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Childhood obesity, food supply environments and socioeconomic segmentation: Exploring spatial patterns in Chilean cities

Obesidad infantil, entornos de provisión de alimentos y segmentación socioeconómica: Explorando patrones espaciales en ciudades chilenas

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ABSTRACT

This paper explores the determinants and distibution of childhood obesity from a spatial dimension in Chile's six most populated cities. We integrated data bases containing socioeconomic characteristics of households, biometric measurements of grade-school students and locations of food retail outlets. Using Geographic Information Systems (GIS), we created a depiction of urban food provision environments, spatial visualizations of socioeconomic segmentation and neighborhood-level childhood obesity rates which were mapped first separately, and then layered onto each other. City sectors with homogeneous socioeconomic characteristics were clustered into Grouped Socioeconomic Zones (GSZ) and the characteristics of neighborhood food commercial outlets synthesized generating a typology that integrates the distances to supermarkets, produce markets and small stores. Consistent with the literature on childhood malnutrition and its determinants, we found that clusters of obesity are inversely correlated with socioeconomic levels. However, the relation between food supply environments and obesity rates is unclear. In our findings, Chilean urban food retail networks are characterized by their extensive coverage and density. While we observe exhibit high levels of segregation in terms of both socioeconomic levels and childhood nutritional status; GSZ with middle and lower incomes have more proximity to produce markets in ways that suggest access to purchasing points of fruits and vegetables might not be a predictor of nutritional status amongst children. The paper concludes by stressing the importance of including contextual specificity in research design and calls for more research on the determinants of childhood obesity in a diversity of global settings.

Keywords: Childhood Malnutrition, Food Provision Environments, Nutritional Inequality, Global South, Chile.

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RESUMEN

Este articulo explora los determinantes y la distribución de la obesidad infantil desde una dimensión espacial en las seis ciudades más pobladas de Chile. Integramos bases de datos que contenían características socioeconómicas de los hogares, mediciones biométricas de estudiantes de ciclo educacional básico y locación de comercios de venta minoristas de alimentos. Usando Sistemas de Información Geográfica (SIG), creamos una representación los entornos urbanos de provisión de alimentos, visualizaciones espaciales de segmentaciones socioeconómicas y tasas de obesidad infantil a nivel de barrios. Estas se cartografiaron primero por separado y luego superpuestas unas sobre otras. Los sectores de la ciudad con características socioeconómicas homogéneas se agruparon en Zonas Socioeconómicas Agrupadas (GSZ por su sigla en inglés); y las características de los establecimientos comerciales alimentarios de los barrios se sintetizaron generando una tipología que integra las distancias a supermercados, ferias de frutas y verduras y almacenes. Consistente con la literatura de malnutrición infantil y sus determinantes, encontramos que las tasas de obesidad están inversamente correlacionados con los niveles socioeconómicos. Sin embargo, la relación entre entornos de provisión de alimentos y tasas de obesidad son poco claras. En nuestros hallazgos, las redes chilenas de comercios de venta minorista en contextos urbanos son caracterizadas por la extensa cobertura y densidad. Aunque observamos altos niveles de segregación tanto en términos socioeconómicos, como en el estado nutricional infantil; las GSZ con ingresos medios y bajos tienen mayor proximidad a ferias, lo que sugiere que el acceso a los puntos de compra de frutas y verduras podría no ser un indicador del estado nutricional de los niños. El articulo concluye destacando la importancia de incluir el contexto especifico en el diseño de investigación y llama a realizar más investigaciones sobre los determinantes de la obesidad infantil en la diversidad de escenarios globales.

Palabras clave: Malnutrición infantil, entornos de provisión de alimentos, desigualdad nutricional, sur global, Chile.

1. Introduction

From the early 20th century to the present, childhood malnutrition in all its forms has been a major public health concern in Chile. However, the country experienced a rapid nutritional transition, and the focus shifted from undernutrition to skyrocketing childhood obesity rates. The rate of infant malnutrition by undernutrition dropped significantly from 37% in 1960 to under 1% in 2015 (Mönckeberg, 2003). By 2020, 54.1% of children were classified as overweight or obese and there was an unprecedented acceleration severe obesity among school-aged children occurring between 2020 and 2022 (JUNAEB, 2020, 2023). These trends are part of a broader process of modernization of food environments, which included increases in food safety as well as greater accessibility of processed foods.

Research on childhood obesity identifies determinants related to lifestyle decisions and parental responsibility as well as structural factors such as income and educational levels, finding an inverse interrelationship between poverty and obesity. There is also a growing line of research on how spatial factors, including the characteristics of food environments, affect eating patterns in high-income countries. While there is a solid body of research which concludes that childhood obesity is highly concentrated in lower-income populations in upper-middle income countries such as Chile, less is known about the opportunities for food acquisition in residential neighborhoods. Do the urban poor have less or worse food access? Are there differences in ratio of super-

markets, small stores and produce markets in neighborhoods of different incomes and can these account for differences in nutritional outcomes?

This paper explores the spatial dimension of differences in urban food provision environments, their segmentation across spatial and index (SEI), and their relationship to neighborhood childhood obesity rates. To do so we organized and mapped socioeconomic segmentation, neighborhood-level childhood obesity rates and created spatial depictions of urban food provision environments based on the location of food retail outlets. Each of these elements was mapped separately and then layered onto each other. While the findings cannot account for the nature of the relationship between food environments and their determinants, they do shed light on the unique characteristics of food supply environments in urban Chile. In the next section we briefly review the state of the art on the topic and case and then move on to present our data, analysis, findings and conclusions, highlighting the contributions and limits of this research.

2. Theory

In recent decades, childhood obesity has increased considerably in upper-middle and middle-income countries (NCD Risk Factor Collaboration, 2017; Popkin 1999, 2001). In the discussion about the drivers of this increase in childhood obesity there is a tension between explanations involving parental choices and within-family variables such as sedentary lifestyles, eating habits and parental body mass index (BMI) (Trapp et al., 2015; Davison & Birch, 2001; Parsons et al., 1999); and structural factors that focus on the correlations between socioeconomic variables and nutritional status (Dinsa et al., 2012; Marteleto et al., 2018; Ranjit et al., 2015).

The literature specific to the Chilean case follows the same investigative tendencies and hypotheses have documented the inverse correlation between socioeconomic level and body mass index (Herrera et al., 2017; González-Zapata et al., 2017) and been concentrated in frameworks where childhood obesity is a consequence of lifestyle choices (Díaz-Martinez et al., 2018; Garrido-Mendez et al., 2017; Olivares et al., 2007). Longitudinal analyses examined shifts in consumption patterns (Crovetto & Uauy, 2014; Llorca et al., 2020), contextualizing these as part of the worldwide nutritional transition (Celis-Morales et al., 2017; Popkin & Reardon, 2018; Uauy et al., 2001). Some studies attempt to bridge individual, within-household, and structural determinants (Azar et al., 2015; Salinas & Goldsmith Weil, 2020; Ranjit et al., 2015) and structural determinants.

There is also a growing interest in the socio-spatial characteristics of food environments. These have explored spatial variation of food consumption (Morrison et al., 2011); cases with a focus on specific vulnerable groups (LeDoux & Vojnovic, 2014; Li & Ashuri, 2018); accessibility to types of food supply by proximity (Eckert & Shetty, 2011; Horner & Wood, 2014) and engaged clustering techniques to assess food supply typologies and access (Leslie et al., 2012; Cervigni et al., 2020; Garcia et al., 2020). Research on socio-spatial segregation has described how neoliberal dynamics have conditioned access to housing and urban services (Orellana et al. 2012), deepening inequality with auto-segregated high-income peripheries and marginalized peripheries that concentrate the lowest SEI households, conditioning access and modes of use of urban services (Encinas et al., 2019; Hidalgo et al., 2016; Vergara-Perucich, 2021).

A common element in much of research on food environments is the emphasis on *food access*, which was initially measured as the distance to the nearest supermarket or large grocery store (USDA, 2009). Communities with insufficient access were labeled as *food deserts* – defined as "low-income areas in which healthy food are expensive, of poor quality or inaccessible and therefore contributing to rising rates of obesity and diet-related chronic diseases" (Shannon, 2014); and this notion was widely discussed in policy designs.

The concept of food desert and hyper-focus on proximity has received criticism for oversimplification and Widener (2017) suggests including considerations of accommodation (type of payment), affordability and accessibility. This notion is further challenged by alternate food environment prototypes such as *food swamps*, where it is the overabundance of consumption opportunities in particularly of calorie-dense foods, that inhibits healthy eating patterns (Bridle-Fitzpatrick, 2015). A third categorization is that of *food oasis* described as a sparsely populated food retail environment which protects against impulse purchases and provides a "cooler decision environment," and is therefore more conducive to healthy eating patterns (Bridle-Fitzpatrick, 2015); or alternately as a territory with the best possible access to fresh foods (Gónzalez-Alejo et al., 2015). This line of research examines the specific roles played by different supply categories, such as local grocery stores (Raja et al., 2008; Yang et al., 2020) or supermarkets (Larsen & Gillilan 2008; Barnes et al., 2016), and access constraints, including the longer distances in rural areas (McEntee & Agyeman, 2010; Hubley, 2011; Mulrooney et al., 2017) and store hours (Glanz et al., 2005; Chen & Clark, 2013).

While the bulk of this research took place in cities of upper-income countries, an emerging research agenda has embarked on an exploration of Latin American food environments. Examples include case studies in Mexico City which identify food deserts and swamps (González-Alejo et al., 2019; Bridle-Fizpatrick, 2015); analyses on the effects of types of food supply on female obesity in urban Brazil (Backes et al., 2019); the relation between fast-food environments and increased chances of being in the over-weight category amongst adolescents (Nogueira et al., 2020); mapping food retail in residential areas with high and low obesity prevalence (Mendes et al., 2019); and the impact of the density of healthy and unhealthy food outlets alongside income on fruit and vegetable intakes (Pessoa et al., 2015). This literature has employed heterogenous methodological approaches without a generalized consensus on appropriate measurements of distances and category (González-Alejo et al., 2019; Križan et al., 2015). In conjunction, these works instruct us on the importance of being deliberate about methodological decisions such as the inclusion of traditional types of commerce in dialogue with case particularities, as well as carefully laying out assumptions, data sources and methods, as we will do in the following section.

3. Data and case background

The analysis includes Chile's six most populated cities, which according to the latest available census data jointly house 52.4% of the country's population (INE, 2018). These are: Santiago Metropolitan Area (SMA; pop. 6,119,984); Concepción Metropolitan Area (CMA; pop. 972,285); Valparaíso Metropolitan Area (VMA; pop. 951,311); La Serena – Coquimbo Conurbation (LCC; pop. 448,784); Antofagasta (AN; pop. 361.873); and Temuco (TM; pop. 358,541). SMA is the capital and most populated city, concentrating approximately one third of the country's population. Except-

ing a few central districts, residential areas are highly segregated by socioeconomic status (SES) with the high-income population concentrated in the eastern part of the city. CMA is a conurbation between Penco (referred to colloquially as Old Concepción) and the Bío-bío River. VMA is a coastal city with a morphology defined by its hills. It hosts the country's historic port and is close to Santiago – 120 km by road. LCC is a coastal city resulting from the conurbation of two cities, the regional capital and its port. It marks the beginning of the Atacama Desert (from south to north). AN is a coastal city and the most populated Chile's arid north. It boasts high levels of economic activity related to mineral (mostly copper) mining in the region. TM is the most populated city south of CMA. It located on a central plain between the Andes and coastal mountains, and its surroundings characterized by temperate forests. It is the capital of the region which concentrates the highest proportion of indigenous population in Chile.

Table 1 sums up the data and sources utilized. Following that table, we provide a brief description of each variable including specifics on how data can be attained, variable construction and discussion of case particularities and assumptions.

Table N°1

Variables and Data Sources

Variable	Description	Data points	Indicator	Data Source
Childhood Obesity	Biometric measurement of children attending educational centers that receive public financing.	45,649 measurements in 1,857 schools.	Percentage of children with obesity from the total measured in the schools of the corresponding GSZ.	Junaeb, Ministry of Education.
Household Socioeconomic Index (SEI)	Socioeconomic classification of the household defined according to census variables of education level and housing characteristics.	3,023,874 households classified according to their socioeconomic status (SES)	Average socioeconomic classification of households in the GSZ.	GfK Chile.
Neighborhood Food Provision Environment	Georeferenced commercial outlets aimed towards household food acquisition and provision.	924 Supermarkets, 484 Produce Markets and 23,435 Neighborhood Grocery Stores.	Average distance of households in the area to the nearest supply (by type) in the GSZ.	GfK Chile, ASOF C.G.

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GFK data for supermarkets and neighborhoods grocery stores. It is based on open-source Census and Casen surveys as well as market research and was lent to researchers by GFK in the format of written consent[3]. ASOF[4] and Junaeb data bases are public and open-sourced; available at https://www.junaeb.cl/mapa-nutricional.

[3] GfK is a German market research company. The data base was selected because it provides the opportunity to explore the spatial dimensions of the socioeconomic distribution of cities at the neighborhood level with more precision than public databases open to the general public. One of the authors collaborated with its construction and knows it well. The information was lent to researchers by GFK in the format of written consent. A copy of this consent can be added as an annex if the editors so decide.

[4] Produce markets belonging to National Union of produce, flea and similar markets collected in an ODEPA data base which includes the location, length and frequency of each market. http://asof.cl/apps/mapaferias.

Neighborhood Food Retail Environment:

Given the focus in this paper on food provision for within-home food environments, we included retail mainly geared towards weekly food shopping and excluded retail primarily targeted towards the sale of prepared foods. Building on the theoretical typology of food environments in Chile proposed by Gálves et. al (2018), this would correspond to the "acquisition" category, which is differentiated from the restaurant and public space environments.

Our analysis does not include food distributed through the "institutional food environment" (Roseco et al., 2016) which include government programs that were key in eradicating infant and childhood undernutrition in the 20th century; for example, school lunches and milk distributed at neighborhood health clinics (Goldsmith Weil, 2019; Goldsmith Weil & Olivares, 2022). It also does not include curb-side kiosks which in Chile can sell everything from ultra-processed snacks to local produce. Moreover, it excludes informal commerce such as roadside stalls, ambulatory sellers, travelling produce trucks nor the virtual food supply including delivery services and purchases made through apps. The inclusion of these would present methodological complexities beyond the scope of this study.

It should be noted that food sales in in Chile are governed by anti-obesity Law 20.606, passed in 2015, which mandates the placement of frontal warning labels on foods high on critical nutrients (calories, sugar, sodium, saturated fats) and bans the sale of these within schools. A few municipalities have layered a ban of the sale of these foods within a radius of 100 to 200 meters around schools (González-Hidalgo et al., 2021), though it is worth noting that these bans are in practice unenforceable.

In terms of the categories proposed by Widener (2017), the maps include data on proximity, and in the following section we briefly introduce each type of outlet in terms of accommodation, affordability and accessibility.

i. **Supermarkets:** In this paper, we use the operationalization proposed by The National Institute of Statistics and Economic Studies of France (INSee), which defines supermarkets as non-specialized self-service retail outlets with a sales area over 200m2 and more than two thirds of its turnover consisting of foodstuffs[5] and 15-minute average walking time as a first cutoff for proximity[6].

   While part of a more general trend towards supermarketization in Latin America, Chile is an outlier in terms of supermarket extension. Furthermore, ownership has become highly concentrated integrating and globalizing logistical and production chains to the extent that by 2011 only six major food retailers jointly controlled 92.5% of market shares (Arboleda, 2020). The location of supermarkets is for the most part determined by their potential profit with low levels of state-led urban planning. In terms of availability, accessibility and

[5] INSEE. Définitions, méthodes et qualité en: https://www.insee.fr/fr/metadonnees/definition/c1825 consultado el 21 de marzo de 2023

[6] Designations of what may be considered an "acceptable" distance to a food source vary in the literature. The 15 minutes walking time" parameter "is based on the concept of "15 minutes city" introduced in Paris in 2016 and prominent in the Smart Cities literature as part of the principle of "chrono-urbanism" where the quality of life in cities varies according to proximity to services (Moreno et al., 2021; Weng et al., 2019). In alignment with other work on Chile for the city of Concepción (Zazo-Moratalla & Napadesky, 2020, Zazo-Moratalla et al., 2019, 2023), 15-minute walking time was our chosen cutoff for proximity.

accommodation; supermarkets have extended hours and function on both weekdays and weekends, accepting payment via credit and debit cards.

ii. **Neighborhood Grocery Stores:** neighborhood scale food commerce, including butchers, greengrocers and bakeries and traditional *almacenes*. Almacenes are small shops that sell assorted groceries usually including a small produce section, basic staples, fresh bread and ultra-processed shelf-stable foods. They are often tended to by their owners and have variable hours, sometimes making after hours sales from behind metal security curtains. It is possible to purchase items in small amounts such as single eggs, tea bags, bouillon cubes, diapers, analgesics by the tablet, cigarettes, toys and stationary items. Local grocery stores play an essential role increasing food accessibility within neighborhoods (hours, informal credit and small purchases), especially those of lower socioeconomic levels which are more dependent on these outlets.

   Liquor shops (*botillerías*) and franchised convenience stores have been excluded from this analysis. These last are relatively new to Chilean food environments. They offer a selection of prepared individually wrapped portions and are concentrated in Central Business Districts (CBD) and in the vicinity of bus and train stations. They are likely to stock less ingredients to prepare family meals as they primarily target commuter populations.

iii. **Produce Markets:** Traditional free-standing fruit and vegetable markets (*ferias libres)* set up on curbs and sidewalks on an once or bi-weekly basis consisting of several or hundreds of vendor stalls. Ferias libres are critical to Chile's food systems (Kanter & Boza 2020), and according to the Research and Agrarian Policies Office of the Ministry of Agriculture (ODEPA) 2013 analysis 70% of the fruits and vegetables traded are through these curb-side markets where they are sold at significantly lower prices than in supermarkets (Silva et. al, 2021).

   Stall vendors generally purchase their wares from wholesalers or agricultural mediators and might have stalls in several locations on different weekdays. Only a small proportion of these can be adequately labeled "farmers markets" which offer higher ratios of local products and foster a connection to local production (Zazo-Moratalla and Napadensky-Pastene, A 2020; Zazo-Moratalla et al., 2019)[7].

   In terms of accommodations, these traditionally require on-site cash payments on site, though we have observed increasing move towards accepting digital bank transfers and card options. While they rank highest on affordability, they also rank low on accessibility. Produce markets are usually open only throughout the mornings and early afternoons. Of the 473 produce markets analyzed here: 212 are available one day p/week, 237 twice a week, seven three days p/ week and only 17 operate all week.

Childhood obesity:

Chile's National Council for School Assistance and Scholarships (JUNAEB) produces a Schoolchildren Nutritional Map (first wave in 2007) which is applied at public or partially publicly funded

[7] For example, according to on-site observations, in the city of Concepción, only 4 of the 32 produce markets (12.5%) were effectively farmers (known in Chile as *mercados campesinos*) (Zazo-Moratalla & Troncoso-González 2019).

schools in Pre-K, Kindergarten, 1st grade and their freshman year of high school[8]. It is based on biometric (height-weight) measurements which are organized by BMI into five nutritional categories: underweight, normal-weight, overweight, obese and severe obesity.

For this analysis, we used measurements taken from 1st grade children 2018. These included measurements of 45.649 first graders (mostly 6-7 years old) attending 1.857 public or state-funded schools, of which 74% live within our selected cities. The JUNAEB nutritional census does not include measurements for students at private educational establishments (329 of the 2,444 primary schools in the analyzed six cities, 13.5%), which means that our data is less precise for highest income groups. The obesity rates include the nutritional categories of obese and severe obesity.

This analysis assumes that families generally live and shop near their respective schools. This assumption is more likely to hold for primary school than for secondary school, where a larger group of students will commute longer distances for school[9].

4. Analysis

In this section we present the processes of creating grouped socioeconomic zones, integrating data into the spatial dimension and grouping food provision environments into a typology.

4.1 Constructing grouped socioeconomic zones (GSZ)

The aggregate six cities included 2.604 census polygons or zones. A household socioeconomic index (SEI) was assigned for each of these, and then scaled to obtain 168 city sectors with homogeneous socioeconomic characteristics (GSZ).

Household socioeconomic index (SEI): The Socioeconomic index was created by the Association of Market Researchers (AIM Chile)[10] based on data from the 2017 Population and Housing National Census and the National Socioeconomic Characterization Survey (CASEN)[11]. Census data is available at the household level and includes: housing materials, educational level of heads of household and overcrowding. Income, which is not asked in census, was estimated using the CASEN. The SEI is the result of multiple linear regressions which were weighted according to Chile's National Statistical Institute's methodological guidelines for creating socioeconomic proxies[12] in order to make an estimation for each household.

Grouped Socioeconomic Zones (GSZ). These are the basic spatial units for this analysis.

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[8] Data is open-access and available at: https://www.junaeb.cl/mapa-nutricional .

[9] While Chile has a voucher system for public schools that permits households to apply to institutions beyond their neighborhoods, there are practical complications that restrict school choice. For more on school transport experiences and. determinants of School choice in Santiago, see: Tiznado-Aitken et al., 2021 and González-Espejo et al., 2022.

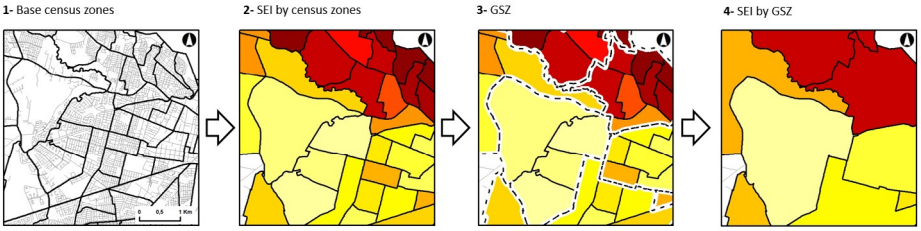
[10] One of the authors collaborated with its construction and information was lent to researchers by GFK in the format of written consent.

[11] Conducted every two years surveying over 50,000 households. "Caracterización Socioeconómica Nacional, Casen" http://observatorio.ministeriodesarrollosocial.gob.cl/encuesta-casen

[12] *Instituto Nacional de Estadístico) https://www.ine.cl/inicio/documentos-de-trabajo/documento/estratificaci%C3%B3n-socioecon%C3%B3mica-del-marco-muestral-de-viviendas-2017*

Figure N°1

Process of elaboration of Grouped Socioeconomic Zones (GSZ)



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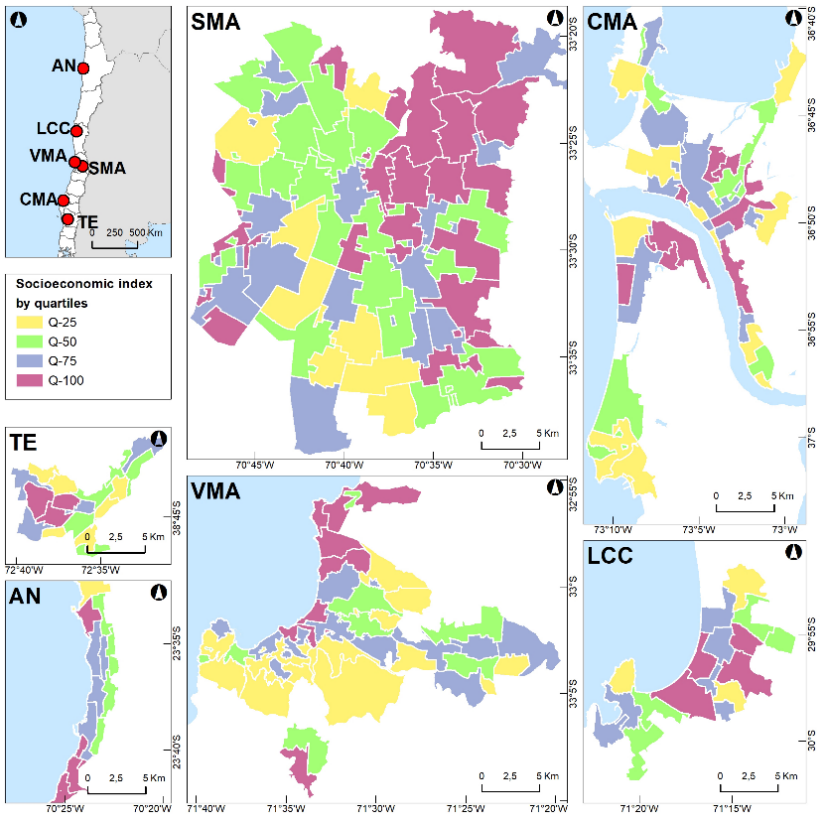
Process for elaboration of GSZ: (1) Starting with the national census geographical data base (INE, 2017); (2) Socioeconomic index (SEI) was estimated for each census zone using the average index of all households in the censal zone; (3) Census zones were grouped according to socioeconomic level and proximity to each other, by geographic clustering with the use of GeoDa software; (4) We obtain the definitive spatial units for the analysis, which have been defined as Grouped Socioeconomic Zones (GSZ) with their own SEI.

Figure N°2

Maps of socioeconomic indexes (categorized by quartiles) for GSZ in the main cities[13] of Chile



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[13] From top right to bottom left, these are Santiago Metropolitan Area, Concepción Metropolitan Area, Valparaíso Metropolitan Area, La Serena-Coquimbo Conurbation and Temuco.

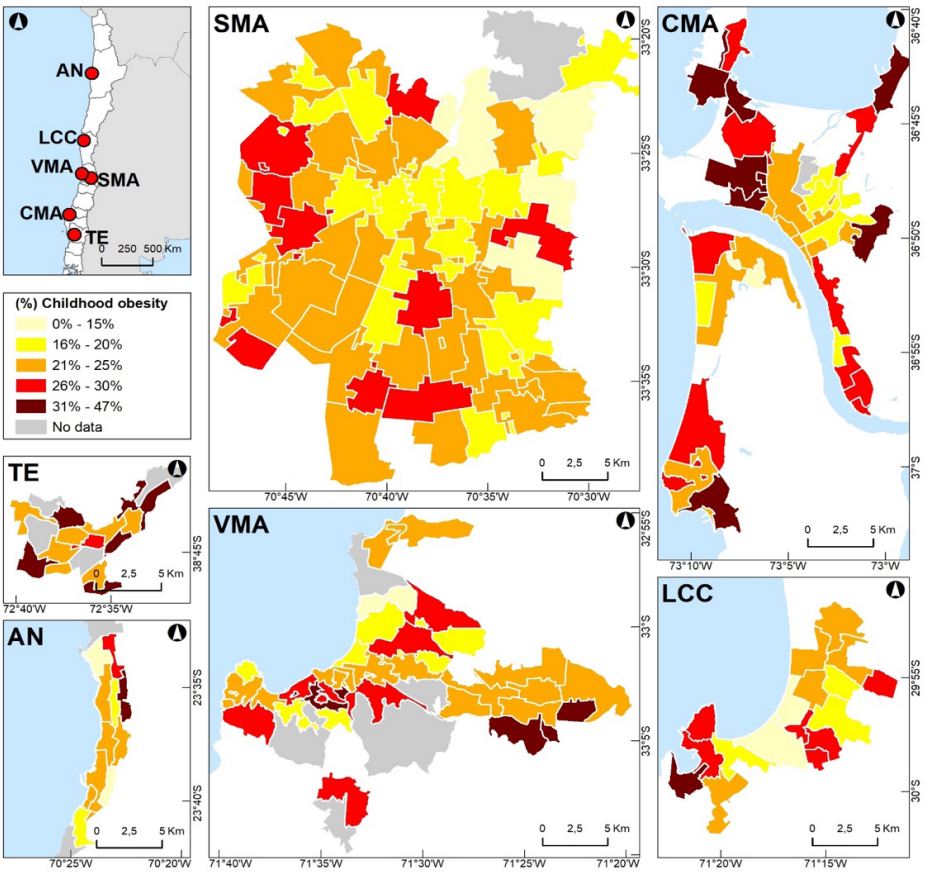
Within each city, GSZs were divided into city-level economic quartiles in ascending order, Q-25 to Q-100, with this last concentrating the highest incomes.

4.2 Georeferencing childhood BMI and food supply data

Junaeb BMI measurements were georeferenced according to school location (figure N° 3). The green dots represent schools with at least three measurements at the first-grade level and the yellow those with less than three biometric measurements (figure N°4). These last were considered insufficient to be representative and discarded from the analysis.

Figure N°3

Prevalence of childhood obesity by city[14]



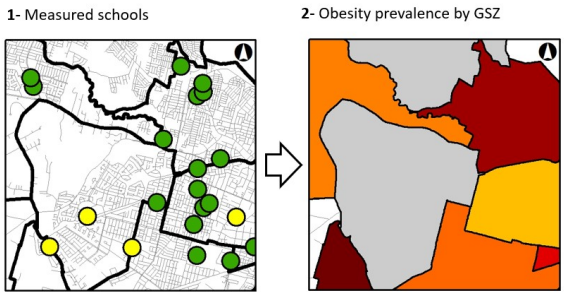
Prepared by authors

[14] From A to E; these are Santiago Metropolitan Area, Concepción Metropolitan Area, Valparaíso Metropolitan Area, La Serena-Coquimbo Conurbation and Temuco.

These were then georeferenced with schools' corresponding overlaid GSZ. The childhood obesity prevalence for each GSZ was obtained by calculating the proportion of measured first graders with obesity over the total of measured first graders for each GSZ (figure N° 4).

Figure N° 4.

Process of Spatialization of Childhood Obesity Rates (GSZ)



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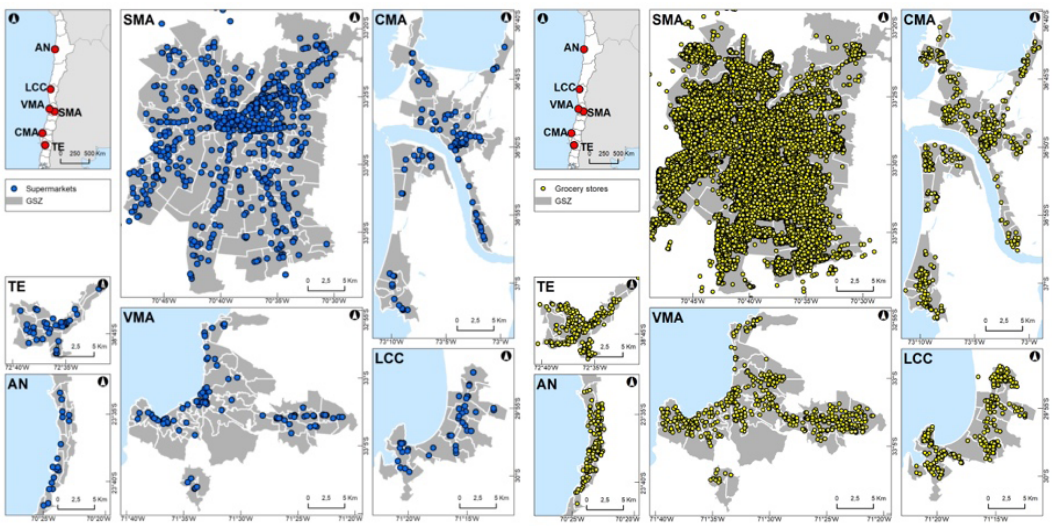
The following three figures show the location of grocery stores (figure n° 5), neighborhood grocery stores (figure n° 6) and produce markets (figure n° 7).

Figures N° 5-7:

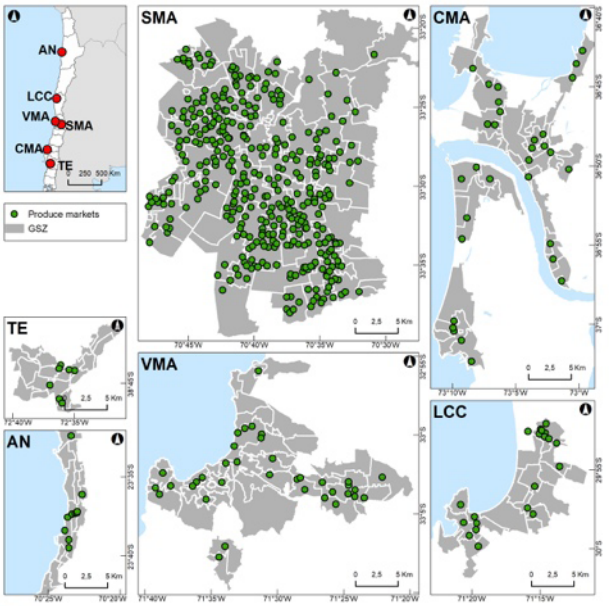
Georeferenced food supply by type:

N°5:
Supermarkets

N°6:
Neighborhood grocery store



N°7:
Produce Market



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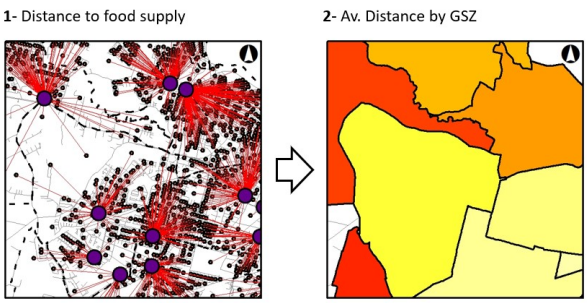
As can be observed, neighborhood grocery stores are most prevalent. In case of supermarkets, we can see that they are grouped in central areas of cities.

4.3 Calculation of distance and creation of food provision typologies

Neighborhood food provision environment: Opportunities for food acquisition within or close to GSZs. It was estimated with the average distance to each of the three categories included (supermarkets, neighborhood grocery stores and produce markets) per GSZ. This was calculated with ArcMap network analysis through the road network. The food outlet databases were georeferenced and the distances from each census block to the nearest supply point were calculated. The value assigned for the GSZ corresponds to the average of the distances of all the households within it.

Figure N°8

Calculating average distance to food supply



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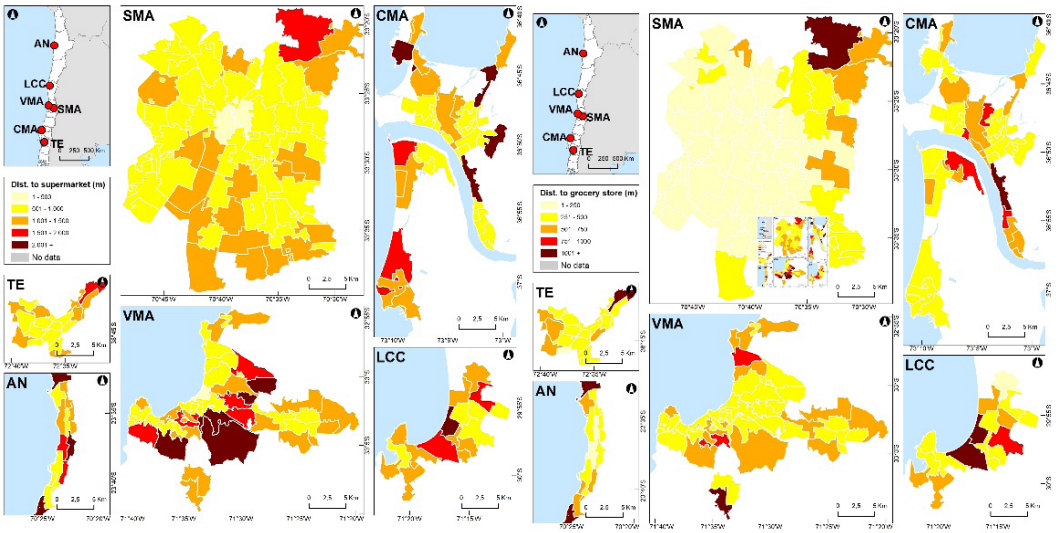
Figures N° 9-11 sum up the average distance to supermarkets, neighborhood grocery stores and produce markets (left to right) where less distance signifies a greater presence of that kind of food supply (higher coverage).

Figures N°9-11:

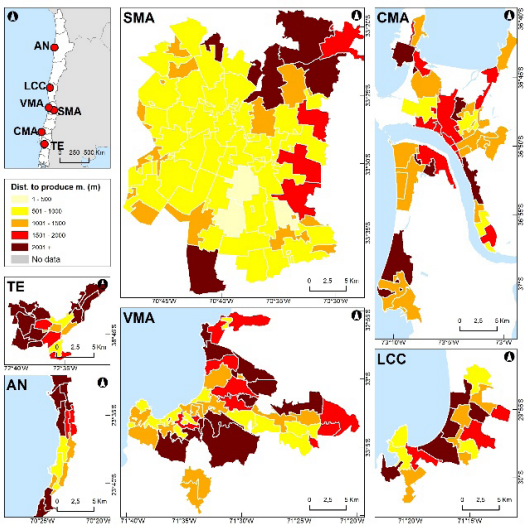
Average Distance to Food Supply by GSZ

N°9:
Supermarkets

N°10:
Neighborhood grocery stores



N°11:
Produce Markets



Prepared by authors

Based on the estimated proximity to food provision variables, a K-median clustering was elaborated to obtain a synthesis of the *Neighborhood Food Provision Environments*. These integrate

the distances to the three food supply categories: supermarkets, neighborhood grocery stores and produce markets.

Walking speed was calculated as 5 km/h[15], which approximates a standard reference. Distances were calculated according to their pathways on the urban grid layer using SIG network analysis. Four different types of food supply environment emerged from the process of clustering (Table n°2) and all types are present in each of the six cities.

Table N°2:

Characteristics of food supply typologies (by cluster centroids)

Type	Supermarket proximity (Average meters)	Produce market proximity (Average meters)	Grocery store proximity (Average meters)
Type 1: Most proximate food supply	753**	794**	180*
Type 2: Supermarkets within walking distance	901**	1549***	480**
Type 3: Produce markets within walking distance	1,350***	1042**	350*
Type 4: Least proximate food supply	1,491***	3,127***	700**

* within 5 minutes walking distance at a speed of 5 km p/hour

** within 15 minutes walking distance

*** over 15 minutes walking distance

Prepared by authors

Type one presents the best indicators of accessibility, with all categories within a walking distance of 15 minutes or less. Type two maintains similar accessibility to supermarkets but has a greater distance to produce markets and local grocery stores. Type three is within 15 minutes to produce markets and local grocery stores but has a greater average distance to supermarkets. Finally, type four presents the greatest distances to all types of food provision opportunities, having only neighborhood grocery stores within 15 minutes average walking distance.

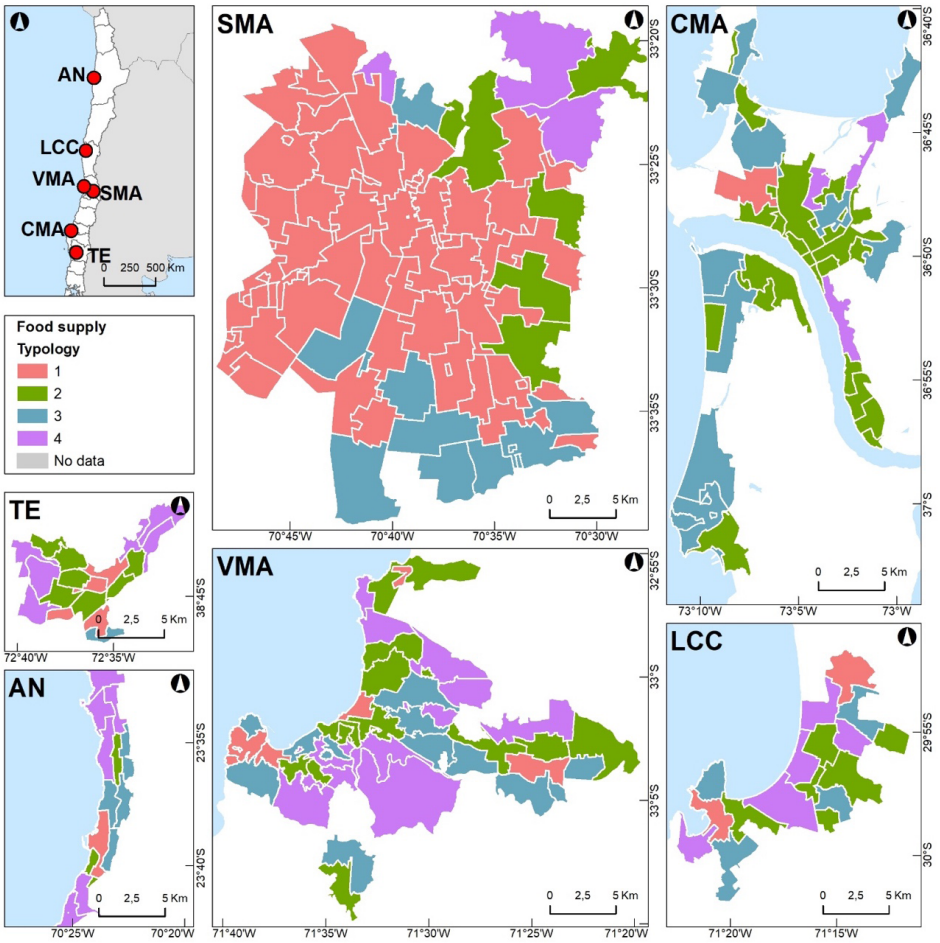
4.4 Characterizing Food Environments

In order to characterize the food environments within each city, we integred the typologies by GSZ for each city.

[15] Browning et al (1985) found an average walking speed of 1,42m/s across groups of different sex and levels of obesity. This translates to 5,1 km/h. In order to simplify, this was rounded off at 5 km/hour in this study.

Figure N°12[16]

Food environment supply types according by GSZ



Prepared by authors

As can be observed, SMA concentrates the bulk ot type 1 food envoronmments (more access and most proximate. In other cities, type type 2 are prevalent in central area and type present in CBD, type while in more residential area we find types 3 and 4 in city peripheries.

[16] From A to E; these are Santiago Metropolitan Area, Concepción Metropolitan Area, Valparaíso Metropolitan Area, La Serena-Coquimbo Conurbation and Temuco.

5. Results

Key indicators are summarized in table n° 3, where cities are listed from north (AN) to south (TM).

Table n° 3:

GSZ summary values of the variables by city

Ciudad	Number of zones	Childhood obesity percentage (%)		Socioeconomic level (index)	Distance to supermarkets (meters)			Distance to produce markets (meters)			Distance to neighborhood grocery stores (meters)		
		Avrg	Std dev	Avrg	Mín	Avrg	Max	Mín	Avrg	Max	Mín	Avrg	Max
Antofagasta (AN)	14	20,4%	6,74%	56	641	1.595	4.391	788	2.648	6.419	238	982	3.931
La Serena – Coquimbo C. (LCC)	16	22,8%	5,77%	53	573	1.205	2.211	753	1.778	3.410	241	606	1.723
Valparaíso M.A. (VMA)	36	23,5%	5,01%	51	454	1.297	3.395	756	1.679	3.846	263	521	1.468
Santiago M.A. (SMA)	56	21,2%	3,90%	55	358	922	1.913	477	1.171	10.006	106	254	1.365
Concepción M. A.. (CMA)	29	26,5%	6,19%	50	689	1.259	2.304	643	1.501	3.021	294	539	1.102
Temuco (TM)	17	28,9%	7,94%	48	530	937	1.541	787	2.676	5.913	249	452	1.187
Total	**168**	**23,40%**	**6,04%**	**52**	**358**	**1.145**	**4.391**	**477**	**1.670**	**10.006**	**106**	**475**	**3.931**

Prepared by authors

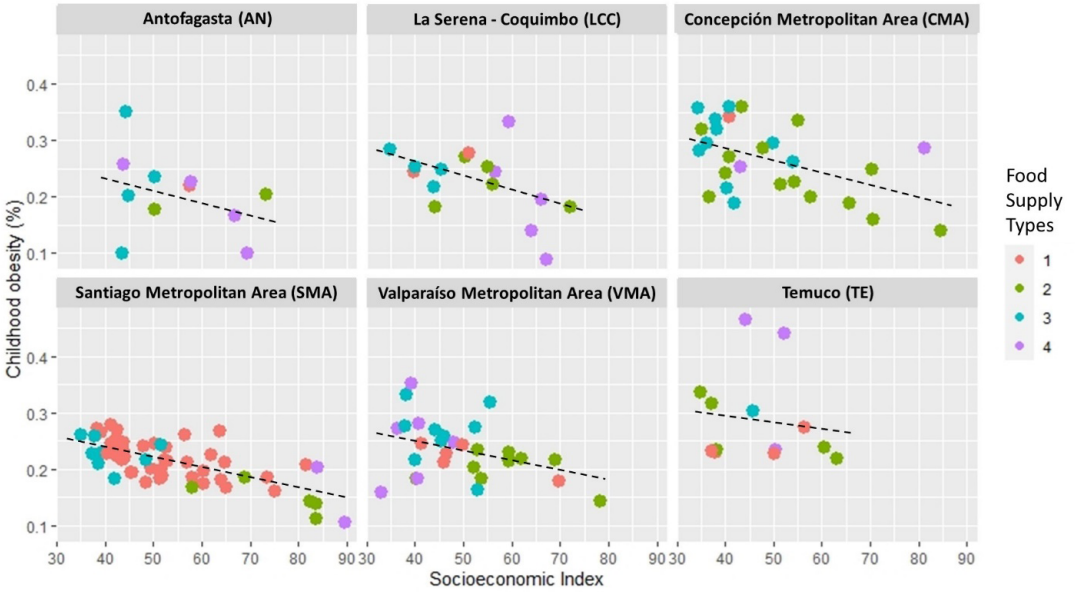
Regarding the SEI, SMA concentrates the GSZ with the highest SEI in the country. SMA and AN have the highest average values, without being exempt from the presence of GSZ with low levels.

Distribution of proximity to food supply points has similar ranges amongst the cities. Minor differences include greater on average proximity to supermarkets in SMA and TM; longer on average distance to produce markets in AN and TM and greater proximity to neighborhood grocery stores in SMA.

Childhood obesity has an overall average of 23.4% and ranges from a prevalence of 9% to a 46.7% p/ GSZ. The northernmost city (AN) shows the lowest indicators of obesity, while the southern cities (CMA and TM) have the highest indicators. The spatial distribution of childhood obesity at the GSZ scale (figure n° 3) shows a tendency to more extreme levels, both high and low, in the peripheries of the cities. In contrast, the inner-city environments where CBD are concentrated have values closer to the city average.

With regard to the typology of food provision environments, figure N° 13 is a synthesis of the reviewed variables, including the relationship between childhood obesity (horizontal axis) and the socioeconomic index (SEI) (vertical axis). It shows the spatial distribution of the supply typologies assigned to each zone in each of the cities studied, according to the K-median clustering based on the variables of proximity to food provision by type of establishment, obtaining a synthesis of the food supply configuration according to their proximity for each GSZ.

Figure N° 13.
Synthesis of the relationship between childhood obesity, socioeconomic index and supply typology by city.



Prepared by authors

Types 1 and 2 are distributed somewhat homogenously across SEI with some concentration of type 2 (walking distance supermarkets) in high income GSZ. Types 3 and 4 tend to be concentrated in low to middle socioeconomic sectors, with some exceptions of type 4 which are located in highest income GSZ.

A summary of results at the city-level is provided in table N° 4.

Table N°4
Description of results by city

City	General description	Socioeconomic – childhood obesity relation	Food supply typology – childhood obesity relation
Antofagasta (AN)	Compact city with a dense center. High SEI sectors concentrated preferentially in the extreme south and segregated neighborhoods towards the eastern periphery of the city.	Among GSZs with lower SEI there are high and low extremes of obesity prevalence. The higher the SEI, the lower the childhood obesity.	No clearly identifiable pattern childhood obesity across types.
La Serena - Coquimbo Conurbation (LCC)	Conurbation of two cities with high SEI population in lower density spaces at the intersection between the two urban centers, and segregated neighborhoods at the northern and peninsula poles.	GSZ with the highest prevalence of childhood obesity are neighborhoods with lower SEI, but not the most segregated.	Higher prevalence of type 3, although type 4 (least proximate food supply) has the values at both extremes of prevalence in the city.

City	General description	Socioeconomic – childhood obesity relation	Food supply typology – childhood obesity relation
Valparaíso Metropolitan Area (VMA)	Metropolitan city with a main center at the coastal intersection of Viña del Mar and Valparaíso. High SEI neighborhoods are located preferentially to the north and low SEI neighborhoods are located further from coast.	GSZs with the highest prevalence of childhood obesity are neighborhoods with lower SEI, but not the most segregated in terms of wealth. Lower prevalence in high-income GSZs.	Higher childhood obesity prevalence in types 3 and 4, although extremely low obesity also present in some type 4 GSZ. Types 1 and 2 with steadily low prevalence.
Santiago Metropolitan Area (SMA)	Metropolitan city with a main center and multiple sub-centers. Marked high SEI sector to the northeast of the city and lower-income neighborhoods to the south and west of the city. Most densely populated food supply environments.	GSZs with the highest prevalence of childhood obesity are segregated neighborhoods with low SEI. Lower prevalence in high-income GSZ.	Type 1 (most proximate) is the most prevalent, but with no visible trend in its relationship with SEI. Higher prevalence in type 3 food supply (Walking distance to produce markets), and lower in types 2 and 4.
Concepción Metropolitan Area (CMA)	Metropolitan city composed of varied urban centers interconnected towards a common center, from which to the south high SEI neighborhoods are located and low SEI neighborhoods tend to be scattered in the peripheries.	Lower SEI GSZs have the highest prevalence of childhood obesity.	Disperse distribution of childhood obesity across food supply types.
Temuco (TM)	Compact city with higher number of lower SEI neighborhoods in the pericenter and higher income households to the east.	High level of generalized childhood obesity.	Extremely higher prevalence in GSZ with type 4. In type 1 childhood obesity has the lowest values in the city.

Prepared by authors

6. Discussion and Conclusions

Based on our analysis of Chile's six most populated cities, we found that consistent with findings in national-level literature, childhood obesity is higher in the southern areas of Chile (JUNAEB, 2020; FAO et al., 2020), with greater prevalence of childhood obesity in the cities of TM and CMA. These more southern cities also have a lower average socioeconomic index, which is consistent with the inverse correlation between socioeconomic level and childhood obesity seen in much of the world and case-specific literature. It should be noted that the highest socioeconomic sectors are under-represented in this analysis (329 of the 2,444 primary schools in the analyzed six cities, 13.5%). However, greater access to extracurricular sports, green areas (Fernández, 2022), as well as possibilities for either paid domestic support or more time for family members to dedicate to food acquisition and preparation lead the authors to intuit the inverse relationship between SEI and BMI persists.

In terms of access to produce markets: GSZ with middle and lower incomes have more proximity to produce markets where fruits and vegetable are available at the best prices. This finding

destabilizes hypothesis surrounding the notion of food deserts, where it is the lack of availability of healthy foods located in low-income neighborhoods that drives childhood obesity, at least for the Chilean cities analyzed here. In fact, 57% of GSZ in lowest income Q-25 and 67% in Q-50 are located within a 15m walking distance to produce markets. This descends in GSZ with higher incomes to only 19% in GSZ of the highest quartile, which has an average distance to produce markets which is considerably larger (2000m). In the capital (SMA), which concentrates about a third of the country's population and has the most proximate access to produce markets: 100% of Q-25 and Q-50 GSZ have a produce market located at less than 1250 meters from their homes. This number is 85% and 41% in Q-75 and Q-100 GSZ respectively. This does not mechanically translate to a context where urban residents always have the resources to make purchase at produce markets, where payment is for the most part cash only and which have limited schedules. This is particularly significant in the context of high levels of indebtedness to buy basic goods of Chilean families (Han 2012, García 2019).

Residents have an average distance of only 1145m from homes to supermarkets. Middle-income sectors have the most proximate access: 69% and 83% of GSZ in second and third quartiles are within walking distance with the least proximity in Q-25 (45%). Differences are more pronounced in the capital Santiago where access under 1250m is 38%, 89%, 92% and 88% for quartiles 1-4 respectively. Alongside SMA, TM has the most home-supermarket proximity (average of 82% of GSZ under 1250m) and the northern city of AN has the least, 50% of GSZ. It should be noted that the location of some supermarkets (usually megamarkets within malls) is not the only determinant to access (Errázuriz & Valdés, 2018), being in some cases difficult and unsafe pedestrianly as they are oriented to vehicles entering from highways or major avenues creating de-facto barriers between low-income neighborhoods and malls despite being close in distance.

In terms of our food supply typology, it should be noted that this classification has an "ableism" bias and does not account for the full scope of walking capacities[17]. Type 1 food supply environments (most proximate access) are most frequent in the capital of Santiago. Type 4 (least proximate access) appears to be located in qualitatively different urban contexts. In Temuco and Antofagasta, these are present in GSZ located at both SEI extremes: in the lower case with high levels of childhood obesity, and in mid income sectors, with lower rates of childhood obesity. For example, in Antofagasta, type 4 are concentrated in the south (high income, lower obesity) and north (lower income, high obesity) of the city. In the capital of Santiago, type 4 is prevalent in the highest income sectors. Especially for these cases in highest income GSZ, in spite of limitations of data from private schools we conclude that given that access is mediated not only by proximity, but these also cannot be decoded as a food deserts. Higher incomes tend to have access to private vehicles, smart phones and the digital knowhow to increase alternatives that do not require walking to shops (Blanco et al., 2014). In this sense, these might be most aptly categorized as a voluntary food oasis both in terms of effective access to healthy foods and in terms of providing optimal decision-making environments. It should be noted that the city of Valparaíso requires an analysis sensitive to its unique topography which consists of a narrow flat coastal strip that concentrates services and commercial activities, and hilly residential neighborhoods accessible via staircases, elevators and steep roads. Supermarkets and produce markets are concentrated in flat and coastal areas where residents from different kinds of neighborhoods congregate to

[17] See: Herrera Oesterheld and Vera Fuente-Alba, 2021.

shop. Neighborhood grocers are distributed throughout hills. While the 15-minute walking city is a commonly used category, critical feminist analysis suggests this measurement should be complemented with considerations to include mobility of and with children, the elderly, etc (Khavarian-Garmsir, et al 2023, Correa et al 2022, Kern 2022).

An examination of the Chilean case highlights the necessity to adequately capture and description of food environments in different world contexts. Chile is a case of high levels of both income inequality and residential segregation which configures access to services, opportunities and goods (Borsdof, 2003; Garin et al., 2009; Sabatini & Wormald, 2013, Link et al 2015). The analysis of the concentration of childhood obesity in lower socioeconomic groups is complicated by the fact that these receive higher levels of government food aid (in schools and primary health clinics) which were not considered in our study. Furthermore, it may also influence the respective food environments (Sanhueza & Larrañaga, 2008) and the inverse relationship between SEI and BMI integrates a spatial dimension, which as observed in this study, is particularly salient. Chile is also particular in that its bold regulation, which while it has become a policy model for the region, has not reduced the acceleration of childhood obesity. The inverse relationship between Socioeconomic Index (SEI) and higher levels of childhood obesity is complemented with the revelation of the coexistence of a multiplicity of food supply configurations that do not map onto socioeconomic status in simple or linear terms.

Neighborhood food provision environments in Chile take on a multiplicity of forms and their relationship with SEI and health outcomes create a diverse set of configurations. The findings from this study contribute to the literature on food environments and childhood obesity by georeferencing food outlets in Chile's six most populated cities, layering these onto socioeconomic categories and childhood BMI and conducting an inter and intra city analysis. An analysis of proximity – while constituting an important contribution to the discussion, cannot tell the full story. The research process was accompanied by discussions of its limitations and the search for interpretation that permits deepening analyses on how the region's inequitable urban socioeconomic segmentation conditions well-being. Since concluding the data collection for this analysis, the 2020 pandemic and 2021-4 inflationary wave have deeply altered Chilean and global food environments: interrupting production and supply lines, depressing family budgets, increasing food insecurity and childhood malnutrition in all its forms (Goldsmith Weil & Rivera, 2023). For this reason, research that examines the multifactorial causes of childhood nutritional status in distinct global contexts is both necessary and urgent.

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Declaration of Interest

The authors do not declare conflicts of interest.