration of additional databases and extension to other languages beyond English, Spanish and Portuguese could have increased the body of literature included in the review. Finally, the authors were unable to access the full text of 41 articles. Considering the large heterogeneity in the operational definitions of food deserts and food swamps identified in the review, it is unlikely that the inclusion of additional studies would modify the key results and recommendations.

5. Conclusions

Results from the present scoping review showed that the operational definitions of food deserts and food swamps included in empirical articles published in scientific peer-reviewed journals are largely non-consensual and mainly applicable to WEIRD countries. Results support previous calls for moving beyond simplistic definitions of food deserts and food swamps (Mcentee, 2009; Widener, 2018; De Master and Daniels, 2019). Instead, more objective and multivariate continuous measures of physical food accessibility are needed to reflect the complexity of modern food environments globally. This approach is aligned with the recommendation to avoid dichotomization of predictor variables across disciplines, including spatio-temporal statistics (Irwin and McClelland, 2003; Kyomuhangi et al., 2021).

Funding

Financial support was obtained from Agencia Nacional de Investigación e Innovación (Project No. FCE_3_2022_1_172443), Instituto Nacional de Alimentación (Ministerio de Desarrollo Social, Uruguay), and Espacio Interdisciplinario (Universidad de la República, Uruguay).

CRediT authorship contribution statement

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Declaration of Competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.healthplace.2024.103315.

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