

ORIGINAL ARTICLE

Food environment and socioeconomic status influence obesity rates in Seattle and in Paris

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OBJECTIVE: To compare the associations between food environment at the individual level, socioeconomic status (SES) and obesity rates in two cities: Seattle and Paris.

METHODS: Analyses of the SOS (Seattle Obesity Study) were based on a representative sample of 1340 adults in metropolitan Seattle and King County. The RECORD (Residential Environment and Coronary Heart Disease) cohort analyses were based on 7131 adults in central Paris and suburbs. Data on sociodemographics, health and weight were obtained from a telephone survey (SOS) and from in-person interviews (RECORD). Both studies collected data on and geocoded home addresses and food shopping locations. Both studies calculated GIS (Geographic Information System) network distances between home and the supermarket that study respondents listed as their primary food source. Supermarkets were further stratified into three categories by price. Modified Poisson regression models were used to test the associations among food environment variables, SES and obesity.

RESULTS: Physical distance to supermarkets was unrelated to obesity risk. By contrast, lower education and incomes, lower surrounding property values and shopping at lower-cost stores were consistently associated with higher obesity risk.

CONCLUSION: Lower SES was linked to higher obesity risk in both Paris and Seattle, despite differences in urban form, the food environments and in the respective systems of health care. Cross-country comparisons can provide new insights into the social determinants of weight and health.

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Keywords: socioeconomic status (SES); access to supermarket; food environment; food shopping

INTRODUCTION

Socioeconomic status (SES), urban form and the food environment can exert a powerful influence on body weights and health.^{1–3} Both in France and in the United States, higher obesity rates are associated with lower education and incomes, lower occupational status^{4–8} and with lower-quality diets^{9–16}. New geospatial analyses of residential neighborhoods in the United States have found higher obesity rates in more deprived and underserved areas.^{2,17–23} In particular, food deserts, defined as high poverty areas where the nearest supermarket is > 1 mile away, are said to contribute to the American obesity epidemic.^{20,21,24} In France, a study has found that living in low SES neighborhoods (in Paris region) was associated with an increased body mass index (BMI) and waist circumference.²⁵

Most previous studies of the food environment and body weight have measured access to food at some level of geographic aggregation.^{26,27} Among measures of food access were density of grocery stores or fast food restaurants per unit area or the road network distance to the supermarket that was closest to the respondent's home.^{18,19,21,28–31}

One limitation of purely geographic measures is that they do not reflect the actual food environment of study participants. Indeed, most of the studies lacked any data on where people actually shopped or ate. As new generation studies are beginning to show, most of the people do not shop for food in their

immediate neighborhood.^{32–34} In epidemiological terms, mere proximity to a store is no longer a good index of exposure.

The Seattle Obesity Study (SOS) and the Residential Environment and Coronary Heart Disease (RECORD) studies are the only studies, to our knowledge, to include measures of the food environment at the individual level. In both studies, home addresses of study participants as well as the reported locations of their primary food stores were obtained and geocoded. The SOS and RECORD studies calculated distances to supermarkets that were the respondents' primary food sources. Those procedures introduced, for the first time, the personalized dimension of individual food seeking behavior into the study of health and the built environment. Classifying supermarkets by food cost provided the needed additional measure of economic access to foods.³²

Relatively little is known about the role of individualized food environment in relation to diet quality and body weight. The SOS and RECORD databases lent themselves to comparative analyses, given that similar data on SES and food environments were collected in both studies.^{32,33,35,36} To our knowledge, no other study has collected data on SES variables, measures of food environment at the individual level, supermarket type and body weight.³⁷

The present goal was to determine whether obesity rates in different cities are subject to shared socioeconomic and environmental pressures. Obesity rates in France are much lower than the

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reported rates in the United States.^{38,39} Paris and Seattle are highly dissimilar in terms of urban landscape, residential density, walkability, public transport and ease of access to food stores.³³ More critical perhaps is the fact that France and the United States differ greatly in their respective systems of disease prevention and health care. One important question is whether the socioeconomic and environmental determinants of body weight are limited to a specific urban context or are they, in fact, likely to be universal.^{40–43}

METHODS AND PROCEDURES

Population samples in SOS and RECORD studies

The SOS conducted in 2008–2009 was a population-based study of a sample of 2001 adult men and women, residing in King County, WA, USA.³⁵ Detailed methodology has been published before.^{35,36,44} A stratified sampling scheme ensured adequate representation by income range and race/ethnicity. Randomly generated telephone numbers were matched with residential addresses using commercial databases. A pre-notification letter was mailed out to alert potential participants and telephone calls were placed in the afternoons and evenings by trained, computer-assisted interviewers with up to 13 follow-ups. An adult member of the household was randomly selected to be the survey respondent. Exclusion criteria were age <18 years, cell phone numbers and discordance between address data obtained from the vendor and self-reported by the respondent. The study protocol was approved by the UW Institutional Review Board. Analyses were based on 1304 respondents. The locations of SOS study households are indicated in Figure 1.

The RECORD study recruited 7290 participants between March 2007 and February 2008. The participants were affiliated with the French National Health Insurance System for Salaried Workers, which offers a free medical examination every 5 years to all working and retired employees and their families. People take part in preventive health checkups following referral of their family or workplace physician or on the advice of peers. RECORD participants were recruited among persons attending 2-h preventive checkups conducted by the Centre d'Investigations Préventives et Cliniques in four of its health centers located in Paris, Argenteuil, Trappes and Mantes-la-Jolie.^{45–48} Eligibility criteria were: age 30–79 years; ability to complete study questionnaires; and residence in 1 of the 10 (out of 20) pre-selected administrative districts of Paris or in 111 other municipalities of the metropolitan area selected *a priori*. The pre-selection was intended to oversample disadvantaged municipalities and to allow for sufficient power to compare urban and suburban areas. Among potentially eligible respondents, based on age and residence, 10.9% were not selected because of linguistic or cognitive difficulties in filling out study

questionnaires. Of the selected eligible persons, 83.6% accepted to participate and completed the entire data collection protocol for a total of 7131 respondents. The absence of *a priori* sampling of the participants resulted in selection mechanisms that were previously investigated.⁴⁵ High educated participants and residents from high SES neighborhoods and low density neighborhoods had a higher likelihood of participation in the RECORD study.³

Both studies recruited participants from the city and its suburbs. In the SOS, the distinction was between the city of Seattle and the urban growth boundary of King County. In the RECORD study, the key distinction was between the 10 administrative districts in the city of Paris and the 111 municipalities of the Paris metropolitan area (banlieue, Figure 1).⁴⁹

Demographic, socioeconomic, environmental and weight variables

Table 1 summarizes the principal variables used in the analyses of SOS and RECORD data. Both studies collected data on age, gender, education, incomes and household size. Educational attainment was recoded into three comparable categories for analytical purposes: high school or less, some college, and college graduates or higher. Annual household income was divided into tertiles. Questions about marital status and household size were the same in SOS and RECORD. The dichotomous variable living alone or not was computed based on the reported total number of household members in the SOS and was based on a question on cohabitation status in the RECORD study.

Heights and weights were obtained through telephone self-report in the SOS and measured by a nurse in RECORD study using a wall-mounted stadiometer and a calibrated scale (Seca, Paris, France).⁴¹ BMI was calculated as weight (kg) divided by square of height (m). The cutoff point for obesity ($BMI > 30 \text{ kg m}^{-2}$) was the same in both studies.

Geocoding of home addresses

In the SOS, home addresses were geocoded to the centroid of the home parcel using the 2008 King County Assessor parcel data, and standard methods in ArcGIS 9.3.1 (ESRI, Redlands, CA, USA). Addresses that failed the automatic geocoding (30% using a 100% match score) were manually matched using a digital map environment, augmented by online resources such as GoogleMaps, QuestDEX and Yelp. Each home point was checked for plausibility and accuracy.

In the RECORD study, all home addresses were geocoded using the GeoLoc geocoding software of the French National of Statistics and Economic Studies, ensuring full compatibility with the Census data that are geocoded in the same way. Research assistants rectified incorrect or incomplete addresses with the participants by telephone and consulted with the Department of Urban Planning. Exact spatial coordinates and

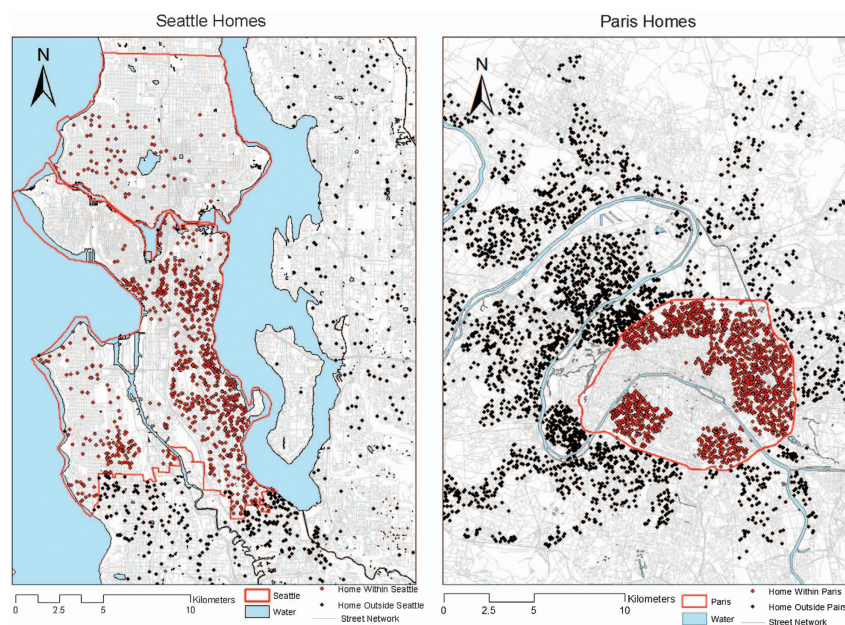


Figure 1. Locations of the study households in the SOS and RECORD studies.

Table 1. Comparison of variables between Seattle and Paris data sets

	Seattle	Paris
Variable name	Age (years)	Age (years)
Measurements	< 45 45–< 65 > = 65	< 45 45–< 65 > = 65
Variable name	Gender	Gender
Measurements	Male Female	Male Female
Variable name	Living alone	Living alone
Measurements	Yes No	Yes No
Variable name	Annual household income	Rvuc (Revenu du ménage par unité de consommation: Household income per unit of consumption per euro per month)
Measurements	Tertile 1 (< 50 000) Tertile 2 (≥ 50 000–< 100 000) Tertile 3 (≥ 100 000)	Tertile 1 (< 1200) Tertile 2 (≥ 1200 to < 2200) Tertile 3 (≥ 2200)
Variable name	Highest education completed	Nivitude_cgi (Niveau d'instruction individuel: education level)
Measurements	High school or less Some college College graduates or higher	1: ne sait pas lire ou écrire le français et sans diplôme; (No education) 2: CAP, BEPC ou brevet des collèges (primary school and lower secondary school) 3: BAC, BTS ou BAC + 2 (higher secondary school and lower tertiary school) 4: supérieur à BAC + 2 (higher tertiary school)
Variable name	Store type by price	Type de supermarché:
Measurements	Low cost Medium cost High cost	hard_discount = 1 hypermarche = 1 OR gd_supermarche = 1 OR pt_supermarche = 1 citymarche = 1 OR magasins_bio = 1
Variable name	BMI	BMI
Measurements	Obese (BMI ≥ 30 kg m ⁻²) Non-obese (BMI < 30 kg m ⁻²)	Obese (BMI ≥ 30 kg m ⁻²) Non-obese (BMI < 30 kg m ⁻²)
Variable name	Perceived health status	Santé_percue
Measurements	Fair/poor Good/very good/excellent	Fair/poor: Scale 0–7 (47%) Good/very good/excellent: Scale 8–10 (53%)
Variable name	Neighborhood assessed property value (property value within the 833 m circular buffer, measured in \$).	Housingrank_500 m (neighborhood property value within the 500 m circular buffer, measured on a 1–1000 scale).
Measurements	70 381–193 106 193 107–248 011 248 012–334 445 334 446–1 086 587	1–301 302–420 421–536 537–1000
Variable name	Distance from home to primary supermarket	Distance_netw_surf (distance entre le supermarché et le lieu de résidence du participant par le réseau de rues: network distance between the supermarket and place of residence of the participant)
Measurements	Km	Km
Variable name	Within the city of Seattle boundary	Within the city of Paris boundary
Measurements	Yes or no	Yes or no

Abbreviation: BMI, body mass index.

accurate block group codes were obtained for 100% of RECORD participants. Both sets of procedures were used to develop spatial coordinates that were used to calculate network distances between the home and the primary supermarket location.

Residential property values

Residential property values in SOS and in RECORD studies were based on buffers centered around each study participant's residence. As such, residential property values represent personalized individual-level metrics that are respondent-centered and independent of any administrative neighborhood or area boundaries.

In the SOS, assessed residential property values were obtained from the 2008 King County tax assessor parcel database. Tax assessment in WA State estimates the full market value of a given property based on recent local sales data (King County Department of Assessments). Property values combined the value of land and improvements (buildings and other structures). These values were averaged within 833-m bandwidth of the individual respondent's home to compute the neighborhood-property value metric. The detailed methodology has already been published.³⁶ For parcels with multiple residential units such as apartment buildings, assessed value per unit was calculated as the sum of a parcel's land and improvement values divided by the number of residential units on the parcel.

In the RECORD study, residential dwelling values were assessed on the basis of notary public data from 2003 to 2007 obtained from Paris-Notaires. After excluding sales with outlying values, prices of sales for each year were standardized on a 1–1000 scale to allow comparability across years and to provide an easier comparison with Seattle. Residential property values within a 500-m radius circular buffers centered on each participant's residence were collected and mean price rank of dwellings sold between 2003 and 2007 in each buffer was then determined. The mean score was categorized by quartiles.

Primary supermarket characteristics

In the SOS, participants were asked to identify their primary food store along with its exact location. Individual full-service supermarkets were identified from the 2008 food establishment permits provided by Public Health Seattle and King County (PHSKC). They were defined as: stores run by nationally or regionally recognized chains, which engaged in retailing a broad selection of foods, such as canned and frozen foods; fresh fruits and vegetables; and fresh and prepared meats. The PHSKC data included 10 254 permit records, 926 of which belonged to 207 unique supermarket stores (most individual supermarkets had multiple permits); 99.6% of the permit addresses were geocoded by the Urban Form Lab (UFL), matched to King County parcel centroids, using ArcGIS, version 9.3.1 (ESRI).

In the RECORD study, participants were asked to report the brand name and street address of the supermarket where they did most of their food shopping.³³ When the exact location of the primary supermarket could not be identified (for example, in cases of single streets with multiple supermarkets of the same brand), study participants were contacted in the month following their health examination to determine where exactly they shopped (790 participants were contacted). Technicians conducting these calls used Google Maps and the websites of the different supermarket brands to obtain the official business identification code (SIRET) of each supermarket. Out of 7290 participants, 7131 could be coded as conducting most of their food shopping in 1097 distinct supermarkets. Following previously published procedures, supermarkets were categorized as hard discount supermarkets, hypermarkets, small/large supermarkets, smaller city markets and organic food stores.³³

Supermarket type by price

In the SOS and the RECORD study, supermarkets were classified into three strata by price. In the SOS, a market basket of 100 commonly consumed foods and beverages, adapted from the Consumer Price Index and Thrifty Food Plan Market Baskets, was developed. It was used to collect food prices from eight store brands: Safeway, Fred Meyer, Quality Food Centers (QFC), Puget Consumer Co-op (PCC), Albertsons, Trader Joe's, Whole Foods and Metropolitan Market. The standardized methodology on the collection of food prices has been published before.⁵⁰ Cluster analysis was used to categorize supermarkets into three price strata—low, medium and high.^{32,51} The lower cost stores included Fred Meyer, Winco Foods, Grocery Outlet and Albertson's, Top Foods; medium cost included Safeway, QFC, Trader Joe's and Red Apple Market; and higher cost included Whole Foods, Metropolitan Market, Madison Market and PCC Natural Markets.

In the RECORD study, supermarkets were classified into three strata by price according to the general knowledge of market segmentation and marketing strategies of the different types of stores. The lower cost stores were 'hard discount' supermarkets; medium-cost stores included large surfaces (hypermarkets) and small/large supermarkets; whereas higher-cost stores combined city markets (Monoprix, Franprix) and organic grocery stores.

Network distances to primary supermarket

Both SOS and RECORD studies calculated road network distances (km) from the home address to the supermarket that was reported to be the primary food source using ArcGIS 9.3.1 (ESRI). In SOS, street network data were obtained from ESRI StreetMap Premium and, in RECORD, from the National Geographic Institute.

Statistical analyses

Modified Poisson regression with robust error variance⁵² was conducted to examine the association between individualized food environment variables (proximity to the primary supermarket and supermarket-type by price), SES and obesity risk. Other covariates included age, gender,

living alone or not, living inside the city or in the suburb, education, household income and neighborhood residential property values. All analyses were conducted using STATA, Statistical Software: Release 10 (StataCorp LP, College Station, TX, USA).

RESULTS

Participant characteristics: SOS and RECORD

The characteristics of SOS and RECORD participants are shown in Table 2. The SOS sample was more likely to be female (63%), married (67%), college educated (57%) and >45 years old (74%). Annual household income was \geq \$50 K for 60% of the sample. For comparison, median income for King County was \$53 157 based on 2000 census data. Obesity prevalence was 21%, similar to the county-wide estimate of 20.2%.

RECORD study participants were more likely to be male (65%), married (70%), and >45 years old (65%). Only 38% were college educated. Obesity prevalence was 12.4%, in line with the French national estimate of 12.4%. Pearson's Chi Square tests indicated that the two samples were statistically comparable by most of the key sociodemographic variables, with the exception of gender and education (P -value <0.001 for each).

Participant characteristics by location of residence are also summarized in Table 2. Living in the city of Seattle, as opposed to living in the suburbs, was associated with higher education, living alone (39% vs 27%), shopping in more expensive supermarkets (20% vs 2%) and with lower obesity rates (18% vs 25%).

Living in the city of Paris, as opposed to living in the suburbs, was also associated with higher education, living alone (37% vs 27%), shopping in more expensive supermarkets (27% vs 12%) and with lower obesity rates (9% vs 14%).

Network distance to primary supermarkets: SOS and RECORD

The median distance between the participants' homes and their primary supermarket was much smaller in Paris than in Seattle (Table 3). The median distance in central Paris was only 440 m as compared with 2.6 km in Seattle. The median distance to the primary supermarket in Paris suburbs was 1.41 km as compared with 3.64 km in Seattle suburbs. By supermarket-type by price, the distance to the higher-cost supermarkets was only 600 m in central Paris and 3.96 km in central Seattle. Paris suburbs also had better access to higher-cost supermarkets than did Seattle suburbs.

Table 4 shows that the sociodemographic profiles of supermarket shoppers were comparable across the two cities. Shoppers at higher-cost supermarkets in Seattle had higher education and incomes, whereas shoppers at lower-cost supermarkets had lower education and incomes. In Seattle, shoppers at low- and medium-cost supermarkets tended to be older and male, whereas shoppers at high-cost supermarkets tended to be younger and female. In the RECORD study, shoppers at high-cost supermarkets had higher education and incomes, with more pronounced effects observed for incomes.

In both Seattle and Paris, high-cost supermarket shoppers had significantly lower obesity rates. In Seattle, obesity prevalence among high-cost supermarket shoppers was only 8%, less than half of the King County average. By contrast, obesity prevalence among low-cost supermarket shoppers was 27%. In Paris, obesity prevalence among high-cost supermarket shoppers was only 7%, whereas among low-cost supermarket shoppers obesity rate was 16%.

Supermarket proximity and price: SOS and RECORD

Modified Poisson regression analyses examined the associations of obesity with food environment variables (supermarket proximity and price) and SES (Table 5).

Table 2. Distribution of study participants by demographic and socioeconomic variables

	Seattle Obesity Study (SOS)			RECORD study		
	Seattle total	Seattle city	Seattle suburb	Paris total	Paris city	Paris suburb
	N = 1340	N = 671	N = 669	N = 7131	N = 2044	N = 5057
<i>Gender</i>						
Men	512 (38%)	243 (36%)	269 (40%)	4658 (65%)	1315 (64%)	3343 (66%)
Women	828 (62%)	428 (64%)	400 (60%)	2473 (35%)	729 (36%)	1744 (34%)
<i>Age categories (years)</i>						
18 to <45	348 (26%)	197 (29%)	151 (23%)	2535 (35%)	746 (37%)	1789 (35%)
45 to <65	691 (52%)	342 (51%)	349 (52%)	3762 (53%)	1022 (50%)	2740 (54%)
≥65	301 (22%)	132 (20%)	169 (25%)	834 (12%)	276 (14%)	558 (11%)
<i>Living alone/not</i>						
Alone	444 (33%)	262 (39%)	182 (27%)	2136 (30%)	751 (37%)	1385(27%)
With others	895 (67%)	409 (61%)	486 (73%)	4995 (70%)	1293 (63%)	3702(73%)
<i>Annual household income</i>						
Tertile 1	540 (40%)	277 (41%)	263 (39%)	2706 (38%)	562 (28%)	2153 (43%)
Tertile 2	457 (34%)	220 (33%)	237 (36%)	2451 (35%)	770 (38%)	1698 (33%)
Tertile 3	343 (26%)	174 (26%)	169 (25%)	1936 (27%)	712 (35%)	1207 (24%)
<i>Education</i>						
High school or less	246 (18%)	87 (13%)	159 (24%)	2303 (36%)	480 (24%)	1823 (36%)
Some college	338 (25%)	150 (22%)	188 (28%)	2098 (30%)	560 (28%)	1538 (31%)
College graduates or higher	756 (57%)	434 (65%)	322 (48%)	2672 (38%)	990 (48%)	1682 (33%)
<i>Neighborhood property value</i>						
Quartile 1	335 (25%)	93 (14%)	242 (36%)	1771 (25%)	352 (17%)	1419 (28%)
Quartile 2	335 (25%)	200 (30%)	135 (20%)	1766 (25%)	747 (37%)	1019 (20%)
Quartile 3	335 (25%)	183 (27%)	152 (23%)	1771 (25%)	533 (26%)	1238 (25%)
Quartile 4	335 (25%)	195 (29%)	140 (21%)	1775 (25%)	390 (19%)	1385 (27%)
<i>Supermarket type</i>						
Low cost	401 (30%)	75 (11%)	326 (49%)	773 (11%)	212 (10%)	561 (11%)
Medium cost	793 (59%)	463 (69%)	330 (49%)	5160 (73%)	1282 (63%)	3878 (77%)
High cost	146 (11%)	133 (20%)	13 (2%)	1149 (16%)	543 (27%)	606 (12%)
<i>BMI</i>						
Obese (BMI ≥ 30 kg m ⁻²)	283 (21%)	199 (18%)	164 (25%)	880 (12%)	192 (9%)	688 (14%)
Non-obese (BMI < 30 kg m ⁻²)	1057 (79%)	552 (82%)	505 (75%)	6192 (88%)	1849 (91%)	4343 (86%)

Abbreviations: BMI, body mass index; RECORD, Residential Environment and Coronary Heart Disease.

Model 1 confirmed the inverse association between obesity and both individual SES (education and household income) and neighborhood-property values, adjusting for demographic variables and city limits. In both Seattle and Paris, higher education and higher household income were associated with lower obesity risk. In both the cities, higher residential property values were associated with a 40% lower obesity risk.

Model 2 introduced the two distinct supermarket variables: proximity and price. Obesity risk among shoppers at higher-cost supermarkets was reduced by 60% in Seattle and by 52% in Paris, relative to shoppers at lower-cost supermarkets, adjusting for individual- and neighborhood-level SES, demographic and distance variables. In both the cities, there was a graded inverse relationship between supermarket category by cost and obesity risk. No associations were observed between distance to the primary supermarket and obesity risk, either in Seattle or in Paris.

DISCUSSION

The SOS and RECORD studies represent the first cross-city and cross-country comparison of the relative contribution of the individualized food environment variables and SES measures to obesity rates. As distinct from the neighborhood-based food

environment, our individual-level measures of the food environment took into account actual food shopping destinations of the study respondents. Those included distance from home to the primary supermarket (a measure of physical access), as well as the price level of the primary supermarket used (a supermarket measure of economic access).

Analyses of the SOS and RECORD data showed that lower education and incomes in both Seattle and Paris were associated with higher obesity risk. Lower residential property values, an additional measure of SES reflecting wealth or the absence of wealth, were also associated with higher obesity risk. Finally, shopping at lower-cost supermarkets was associated with higher obesity risk in both the cities. Comparable findings of a significant SES gradient in obesity were obtained for the two cities and for the suburban areas.

By contrast, higher SES that was linked to living in more affluent neighborhoods and shopping at higher-cost supermarkets exerted a protective effect on obesity risk. Regression models showed that the social mechanisms underlying obesity rates in the two cities were remarkably similar. Some small differences were observed. In the Seattle, residential property values were a better predictor of obesity rates than either education or income. In some US-based studies, education was more protective for

Table 3. Network distances (km) to primary supermarkets by store type

	Seattle Obesity Study (SOS)			RECORD study		
	Seattle total N = 1340	Seattle city N = 671	Seattle suburb N = 669	Paris total N = 7131	Paris city N = 2044	Paris suburb N = 5057
<i>Distance to store (in km)^a</i>						
Mean \pm s.d.	4.08 \pm 3.43	3.63 \pm 3.48	4.53 \pm 3.32	2.37 \pm 5.50	1.65 \pm 6.30	2.65 \pm 5.12
Median (IQR)	3.08 (1.66, 5.52)	2.60 (1.32, 4.60)	3.64 (2.31, 5.95)	1.02 (0.43, 2.48)	0.44 (0.24, 0.91)	1.41 (0.63, 3.04)
<i>Distance by store type (km, mean \pm s.d.)^a</i>						
Low cost	5.23 \pm 3.58	7.49 \pm 4.17	4.71 \pm 3.22	1.96 \pm 4.26	0.69 \pm 1.28	2.44 \pm 4.85
Medium cost	3.45 \pm 2.92	2.91 \pm 2.60	4.19 \pm 3.19	2.74 \pm 6.10	2.28 \pm 7.88	2.86 \pm 5.38
High cost	4.36 \pm 4.52	3.96 \pm 4.21	8.47 \pm 5.61	0.98 \pm 2.02	0.60 \pm 0.59	1.32 \pm 2.69

Abbreviation: RECORD, Residential Environment and Coronary Heart Disease. ^aNote: 29 samples in the Paris data set with a reported travel distance > 100 km were removed from the above descriptive analysis.

Table 4. Participant characteristics by store type

	Seattle Obesity Study (SOS)			RECORD study		
	Lower cost N = 401	Medium cost N = 793	Higher cost N = 146	Lower cost N = 773	Medium cost N = 5160	Higher cost N = 1149
<i>Gender</i>						
Men	157 (39%)	313 (39%)	42 (29%)	474 (61%)	3444 (67%)	710 (62%)
Women	244 (61%)	480 (61%)	104 (71%)	299 (39%)	1716 (33%)	439 (38%)
<i>Income</i>						
Tertile 1	186 (46%)	319 (40%)	35 (24%)	499 (65%)	1980 (39%)	210 (18%)
Tertile 2	134 (34%)	263 (33%)	60 (41%)	197 (25%)	1806 (35%)	433 (38%)
Tertile 3	81 (20%)	211 (27%)	51 (35%)	76 (10%)	1347 (26%)	497 (44%)
<i>Education</i>						
High school or less	98 (25%)	143 (18%)	5 (3%)	341 (45%)	1712 (33%)	238 (21%)
Some college	122 (30%)	200 (25%)	16 (11%)	237 (31%)	1539 (30%)	309 (27%)
College graduate or higher	181 (45%)	450 (57%)	125 (86%)	187 (24%)	1852 (37%)	590 (52%)
<i>Property value</i>						
Quartile 1	158 (39%)	163 (21%)	14 (10%)	284 (37%)	1348 (26%)	124 (11%)
Quartile 2	113 (28%)	190 (24%)	32 (22%)	213 (28%)	1236 (24%)	311 (27%)
Quartile 3	83 (21%)	214 (27%)	38 (26%)	146 (19%)	1305 (26%)	313 (27%)
Quartile 4	47 (12%)	226 (29%)	62 (42%)	128 (16%)	1234 (24%)	393 (35%)
<i>Residence</i>						
City	75 (19%)	463 (58%)	133 (91%)	212 (27%)	1282 (25%)	543 (47%)
Suburb	326 (81%)	330 (42%)	13 (9%)	561 (73%)	3878 (75%)	606 (53%)
<i>Body weight</i>						
Obese	109 (27%)	163 (21%)	11 (8%)	124 (16%)	677 (13%)	75 (7%)
Non-obese	292 (73%)	630 (79%)	135 (92%)	635 (84%)	4441 (87%)	1073 (93%)

Abbreviation: RECORD, Residential Environment and Coronary Heart Disease.

obesity than were incomes, suggesting that better education might be a way to reduce socioeconomic inequalities and improve health.⁵³ In Paris, residential property values and education were closely linked.

The current distinction between physical and economic access to foods has relevance to the obesity-prevention strategies as adopted, respectively, by the United States and by France. First, physical distance to the primary supermarket had no impact on obesity rates either in Seattle or in Paris. These findings run counter to the general consensus in the United States that distance to the nearest supermarket is a predictor of both diet quality and body weight,^{19,20,24,28,54–56} especially in underserved

areas.^{18,20} Previous analyses of RECORD data reported only a very slightly higher BMI among participants shopping the furthest from their residence.³³ On balance, these results suggest that distance to food stores, even when paired with presumably different travel modes⁵⁷ (driving in Seattle and a mix of walking and driving in Paris) may have no direct influence on body weight.

By contrast, obesity rates varied sharply by supermarket type. Now, one popular assumption has been that all supermarkets offer healthful foods at an affordable cost.^{2,19,24,54,55,58–60} However, not all supermarket chains offer food at the same low cost,^{20,26,61–64} and it is well known that different chains cater to the different socioeconomic groups. One interpretation of the present data is

Table 5. Poisson regression with robust error variance to examine the association between obesity, food environment variables (supermarket proximity and type) and SES measures in the SOS and RECORD studies

Independent variables	Seattle Obesity Study (SOS)				RECORD study			
	Model 1		Model 2		Model 1		Model 2	
	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI
<i>Supermarket category</i>								
Lower cost			Ref.				Ref.	
Medium cost			0.89	0.70, 1.15			0.88	0.71, 1.09
Higher cost			0.40	0.21, 0.75			0.48	0.34, 0.66
<i>Distance to primary store</i>								
Every 1 km			1.01	0.98, 1.04			1.00	0.99, 1.01
<i>Neighborhood property value</i>								
Quartile 1	Ref.		Ref.		Ref.		Ref.	
Quartile 2	0.99	0.76, 1.29	0.98	0.75, 1.28	0.83	0.68, 1.01	0.85	0.70, 1.03
Quartile 3	0.77	0.57, 1.04	0.78	0.58, 1.05	0.66	0.54, 0.82	0.69	0.56, 0.85
Quartile 4	0.56	0.39, 0.82	0.60	0.41, 0.87	0.59	0.47, 0.73	0.61	0.49, 0.77
<i>Annual household income</i>								
Tertile 1	Ref.		Ref.		Ref.		Ref.	
Tertile 2	0.79	0.61, 1.01	0.82	0.63, 1.05	0.69	0.58, 0.82	0.72	0.60, 0.86
Tertile 3	0.63	0.45, 0.88	0.65	0.46, 0.92	0.75	0.61, 0.92	0.80	0.64, 0.99
<i>Highest education completed</i>								
High school or less	Ref.		Ref.		Ref.		Ref.	
Some college	0.77	0.58, 1.02	0.77	0.58, 1.02	0.71	0.60, 0.85	0.72	0.61, 0.86
College graduates or higher	0.73	0.56, 0.95	0.76	0.58, 0.99	0.51	0.42, 0.62	0.52	0.43, 0.64

Abbreviations: CI, confidence interval; RECORD, Residential Environment and Coronary Heart Disease; RR, relative risk. Model 1: Adjusted for age, gender, living alone or not, living within city limits or not, education, household income and neighborhood property value. Model 2: Model 1 + supermarket type and supermarket distance. Bold values are statistically significant at the 0.05 level.

that supermarket choice was an understudied manifestation of social class.³⁶ Food-related attitudes and psychosocial factors are other variables that may influence the choice of the supermarket and foods purchased. Additional research will help determine what attitudinal, cultural or psychosocial variables, other than price, contributed to selecting one supermarket over another.

When it comes to policy, building new supermarkets in lower-income neighborhoods is thought to prevent obesity in the United States.^{20,32} By contrast, US government reports have dismissed the issue of food prices as a potential contributing variable,⁶⁵ suggesting that foods costs do not pose a barrier to the adoption of healthier diets, even by low income families on food receiving food assistance. Yet low income communities may be vulnerable to obesity not because the nearest supermarket is several kilometers away but because lower-cost foods tend to be energy dense but nutrient poor. In other words, access to food needs to be measured also in economic terms. In France, supermarket coverage is considered to be adequate. Both researchers and policymakers have focused on the quality of foods available in affluent vs deprived neighborhoods.

Both the SOS and RECORD studies had limitations. The SOS sample, based on a random landline-telephone survey (a standard BRFSS procedure) was older, better educated and had a higher proportion of females. Conversely, the Paris sample was largely male and had a lower proportion of college-educated respondents. BMI data were based on self-reported heights and weights in SOS. It is already known that the overweight or obese individuals tend to under-report their weight, which may have attenuated our results. However, the comparisons across Seattle and Paris would remain unaffected. In the SOS, classification of supermarkets by price was based on a direct assessment of a market basket of foods. The French classification was based on

supermarket characteristics as described in the literature. The property values were computed using different spatial units (500 m buffer in Paris vs 833 m buffer in Seattle); however, these buffers sizes were determined based on the different urban form of the respective cities. Neighborhood-property values measured as buffers raised concerns for spatial clustering and correlation, although previous research using the SOS data set showed that there was no spatial clustering in the neighborhood-property value estimations.^{36,66} Both studies were cross sectional, limiting our ability to draw causal inference from the observed associations.

Nonetheless, the present results underscored the importance of obtaining data on actual food shopping locations to complement objective information on the neighborhood-based food environment around the residence or workplace. Measuring the food environment at the individual level requires knowing who shops for food where, how often and why. Lacking such behavioral data, past studies were forced to assume, perhaps incorrectly, that most people shopped for food within their neighborhood. In the SOS, only 14% and, in the RECORD study, only 11.4% of the respondents shopped for food either at the closest supermarket or in their own residential neighborhood.³³ It appears that people are willing to travel longer distances from home to arrive at the supermarket of their choice.

The present Seattle-Paris comparisons are valuable given the different socioeconomic, behavioral and environmental context of the two cities. The relative influences of income, education and property values on obesity rates in different countries can provide an insight into mechanisms that determine food choices, diet quality and selected health outcomes.⁶⁷⁻⁶⁹ Given the wide differences in urban form between Seattle and Paris, the present analyses attest to the potential generalizability of the socioeconomic determinants of weight and health.

The much higher prevalence of adult obesity in the United States as compared with France^{38,39} can also be discussed in the context of very different social and medical systems dealing with disease prevention and health care. The present findings of a comparable SES gradient suggest that socioeconomic variables affect body weight even when the population has equal access to health care.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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