Food availability and affordability in a Mediterranean urban context: Associations by store type and area-level socioeconomic status

Shortened title

Mediterranean consumer food environment

Authorship

Carlos Fernández-Escobar[1,2], Julia Díez[2], Alba Martínez-García[3], Usama Bilal[4], Martin O'Flaherty[5], Manuel Franco[2,6]

Affiliations

[1]National School of Public Health, Institute of Health Carlos III, Calle Sinesio Delgado 10, 28039 Madrid, Spain

[2]Public Health and Epidemiology Research Group, Faculty of Medicine and Health Sciences, University of Alcalá, 28871 Alcalá de Henares, Spain

[3]Department of Community Nursing, Preventive Medicine and Public Health and History of Science, University of Alicante, 03690 Alicante, Spain

[4] Urban Health Collaborative and Department of Epidemiology and Biostatistics, Dornsife School of Public Health, Drexel University, 3215 Market Street, Philadelphia, PA 19104, USA

[5]Department of Public Health, Policy and Systems, University of Liverpool, Whelan Bd, L69 3GB, Liverpool, United Kingdom

[6]Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, 615 North Wolfe Street, W6508, Baltimore, MD 21205, USA.

Corresponding author

Alba Martínez-García, PhD. Department of Community Nursing, Preventive Medicine and Public Health and History of Science, University of Alicante, 03690 Alicante, Spain. E-mail: alba.martinez@ua.es

Authorship

JD and MF conceived and designed the study. CFE, JD, and AMG collected the data. CFE led the analysis of the data and wrote the first draft. CFE and JD verified the underlying data. JD, AMG, UB, MOF and MF contributed to the interpretation of the data. AMG secured study funding. JD, AMG, UB, MOF and MF provided critical revisions and read and approved the submitted manuscript. All authors had full access to the data in the study and had final responsibility for the decision to submit for publication.

Data sharing

Databases and analysis code in Stata will be available with publication by request to the corresponding author at alba.martinez@ua.es

Ethical Standards Disclosure:

N/A

Abstract

Objective

Although food environments have been highlighted as potentially effective targets to improve population diets, evidence on Mediterranean food environments is lacking. We examined differences in food availability and affordability in Madrid (Spain) by store type and area-level socioeconomic status.

Design

Cross-sectional study. Trained researchers conducted food store audits using the validated NEMS-S-MED tool to measure the availability and price of 12 food groups(specific foods=35). We computed NEMS-S-MED scores and summarized price data with a Relative Price Index (RPI, comparing prices across stores) and an Affordability Index (normalizing prices by area-level income). We compared availability and affordability of 'healthier–less healthy' food pairs, scores between food store types (supermarkets, specialized, convenience stores, and others) and area-level socioeconomic status using ANOVA and multilevel regression models.

Setting

City of Madrid. 2016 and 2019 to cover a representative sample.

Participants

Food stores within a socioeconomically diverse sample of 63 census tracts (n=151).

Results

Supermarkets had higher food availability (37.5/49 NEMS-S-MED points), compared to convenience stores(13.5/49), and specialized stores(8/49). Supermarkets offered lower prices (RPI: 0.83) than specialized stores(RPI: 0.97) and convenience stores(RPI: 2.06). Both 'healthy' and 'less healthy' items were more available in supermarkets. We found no differences in food availability or price by area-level socioeconomic status, but affordability was higher in higher-income areas.

Conclusions

Supermarkets offered higher food availability and affordability for healthy and less healthy food items. Promoting healthy food availability through supermarkets and specialized stores and/or limiting access to convenience stores are promising policy options to achieve a healthier food environment.

Keywords

Food environment, NEMS-S-MED, Food availability, Food prices

Introduction

Unhealthy diets are the leading risk factor of non-communicable diseases (NCDs) morbidity and mortality[1] and contribute to socioeconomic inequities.[2] Food environments are defined as 'the collective physical, economic, political and socio-cultural circumstances surrounding population's food/beverage options and nutritional status'.[3] Specifically, Glanz et al. conceptualized the retail food environment as encompassing both the 'community food environment' (physical access to food outlets) and the 'consumer food environment' (availability of healthy food, price, promotion and placement within outlets).[4] Given their potential role in shaping food access within people's living and working environments, food environments have received growing scientific and political attention over the last decades.[5-7]

Previous research has assessed the evidence between the consumer food environment and dietary/health outcomes; however, the associations varied.[8-10] This lack of consistency may be partly due to three issues. First, affordability has been often unaccounted for.[6,11] Second, more evidence is needed to understand the interaction between the consumer food environment and area-level socioeconomic status. Although socioeconomically disadvantaged urban areas have shown greater accessibility to unhealthy foods, this relationship varies when considering affordability of healthy foods.[12–14] Third, consumer food environments are context-dependent and vary between countries, cities or neighborhoods.[15] Yet, current evidence is still focused on Anglo-Saxon settings like the United States (US), Australia, or Canada.[6] The lack of evidence in Southern Europe[16,17] is a key shortcoming for the identification of the effects of exposure to Mediterranean food environment.[18]

To fill these gaps, this study aimed to examine differences in availability and affordability of different food products in the city of Madrid (Spain) by store type and area-level socioeconomic status.

Methods

Study design and sample

This study was part of the Heart Healthy Hoods project, which analyzed the relationship between the socio-physical urban environment and cardiovascular health in Madrid, Spain.[19] Madrid is organized into 21 administrative districts, which are divided into 129 neighborhoods, and into 2443 census tracts - the smallest administrative areas in Madrid,

with a median population of 1500 residents. We used a multistage design to sample diverse areas (see Figure S1). We sampled three neighborhoods (high-, middle-, and low-SES) per district and selected median census tracts in each neighborhood in terms of socioeconomic characteristics (N = 63). Sampling strategy has been described in more detail elsewhere.[20,21]

Data collection

We conducted store audits using the 'Nutrition Environment Measures Survey in Stores for Mediterranean contexts' (NEMS-S-MED) tool.[21] The original NEMS-S,[22] designed for the US context, is one of the most widely used tools for conducting food store audits.[23] The adapted NEMS-S-MED tool evaluates availability and price within 12 food groups: fresh fruits, vegetables, nuts, non-alcoholic beverages, bread, cereals and bakery, milk and dairy, eggs, oil and butter, rice, legumes, meat, and fish. We also recorded availability of alcoholic beverages. Data collection occurred in two waves in June-July 2016 and November-December 2019 (Figure S2), on weekdays and during business hours. Trained observers audited all food stores located within each census tract, assessing and scoring each measure following a standard protocol. We integrated the NEMS-S-MED audit tool into the Open Data Kit app for Android smartphones to facilitate data collection. More details are available elsewhere.[21]

Measures

We measured availability of food by the presence of selected food items within 12 food groups (i.e., apples in the 'fresh fruit' group) (Table A1). NEMS-S-MED score ranges from 0 to 49, with higher scores representing higher availability and variety and lower prices of healthier food options.[21] We recorded price (either per grams or per item if sold only by the piece) of selected items, to be compared between food stores. All prices reflect non-sale price. NEMS-S-MED tool is available elsewhere.[21]

We categorized food stores into supermarkets (including discounters), convenience stores (including corner stores and gas stations), and traditional/specialized stores (fruits and vegetables stores, butcheries, fishmongers, and bakeries) based on previous research.[21,24] We excluded food markets and food galleries. Food markets in Spain are a collection of tens of stalls mostly dedicated to retailing a single category of foods (e.g., fruits/vegetables, fish, meat, bakery products, etc.). Standard tools for healthy food availability measures can fail to capture the effect of these retailers.[19]

To measure area-level SES, we used a validated composite index at census tract level.[25] This SES index is constructed from seven indicators: (1) low education, (2) high education, (3) part-time employment, (4) temporary employment, (5) manual occupational class, (6) average housing prices, and (7) unemployment rate. Further details are available elsewhere.[25] We operationalized this measure into quintiles (Q1 = most socioeconomically disadvantaged and Q5 = most socioeconomically advantaged) using data from 2017. We also obtained the census tract mean income per capita from the National Institute of Statistics.[26]

Statistical analyses

We calculated descriptive statistics of availability and price by food store type and area-level SES (quintiles). We compared availability and price of 'healthier – less healthy' food pairs and tested for differences using two-sample test of proportions and Wilcoxon matched-pairs signed-rank test, respectively.

We summarized price data calculating a Relative Price Index for each store:

$$Relative\ Price\ Index = \sum \frac{(p_i/\bar{p}_i)}{n}$$

Where p_i is the price of a food item, $\bar{p}_i$ is the mean price of that item across all stores in our sample, and n is the total number of food items with recorded price in the store. This allowed us to compare between food stores that sold a different number of distinct products (e.g., a fruit and vegetables store vs. a supermarket).

To account for different purchasing power of residents, we also computed an Affordability Index for each food store, dividing the relative mean income per capita of its census tract by the Relative Price Index of the retailer:

$$Affordability\ Index = \frac{\overline{income}\ (census\ tract) \Big/ \overline{income}\ (city)}{Relative\ Price\ Index}$$

Income (city) refers to the mean income per capita in Madrid and was sourced directly from the National Statistics Institute.[26] A higher Affordability Index means that the food store is more affordable, considering the mean income of their census tract.

We computed NEMS-S-MED score, RPI, and Affordability Index for each store. We compared these metrics by store type and quintile of area-level SES using ANOVA. In addition, we fitted a multilevel regression model of stores nested in census tracts, including a

fixed effect for store type, area-level SES, and year of data collection. Data analysis was conducted with Stata 15 (StataCorp, 2017).

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Descriptive data

We audited 151 food retailers. Almost half of them (45.0%, n = 68) were convenience stores, followed by specialized stores (30.5%, n = 46), supermarkets (18.5%, n = 28), and others (6.0%, n = 9), the latter including coffee shops and herbalists selling food products.

Table 1 displays food availability of NEMS-S-MED food items. Most frequent available items were eggs, alcoholic drinks, cola drinks, not-100% juice, legumes, cold meat, and milk, each of them with an availability greater than 70%. Least common items were fresh fish (13.3%), whole rice (17.3%), processed and unprocessed frozen fish (18.0% and 20.0%, respectively), chicken and beef (19.3% each), and frozen vegetables (21.3%). Mean availability across all food items was 89.7% in supermarkets, 60.1% in convenience stores, 22.5% in specialized stores, and 32.1% in other stores. The biggest difference in availability between supermarkets and convenience stores were for fresh meat, fish, fresh fruit, and whole rice. Supermarkets had similar availability of fruit and vegetables, meat, and bread than fruit and vegetables stores, butchers, and bakeries, respectively (Table A2). However, fresh and unprocessed frozen fish had lower availability in supermarkets (57.1% and 78.6%, respectively) vs. fishmongers (100%). 'Less healthy' alternatives (e.g., salty nuts, not-100% juice, cola drinks, sugary cereals, cold meat, and confectionery) were more available in supermarkets than in specialized stores.

Table A3 shows a comparison of pairs of 'healthy-less healthy' alternatives. Most healthier food items were less available than their less healthy counterparts, e.g., juice 100% than not-100% juice, low sugar cereals than regular ones, virgin olive oil than refined sunflower oil, or whole rice than white rice. There were no differences in availability between light and regular cola drinks, skimmed milk and whole milk, chicken and beef, or unprocessed and processed frozen fish. Some healthier items were more expensive than their less healthy pairs (olive oil,

whole rice and 100% juice), one item (chicken) was cheaper, and several pairs had a similar price (cola drinks, cereals, and milk).

NEMS-S-MED Score

We found a large variability in NEMS-S-MED scores by type of retailer, with an overall median of 13 out of a total of 49 points (interquartile range, IQR: 12) (Figure 1 and Table A4). Supermarkets had the highest total score (median: 37.5, IQR:12.5), followed by small/convenience stores (median: 13.5, IQR: 6). As a group, specialized stores scored a median of 8 out of 49 points. Of those, fruit stores had the highest availability (median: 11, IQR: 3).

Price

The Relative Price Index (RPI) ranged from 0.52 (price of food items was 48% lower than average) to 4.22 (price of food items was 322% higher than average). As seen in Table A5, fishmongers had the lowest RPI, although it accounted only for the price of hake, and the difference with supermarkets was not significant. Apart from fishmongers, supermarkets had the lowest overall RPI (median 0.83, IQR 0.33), followed by other specialized stores (median ranging from 0.96 to 0.98). Convenience stores were more expensive than supermarkets (median 1.02, IQR 0.26), and retailers in the "other" category were the most expensive of all (median 2.06, IQR 1.13). Supermarkets had significantly lower prices in fresh fruits and vegetables, cola drinks, regular cereals, milk, sunflower oil, white rice, and beef compared to convenience stores (Table A6). Prices of fruit and vegetables was similar between supermarkets and fruit and vegetables stores (p=0.54) (Table A7).

Area-level socio-economic differences

Table 2 shows number of food retailers, median values of NEMS-S-MED scores, and mean values of RPI, Affordability Index and SES Index across quintiles of SES. Median number of food stores was similar between SES quintiles (p=0.84). Median total NEM-S-MED scores went from 12 to 18, without significant differences (p=0.39). The same was true for RPI (mean 0.95 to 1.24, p=0.18). Affordability Index increased monotonically with SES, indicating higher affordability in higher SES areas (p<0.01).

Table 3 shows results from a multilevel linear regression model. Across all dependent variables (NEM-S-MED scores, Relative Price Index and Affordability Index), most of the variability was at store level as compared to census tract level (Intraclass Correlation = 23%,

17%, 17%, 13% and 33% for total NEMS-S-MED score, availability score, price score, RPI, and Affordability Index, respectively). All store types had lower NEMS-S-MED total, availability, and price scores than supermarkets (p<0.01). Supermarkets showed the lowest prices, although the difference was only significant when comparing supermarkets to bakeries and "other" stores. All store types but fishmongers were less affordable that supermarkets. NEM-S-MED scores were not different between SES quintiles. There were RPI differences across SES quintiles for the quintile with the highest index, which showed a RPI 0.38 points higher than the low-SES quintile (95% CI: 0.13-0.64, p<0.05). No other differences were observed by SES. Affordability Index was associated with census tract-level SES, showing higher affordability in high-income areas (p<0.01).

Discussion

This study evaluated the consumer food environment in Madrid, Spain, an example of a Southern European/Mediterranean urban context. We report three key findings. First, we found that food availability and affordability were greater in supermarkets and specialized stores than in convenience stores. Second, we found no socioeconomic inequities in the number of food stores per census tract, or healthy food availability. Third, we found that in higher-income areas food prices were above average, although affordability was also higher than in lower-income areas.

Previous research in other countries has found a higher availability and affordability of healthy food in supermarkets and larger stores than in smaller stores.[16,27–29] However, this is also true for ultra-processed foods and other unhealthy foods, as we have also seen in our data, making supermarkets a 'double-edged sword'.[30] As other studies have shown, product placement strategies in supermarkets promote higher sales and consumption of both healthy and unhealthy foods.[31] Supermarkets are the main source of foods and beverages purchased for home consumption in Spain, accounting for 61.4% of all Spain retail grocery sales in 2019.[32] However, small specialized stores still contribute to approximately 30% of all fresh food sales.[32]

Due to the political and economic implications that supermarkets have on the food systems and the retail food environment,[33,34] and their prominence in Spanish local food environments in terms of food availability, food prices, and high sales volume, supermarkets are a desirable target for health-promoting policies. In this regard, supermarket, and food environment, actions supporting healthy and sustainable diets would be to ensure the affordability and

availability of a variety of healthy foods, along with the reduction or withdrawal on unhealthy products such as confectionery, snacks and sugary drinks, in addition to the development of interventions that encourage healthy food choices by consumers.[33-35]

On the other hand, traditional specialized stores offered high fresh food availability at comparable prices to supermarkets, with the added benefit of lower availability of unhealthy products (i.e., alcoholic drinks or confectionery). Although replacement of traditional shops with supermarkets may have deleterious effects overall by moving diets towards a more Western pattern, high in ultra-processed foods,[30] some authors advocate for increasing the number of supermarkets, specially in deprived or underserved neighborhoods.[14] We found that supermarkets were as prevalent as specialized stores in census tracts (usually 0-1 supermarkets and 0-1 specialized stores per census tract), but several different specialized stores are needed to offer a viable alternative for supermarkets in terms of fresh food availability (e.g., at least a fruit store, a butchers and a fishmongers). Increasing the number and variety of traditional stores may be a promising strategy to promote fresh product purchases.[14,36] Alternatively, public food markets, which include multiple stalls of a diverse set of specialized stores, may also increase healthy food availability. City governments can use their licensing powers to ensure the presence of a variety of traditional stores in all neighborhoods. These local actions should be supported by the local and national governments through the development of policies and interventions promoting healthy retail food environments, as well as encouraging fair, local and proximity trade.[37]

Convenience stores in our sample offered less varied and more expensive food items. From a public health perspective, their widespread presence might be detrimental in local food environments, as they usually lack varied, affordable fresh products, and most food offered are high-calorie, easy-to-preserve items. Proximity to convenience stores in the US has been associated to higher prevalence of obesity.[38] Local interventions that limit access to convenience stores (e.g., via retailer licensing) might be considered.[14] In-store interventions which combine price, engaging information and easier access to and availability of healthy foods are also promising strategies.[39]

In contrast to previous literature set in countries like the US[40] or Brazil,[41] we did not find evidence of 'food deserts', or areas in deprived neighborhoods with low to no access to healthy foods. This is probably due to stark differences in urban planning and food culture across European and American cities. For example, in a previous study we found that more

than three quarters of residents in a Madrid neighborhood lived nearer than 200 meters from a food store with healthy food, in contrast to more than 95% of Baltimore's resident living farther than 400 meters from these stores.[15] This discrepancy also highlights the need to tailor food urban policies to their specific environment, and suggests that some recommended interventions, such as actions to improve availability in food deserts,[42] may be of no use in Mediterranean contexts. However, this aspect should be further studied in other Southern European and Mediterranean context.

We found a homogeneous consumer food environment across all SES quintiles, except for the quintile with the highest index, and most of the variability in availability and affordability scores was at store level. These results are in accordance with recent research conducted in Malta,[27] Australia[29] and the United Kingdom.[28] However, similar prices across the geography can regardless mean a higher financial burden for low-income families, as our Affordability Index showed. This suggests that affordability, and not availability, may be the most important driver of dietary socioeconomic inequities in Mediterranean contexts. Previous literature has shown that healthy foods are considerable more expensive in terms of price per weight or per calorie.[11] In this regard, policy interventions in food prices are recommended as one of the most potentially effective public health policies promoting healthy diets.[43] Either an overall decrease of healthy food prices or a targeted price discount for low-income populations living in 'affordability deserts' may help reduce health inequities. It is important to bare in mind the current income inequality trends in our cities and countries, therefore income and wealth redistribution policies are also relevant pieces for reducing dietary inequities.

We also found that healthier food alternatives, such as whole rice instead of white rice, or virgin olive oil instead of refined sunflower oil, are usually less available and costlier. This may represent a hurdle for low-income individuals and families to switch from less to more healthy diets. Public incentives to reduce price of healthier alternatives, e.g. subsidies for olive oil or whole rice producers, coupled with disincentives towards unhealthy elements (e.g. a sugar tax) are promising policy options to improve consumer food environments.

Study limitations and strengths

This is, to our knowledge, the first study evaluating the consumer food environment in a large city in a Mediterranean context. We sampled a wide variety of socioeconomic backgrounds using reproducible and scalable methods. We used a validated novel audit tool which allowed

us to describe and compare both food availability and affordability of culturally-relevant food items.

Several limitations of our study should be considered. First, some differences in food availability and affordability may exist that we failed to detect due to a possibly small sample. We used a convenience, non-random sample, so extrapolation of results should be cautious, although we selected our sample to guarantee socioeconomic diversity. Second, data collection took place in two discrete time periods, so we cannot evaluate possible seasonal effects or trends in the consumer food environment, although we did not find significant differences between the two data collection points. Third, we focused on store food availability but we lacked direct data on consumer purchases or intake. Furthermore, important aspects of the consumer food environment are missing in NEMS-S-MED, such as presence of marketing campaigns, relative shelf space of different products, food quality, or availability of ultra-processed foods. We also excluded food markets and galleries from our sample. However, the audit tool offers a reasonable compromise between comprehensiveness and practicality, has been previously validated in our context, and can be easily replicated in other Mediterranean cities.

Our results might be cautiously extrapolated to other high-density Mediterranean cities. Madrid has a higher-income, more educated population than the rest of Spain, and is more ethnically diverse with larger socioeconomic inequalities.[44] Smaller, more homogenous cities may exhibit even more consistent consumer food environments. Rural areas or cities with prominent urban sprawls might present greater differences in food availability and access by SES, as is the case with large American cities.

Conclusions

In our study of the consumer food environment of the city of Madrid we found that supermarkets had greater food availability and overall lower prices than specialized and convenience stores, for both healthy and less healthy foods. We found no differences in food availability or price by area-level socioeconomic status, and a higher relative affordability for high-income areas. Further studies should explore the generalizability of these results to other European/Mediterranean cities. Promoting healthy food availability through supermarkets and specialized stores and/or limiting access to convenience stores are promising policy options to achieve a healthier consumer food environment.

Tables

Table 1. Availability of food items by type of food store.

Food item	Type of retailer					
	All (n=151)	Supermarket (n=28)	Convenience store (n=68)	Specialized store (n=46)	Other (n=9)	p-value*
Fresh fruit	56.3	100	47.1	47.8	33.3	<0.01
Fresh vegetables	60.9	100	57.4	47.8	33.3	<0.01
Frozen vegetables	21.2	75.0	10.3	4.3	22.2	<0.01
Unprocessed nuts	55.6	89.3	61.8	26.1	55.6	<0.01
Salty nuts	69.5	96.4	89.7	28.3	44.4	<0.01
Juice 100%	37.1	78.6	38.2	8.7	44.4	<0.01
Not-100% juice	73.5	100	94.1	32.6	44.4	<0.01
Light cola drink	75.5	96.4	100	34.8	33.3	<0.01
Regular cola drink	74.8	96.4	98.5	34.8	33.3	<0.01
Whole bread	54.3	89.3	57.4	34.8	22.2	<0.01
Low sugar cereals	31.8	78.6	30.9	4.3	33.3	<0.01
Regular cereals	43.0	92.9	54.4	2.2	11.1	<0.01
Skimmed milk	71.5	96.4	97.1	26.1	33.3	<0.01
Semi-skimmed milk	71.5	96.4	97.1	28.3	22.2	<0.01
Whole milk	72.2	96.4	97.1	28.3	33.3	<0.01
Skimmed yogurt	37.7	89.3	38.2	6.5	33.3	<0.01
Cream cheese	43.7	92.9	47.1	8.7	44.4	<0.01
Semi-hard cheese	58.3	92.9	75.0	13.0	55.6	<0.01
Eggs	79.5	96.4	92.6	56.5	44.4	<0.01
Olive oil	53.6	85.7	67.6	19.6	22.2	<0.01
Sunflower oil	65.6	100	86.8	19.6	33.3	<0.01
Salt-free butter	35.8	89.3	38.2	4.3	11.1	<0.01
Regular butter	50.3	92.9	63.2	13.0	11.1	<0.01
Whole rice	17.2	60.7	8.8	2.2	22.2	<0.01
White rice	68.2	96.4	91.2	21.7	44.4	<0.01
Legumes	73.5	100	86.8	41.3	55.6	<0.01
Potatoes	58.3	100	52.9	43.5	44.4	<0.01
Chicken	19.9	75.0	1.5	10.9	33.3	<0.01
Beef	19.9	75.0	2.9	10.9	22.2	<0.01
Cold meat	72.8	96.4	92.6	32.6	55.6	<0.01
Fresh fish	13.2	57.1	0.0	6.5	11.1	<0.01
Unprocessed frozen fish	20.5	78.6	7.4	6.5	11.1	<0.01
Processed frozen fish	18.5	71.4	8.8	2.2	11.1	<0.01
Canned tuna	68.2	96.4	94.1	23.9	11.1	<0.01
Confectionery	66.9	100	76.5	39.1	33.3	<0.01

*ANOVA.

Table 2. Differences in number of food retailer, NEMS-S-MED scores, and selected indexes across quintiles of SES.

	Census tract SES Quintile					
	Low (n=11)	**Low-medium (n=8)**	**Medium (n=10)**	**Medium-high (n=12)**	**High (n=11)**	**p-value***
Number of food	2[3]	3.5[3.5]	3[3]	2[2]	2[3]	0.84
Supermarkets	0 [0]	1 [2]	1 [1]	0 [1]	0 [1]	0.12
Convenience	2 [3]	1 [1]	1 [1]	1 [0.5]	1 [1]	0.44
Specialized	0 [1]	1 [1]	0 [1]	0 [0.5]	0 [0]	0.34
Others	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]	0.63
NEMS-S-MED						
Total (0-49)	12 [3.5]	18 [14.25]	13.5 [6.5]	17.5 [14.75]	18 [11.5]	0.39
Availability (0-	9 [2.5]	15.5 [11]	10.5 [4]	14 [12.5]	14 [9.5]	0.30
Price (0-12)	3 [0]	2.5 [2.25]	2.5 [3]	3 [1]	3 [3.5]	0.84
SES Index²	-1.19	-0.62 (0.17)	-0.03 (0.24)	0.55 (0.13)	1.06 (0.22)	<0.01
Price Index²	0.95 (0.15)	1.06 (0.23)	1.02 (0.29)	0.94 (0.15)	1.24 (0.56)	0.18
Affordability	0.66 (0.19)	0.83 (0.27)	0.96 (0.16)	1.28 (0.26)	1.29 (0.37)	<0.01

[1]Median [Interquartile range]. [2] Mean (standard deviation). *ANOVA.

Table 3. Multilevel linear regression model for NEM-S-MED scores, Relative Price Index and Affordability Index.

Parameter	NEMS-S-MED total		NEMS-S-MED		NEMS-S-MED		Price Index		Affordability Index	
Fixed effects	**Estimate**	**95% CI**	**Estimate**	**95% CI**	**Estimate**	**95% CI**	**Estimate**	**95% CI**	**Estimate**	**95% CI**
Type of food retailer (Base:										
Convenience store	**-20.24****	(-22.89, -	**-17.66****	(-19.99, -	**-2.52****	(-3.15,-	0.17	(-0.01,	**-0.27****	(-0.39,-
Fruit & vegetables	**-22.08****	(-25.39, -	**-17.64****	(-20.56, -	**-4.44****	(-5.22,-	0.09	(-0.13,	**-0.16***	(-0.32,-
Butcher's	**-30.96****	(-36.11, -	**-26.46****	(-31.03, -	**-4.51****	(-5.73,-	0.24	(-0.09,	**-0.26***	(-0.50,-
Fishmonger's	**-27.17****	(-34.05, -	**-22.22****	(-28.32, -	**-5.14****	(-6.77,-	0.01	(-0.44,	-0.07	(-0.38,
Bakery	**-29.25****	(-32.84, -	**-25.26****	(-28.44, -	**-4.15****	(-4.99,-	**0.83****	(0.54,	**-0.42****	(-0.64,-
Other	**-23.52****	(-28.01, -	**-19.47****	(-23.43, -	**-4.08****	(-5.14,-	**0.41***	(0.04,	**-0.43****	(-0.68,-
SES Index quintile (Base:										
Low-medium	1.70	(-2.57,	1.82	(-1.73,	-0.06	(-1.00,	0.16	(-0.11,	0.10	(-0.12,
Medium	4.17	(0.07,	**3.71***	(0.30,	0.52	(-0.38,	0.12	(-0.13,	**0.24***	(0.02,
Medium-high	3.24	(-1.13,	3.01	(-0.62,	0.07	(-0.89,	0.18	(-0.09,	**0.51****	(0.29,
High	3.68	(-0.34,	3.37	(0.02,	0.18	(-0.72,	**0.38****	(0.13,	**0.61****	(0.41,
Year (Base: 2016)	-1.80	(-4.74,	-1.25	(-3.68,	-0.50	(-1.15,	-0.11	(-0.31,	0.06	(-0.10,
Random effects										
Census tract-level variance	8.93		5.03		0.36		0.02		0.03	
Store-level variance	30.12		24.02		1.70		0.13		0.06	
Intraclass correlation	0.23		0.17		0.17		0.13		0.33	

Boldface indicates statistical significance (*p<0.05, ** p<0.01). CI: Confidence Interval. Intraclass correlation = census tract-level variance / (census tract-level variance + store-level variance).

Accepted manuscript

References

1 Murray CJL, Aravkin AY, Zheng P, et al. Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet, 2020; 396: 1223-1224

2 Méjean C, Droomers M, Schouw YT van der, et al. The contribution of diet and lifestyle to socioeconomic inequalities in cardiovascular morbidity and mortality. Int J Cardiol 2013; 168: 5190–5.

3 Egger G, Swinburn B. An "ecological" approach to the obesity pandemic. BMJ 1997; 315: 477-480

4 Glanz K, Sallis JF, Saelens BE, et al. Healthy nutrition environments: concepts and measures. Am J Health Promot AJHP 2005; 19: 330–3, ii.

5 Feng J, Glass TA, Curriero FC, et al. The built environment and obesity: a systematic review of the epidemiologic evidence. Health Place 2010; 16: 175–90.

6 Lee A, Mhurchu CN, Sacks G, et al. Monitoring the price and affordability of foods and diets globally. Obes Rev Off J Int Assoc Study Obes 2013; 14 Suppl 1: 82–95.

7 Swinburn BA, Sacks G, Hall KD, et al. The global obesity pandemic: shaped by global drivers and local environments. The Lancet 2011; 378: 804–14.

8 Gustafson A, Hankins S, Jilcott S. Measures of the consumer food store environment: a systematic review of the evidence 2000-2011. J Community Health 2012; 37: 897–911.

9 Caspi CE, Sorensen G, Subramanian SV, et al. The local food environment and diet: a systematic review. Health Place 2012; 18: 1172–87.

10 Black C, Moon G, Baird J. Dietary inequalities: what is the evidence for the effect of the neighbourhood food environment? Health Place 2014; 27: 229–42.

11 Darmon N, Drewnowski A. Contribution of food prices and diet cost to socioeconomic disparities in diet quality and health: a systematic review and analysis. Nutr Rev 2015; 73: 643–60.

12 Hallum SH, Hughey SM, Wende ME, et al. Healthy and unhealthy food environments are linked with neighbourhood socio-economic disadvantage: an innovative geospatial approach to understanding food access inequities. Public Health Nutr 2020; 23: 3190–6.

13 Schultz S, Cameron AJ, Grigsby-Duffy L, et al. Availability and placement of healthy and discretionary food in Australian supermarkets by chain and level of socio-economic disadvantage. Public Health Nutr 2021; 24: 203–14.

14 Story M, Kaphingst KM, Robinson-O'Brien R, et al. Creating healthy food and eating environments: policy and environmental approaches. Annu Rev Public Health 2008; 29: 253–72.

15 Díez J, Bilal U, Cebrecos A, et al. Understanding differences in the local food environment across countries: A case study in Madrid (Spain) and Baltimore (USA). Prev Med 2016; 89: 237–44.

16 Stroebele-Benschop N, Wolf K, Palmer K, et al. Comparison of food and beverage products' availability, variety, price and quality in German and US supermarkets. Public Health Nutr 2020; 23: 3387–93.

17 Drewnowski A, Moudon AV, Jiao J, et al. Food environment and socioeconomic status influence obesity rates in Seattle and in Paris. Int J Obes 2014; 38: 306–14.

18 Estruch R, Ros E, Salas-Salvadó J, et al. Primary Prevention of Cardiovascular Disease with a Mediterranean Diet Supplemented with Extra-Virgin Olive Oil or Nuts. N Engl J Med 2018; 378: e34.

19 Bilal U, Díez J, Alfayate S, et al. Population cardiovascular health and urban environments: the Heart Healthy Hoods exploratory study in Madrid, Spain. BMC Med Res Methodol 2016; 16: 104.

20 Díez J, Cebrecos A, Galán I, et al. Assessing the Retail Food Environment in Madrid: An Evaluation of Administrative Data against Ground Truthing. Int J Environ Res Public Health 2019; 16: 3538.

21 Martínez-García A, Díez J, Fernández-Escobar C, et al. Adaptation and Evaluation of the Nutrition Environment Measures Survey in Stores to Assess Mediterranean Food Environments (NEMS-S-MED). Int J Environ Res Public Health 2020; 17: 7031.

22 Glanz K, Sallis JF, Saelens BE, et al. Nutrition Environment Measures Survey in stores (NEMS-S): development and evaluation. Am J Prev Med 2007; 32: 282–9.

23 Glanz K, Johnson L, Yaroch AL, et al. Measures of Retail Food Store Environments and Sales: Review and Implications for Healthy Eating Initiatives. J Nutr Educ Behav 2016; 48: 280-288.e1.

24 Díez J, Bilal U, Franco M. Unique features of the Mediterranean food environment: Implications for the prevention of chronic diseases Rh: Mediterranean food environments. Eur J Clin Nutr 2018; published online Nov 28. DOI:10.1038/s41430-018-0311-y.

25 Gullón P, Bilal U, Cebrecos A, et al. Intersection of neighborhood dynamics and socioeconomic status in small-area walkability: the Heart Healthy Hoods project. Int J Health Geogr 2017; 16. DOI:10.1186/s12942-017-0095-7.

26 Instituto Nacional de Estadística. Atlas de distribución de renta de los hogares. https://www.ine.es/experimental/atlas/experimental_atlas.htm (accessed Sept 8, 2020).

27 Cauchi D, Pliakas T, Knai C. Food environments in Malta: Associations with store size and area-level deprivation. Food Policy 2017; 71: 39–47.

28 Harmer G, Jebb SA, Ntani G, et al. Capturing the Healthfulness of the In-store Environments of United Kingdom Supermarket Stores Over 5 Months (January–May 2019). Am J Prev Med 2021; published online June 20. DOI:10.1016/j.amepre.2021.04.012.

29 Millichamp A, Gallegos D. Comparing the availability, price, variety and quality of fruits and vegetables across retail outlets and by area-level socio-economic position. Public Health Nutr 2013; 16: 171–8.

30 Hawkes C. Dietary Implications of Supermarket Development: A Global Perspective. Dev Policy Rev 2008; 26: 657–92.

31 Shaw SC, Ntani G, Baird J, et al. A systematic review of the influences of food store product placement on dietary-related outcomes. Nutr Rev 2020; 78: 1030–45.

32 Ministerio de Agricultura, Pesca y Alimentación. Informe del consumo de alimentación en España 2019. Madrid: Ministerio de Agricultura, Pesca y Alimentación, 2020 https://www.mapa.gob.es/images/es/informe2019_v2_tcm30-540250.pdf (accessed July 6, 2021).

33 Pulker CE, Trapp GSA, Scott JA, et al. What are the position and power of supermarkets in the Australian food system, and the implications for public health? A systematic scoping review. Obesity Reviews 2017; 19(2):198-218. doi:10.1111/obr.12635

34 Pulker CE, Trapp GSA, Scott J, et al. Global supermarkets' corporate social responsibility commitments to public health: a content analysis. Global Health 2018; 14, 121. https://doi.org/10.1186/s12992-018-0440-z

35 Machín L, Curutchet MR, Gugliucci V, et al. The habitual nature of food purchases at the supermarket: Implications for policy making. Appetite 2020; 155, 104844. doi:10.1016/j.appet.2020.104844

36 Bivoltsis A, Trapp G, Knuiman M, et al. Do Changes in the Local Food Environment Within New Residential Developments Influence the Diets of Residents? Longitudinal Results from RESIDE. Int J Environ Res Public Health 2020; 17: E6778.

37 Djojosoeparto SK, Kamphuis CBM, Vandevijvere S, et al. The Healthy Food Environment Policy Index (Food-EPI): European Union. An assessment of EU-level policies influencing food environments and priority actions to create healthy food environments in the EU. Utrecht, Utrecht University, The Netherlands, 2021.

38 Morland K, Diez Roux AV, Wing S. Supermarkets, Other Food Stores, and Obesity: The Atherosclerosis Risk in Communities Study. Am J Prev Med 2006; 30: 333–9.

39 Adam A, Jensen JD. What is the effectiveness of obesity related interventions at retail grocery stores and supermarkets? —a systematic review. BMC Public Health 2016; 16: 1247.

40 Goodman M, Thomson J, Landry A. Food Environment in the Lower Mississippi Delta: Food Deserts, Food Swamps and Hot Spots. Int J Environ Res Public Health 2020; 17: E3354.

41 Lopes MS, Caiaffa WT, Andrade AC de S, et al. Spatial inequalities of retail food stores may determine availability of healthful food choices in a Brazilian metropolis. Public Health Nutr 2021; : 1–25.

42 Ghosh-Dastidar M, Hunter G, Collins RL, et al. Does opening a supermarket in a food desert change the food environment? Health Place 2017; 46: 249–56.

43 Thow AM, M Downs S, Mayes C, et al. Fiscal policy to improve diets and prevent noncommunicable diseases: from recommendations to action. Bull World Health Organ 2018; 96: 201–10.

44 Hortas-Rico M, Onrubia J. Renta personal de los municipios españoles y su distribución, años 2011 y 2014. FEDEA, 2020.
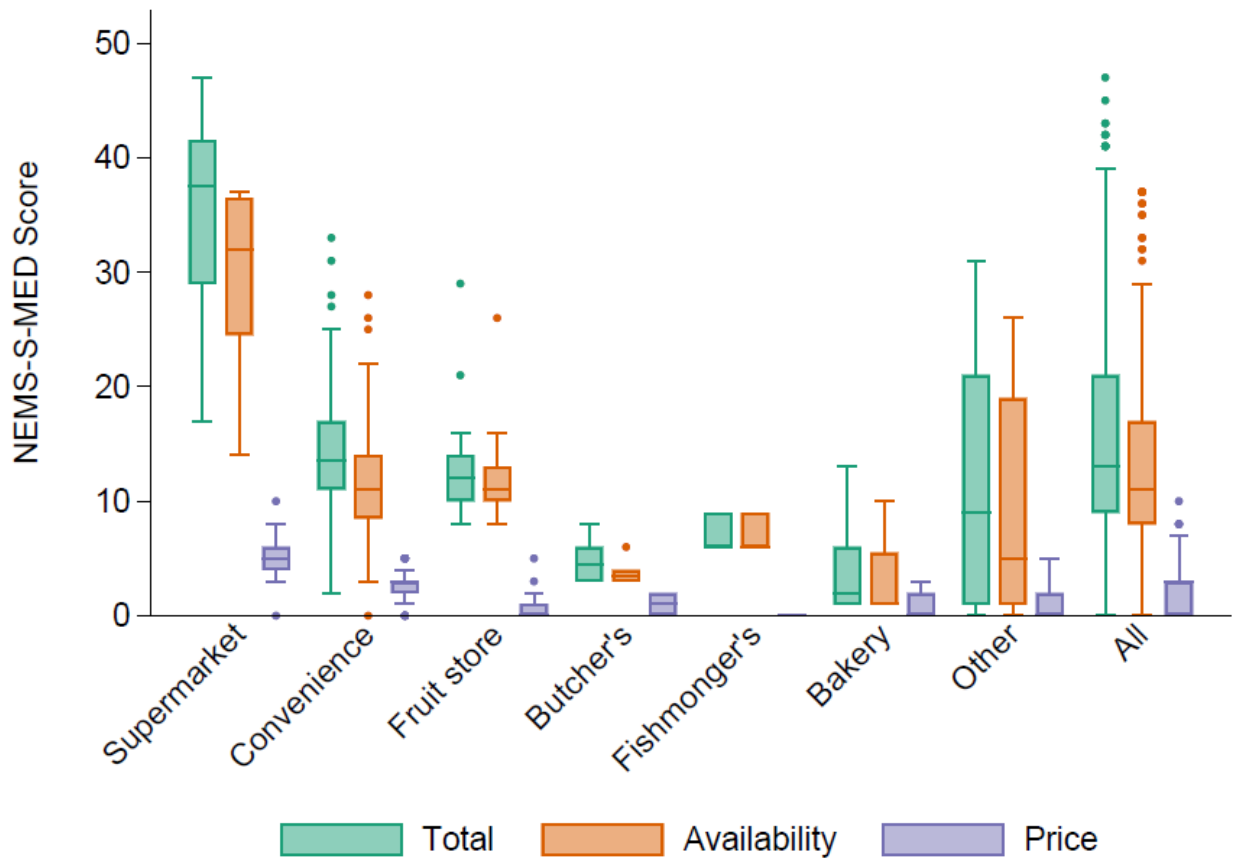
Figure legends

Figure 1. NEMS-S-MED scores by store type.