Chapter 2.2.4 Interactions between supermarket proximity and educational attainment predict likelihood of overweight and obesity in Cambridgeshire, UK


Submitted

Abstract

We aimed to examine associations between supermarket proximity and education, with body weight, overweight and obesity. Also, we examined the magnitude and excess risk of overweight and obesity associated with poorest supermarket access and lowest education combined, relative to those with greatest supermarket access and highest education. This was a population based, cross sectional study, using individual level participant data and objectively measured supermarket proximity. Adults participated in the Fenland Study, Cambridgeshire, UK (n=9702, aged 29-64 years), and provided home addresses. Major chain supermarket locations were provided by local authorities. Supermarket proximity was calculated as the shortest street network distance from home address to nearest supermarket. Proximity was divided into tertiles. Educational attainment groups were: lowest (≤11 years of education), middle (11-13 years) and highest (>13 years). Main outcome measures were measured body mass index; overweight and obesity body mass index cut-offs as defined by the World Health Organization. In adjusted multiple linear and multinomial logistic regression models, participants living farthest away from a supermarket had higher body mass index (β coefficient=0.58, 95% confidence interval 0.35 to 0.81; P<0.001) and odds of obesity (odds ratio 1.27, 1.11 to 1.44), relative to those living closest, with evidence of dose-response associations. Lower education was also independently associated with higher body mass index and odds of obesity. Those least educated and living farthest away from their nearest supermarket were 4.29 (3.20 to 5.76) times more likely to be obese, relative to those highest educated and living closest. Relative excess risk due to interaction (RERI) for obesity was 0.37, suggesting positive additive interaction between education and supermarket proximity. Results for overweight were similar. Poorer supermarket access and lower education were independently associated with higher body weight and greater likelihood of overweight and obesity, and in combination, with a fourfold greater likelihood of being obese. Evidence of additive interaction suggests excess risk of overweight and obesity associated with having both poor supermarket access and low education. These findings contribute to our understanding of observed and continued socioeconomic inequalities in weight status in the UK.
Introduction

Overweight and obesity are major and increasingly severe public health problems. By 2050, 60% of men and 50% of women are predicted to be obese in the UK.[1] Obesity is associated with increased risk of type 2 diabetes, coronary heart disease and stroke.[2] These comorbidities and others have substantial social and economic implications. Through lost working hours and healthcare costs for example, overweight and obesity are forecast to cost the UK economy £49.9 billion annually by 2050.[1]

The causes of obesity are many and varied, including factors at individual, interpersonal, organisational, environmental and public policy levels. At the individual level, socioeconomic status has been consistently associated with weight. Clear gradients in obesity rates have been observed across markers of socioeconomic status including education, household income and occupational social class.[3-5] Recent findings from the Health Survey for England showed 47% lower obesity prevalence among those with degree level qualifications compared to those with no qualifications.[6]

Characteristics of neighbourhood food environments, including the density, distribution and variety of food stores within our towns and cities, are also increasingly viewed as important environmental contributors to body weight and health. Offering a range of fresh, healthy produce at a variety of price points, access to neighbourhood supermarkets may be especially important for supporting healthy food choices and healthy weights. However, the scientific evidence base regarding the impact of neighbourhood supermarket access on weight remains relatively small and largely equivocal.[7-9]

Further research is required as poor neighbourhood supermarket access represents a modifiable risk factor for obesity that could be leveraged to reduce both present and future obesity burdens. A limited number of government policy programmes, both from the US, including the Pennsylvania Fresh Food Financing Initiative[10] and the White House Task Force on Obesity’s Healthy Food Financing Initiative,[11] have already sought to improve poor neighbourhood fresh food retail in order to improve health. However, a lack of clarity in the research evidence, especially in the UK,[7] has constrained our understanding of how successful these interventions might be, and may have limited their introduction outside the US in particular.

Unlike in the US,[12] research does not suggest that supermarkets are inequitably distributed by socioeconomic status in the UK.[13-15] However, supermarket access inevitably varies both spatially and across population groups. Where it occurs, the combined effects of poor neighbourhood supermarket access and low socioeconomic status on body weight are unknown. Moreover, people from low socioeconomic status backgrounds may be especially vulnerable to their environments,[16,17] with low socioeconomic status potentially exaggerating the effects of poor supermarket access.[18] This would represent a significant challenge to maintenance of healthy weight, potentially contributing to observed socioeconomic inequalities in the UK and elsewhere.

The purpose of this study was to establish main independent associations between supermarket proximity and education, with body weight, overweight and obesity in the UK. Principally, our study was also motivated by a need to better understand the magnitude and excess odds of overweight and obesity associated with the combined effect of poorest supermarket access and lowest education, relative to those with greatest access and highest education.
Methods

Study sample
We used data from the Fenland Study, a population based cohort of adults aged 29-64 years (born 1950-1975) in Cambridgeshire, UK. The Fenland Study was conducted by the MRC Epidemiology Unit (for more details: www.mrc-epid.cam.ac.uk/research/studies/fenland/). Recruitment took place from general practice lists in Cambridge, Ely and Wisbech between 2005 and 2014. At the time of this analysis, 11,857 participants had been enrolled into the study. Participants completed general questionnaires related to their lifestyle, medical history and home address, and were weighed and measured by trained researchers. All study procedures were approved by the Health Research Authority NRES Committee East of England-Cambridge Central.

Exposure – supermarket proximity
Participants’ home addresses were mapped by postcode using a geographic information system (ArcGIS 10, ESRI). Postcodes in the UK contain only 15 individual addresses on average and therefore allow for relatively precise geocoding. Data on the locations of food outlets were sourced from 10 local authorities covering the study area in December 2011, and mapped by postcode. Accurate food outlet records are held by local authorities to facilitate routine food hygiene inspections.[19] Food outlets were classified by type by a single researcher (eliminating inter-rater bias), according to a previously published classification scheme as: restaurants; convenience stores; cafes; entertainment venues selling food; specialist retailers such as butchers and fishmongers; takeaway food (‘fast food’) outlets; or supermarkets.[19] We classified supermarkets as the seven national chain retailers who have a substantial share of the UK grocery market: Tesco, Sainsbury’s, ASDA, Morrisons (who between them hold 73% of total market share), Waitrose, Aldi and the Co-operative.[20] Using Ordnance Survey’s MasterMap Integrated Transport Network, calculated supermarket access as proximity (km) from home to work along the shortest street network route.

Outcomes – body mass index, overweight and obesity
Body mass index (kg/m²) was calculated from measured height and weight. We applied World Health Organization cut-offs for overweight (25 ≥ body mass index < 30) and obesity (≥ 30).

Statistical analyses
We used multiple linear regression models to estimate associations between supermarket proximity and body mass index. Using dummy variables, we modelled supermarket proximity in tertiles, relative to those living closest to their nearest supermarket. Covariates were selected a priori, and fully adjusted models included the following: age, sex, car access (as a proxy for mobility beyond the immediate neighbourhood), smoking status and physical activity energy expenditure (kJ/kg per day, estimated from combined heart rate sensors and accelerometers (Actiheart, CamNtech) worn for up to six days,[21,22] with participants with less than 48h wear time excluded (n=101)). In order to minimise residual confounding, we adjusted for the number of other types of food outlet within a 1 mile Euclidean radius buffer of the participant’s nearest supermarket. These other types of food outlets were restaurants, convenience stores, cafes, entertainment venues, specialist retailers, other supermarkets and takeaway food outlets. We also adjusted for highest educational attainment and total
household income as indicators of socioeconomic status. Educational attainment groups were: lowest (up to 11 years of education), middle (13 to 13 years of education), and highest (more than 13 years of education). Total gross household income groups were: lowest (<£20,000), middle (£20,000-£40,000), and highest (>£40,000).

We adjusted for the same covariates in multinominal logistic regression models to estimate associations between supermarket proximity and odds of overweight and obesity. We calculated relative excess risk due to interaction (RERI), which quantifies interaction on an additive scale relative to a single reference group (closest supermarket proximity tertile, highest educated), for the combined associations of education and supermarket access with odds of overweight and obesity. Excess risk of overweight and obesity would be indicated by a combined risk greater than the additive effects of each risk factor in isolation.[23,24] RERI was calculated as follows:

$$RERI = OR_{11} - OR_{10} - OR_{01} + 1$$

where ORs are odds ratios for being overweight or obese for those with lowest supermarket access and lowest education (OR$_{11}$), those with greatest supermarket access and lowest education (OR$_{10}$) and those with lowest supermarket access and highest education (OR$_{01}$).[23] Positive additive interaction is indicated by RERI scores greater than zero. RERI results are presented according to established guidelines.[23]

To establish independent associations of education with body weight, odds of overweight and obesity, we used multiple linear and logistic regression models adjusting for the same set of covariates, but substituting highest educational attainment for supermarket proximity. The reference group in these models was those with highest educational attainment.

In all analyses we excluded participants with missing data (n=629), as well as those living outside the study area of Cambridgeshire (n=1425), resulting in an analytic sample of 9702. The complete case analytic sample remained representative of the full Fenland Study sample across key variables (data not shown). All analyses were conducted using PASW Statistics 21.0 (SPSS Inc., Chicago).

**Results**

**Sample characteristics**

Table 2.2.4.1 shows descriptive statistics for the study sample stratified by educational attainment. Mean (SD) age of the participants was 48.1 (7.3) years, with 48.9% of the sample being male. Mean (SD) body mass index was 26.9 (4.7), with 40.3% of the sample being overweight and 21.0% being obese. Mean street network distance to the nearest supermarket was 3.8km. Relative to the most educated, those least educated were on average 33% further away from their nearest supermarket.

Mean body mass index was 2.0 units higher in those with lowest levels of education compared to those with highest levels of education. A greater proportion of those lowest educated were also overweight or obese. In multivariable adjusted models (Table 2.2.4.1), those with lowest levels of education had a
BMI 1.77 (95% CI 1.49, 2.04) units greater on average than those most educated, and were over twice as likely to be overweight (OR=2.11, 95% CI 1.85, 2.42) or obese (OR=2.01, 95% CI 1.71, 2.36).
Table 2.2.4.1. Characteristics of participants in the Fenland study sample, Cambridgeshire, UK, by educational attainment (n=9702).

<table>
<thead>
<tr>
<th></th>
<th>Educational Attainment a</th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Highest (n=3157)</td>
<td>Middle (n=4565)</td>
<td>Lowest (n=1980)</td>
<td>All (n=9702)</td>
</tr>
<tr>
<td>Age</td>
<td>47.1 (7.6)</td>
<td>48.3 (7.1)</td>
<td>49.1 (7.0)</td>
<td>48.1 (7.3)</td>
</tr>
<tr>
<td>Men (n (%) of participants)</td>
<td>1603 (50.8)</td>
<td>2301 (50.4)</td>
<td>843 (42.6)</td>
<td>4747 (48.9)</td>
</tr>
<tr>
<td>Physical activity energy expenditure (kJ/kg/day)</td>
<td>53.1 (20.1)</td>
<td>55.1 (22.5)</td>
<td>54.8 (24.0)</td>
<td>54.4 (22.1)</td>
</tr>
<tr>
<td>Household income &gt;£40,000 (n (%) of participants)</td>
<td>2360 (74.8)</td>
<td>2090 (45.8)</td>
<td>585 (29.5)</td>
<td>5035 (51.9)</td>
</tr>
<tr>
<td>Car access (n (%) of participants)</td>
<td>2861 (90.6)</td>
<td>4393 (96.2)</td>
<td>1865 (94.2)</td>
<td>9119 (94.0)</td>
</tr>
<tr>
<td>Current smoker (n (% of participants)</td>
<td>199 (6.3)</td>
<td>604 (13.2)</td>
<td>347 (17.5)</td>
<td>1150 (11.9)</td>
</tr>
<tr>
<td>Distance to nearest supermarket (km)</td>
<td>3.0 (3.4)</td>
<td>4.2 (3.7)</td>
<td>4.0 (3.6)</td>
<td>3.8 (3.6)</td>
</tr>
<tr>
<td>Food outlets within a 1 mile Euclidean buffer of the nearest supermarket (n)</td>
<td>134.6 (119.7)</td>
<td>79.8 (69.6)</td>
<td>76.9 (60.2)</td>
<td>97.0 (91.5)</td>
</tr>
<tr>
<td>Body mass index (kg/m$^2$)</td>
<td>25.7 (4.3)</td>
<td>27.3 (4.8)</td>
<td>27.7 (4.9)</td>
<td>26.9 (4.7)</td>
</tr>
<tr>
<td>Overweight, 25kg/m$^2$ &gt; BMI ≤ 30kg/m$^2$ (n (%) of participants)</td>
<td>1178 (37.3)</td>
<td>1897 (41.6)</td>
<td>833 (42.1)</td>
<td>3908 (40.3)</td>
</tr>
<tr>
<td>Obese, BMI &gt; 30kg/m$^2$ (n (%) of participants)</td>
<td>414 (13.1)</td>
<td>1110 (24.3)</td>
<td>514 (26.0)</td>
<td>2038 (21.0)</td>
</tr>
</tbody>
</table>

Adjusted weight status outcomes b

- Body mass index (kg/m$^2$), $\beta$ (95% CI) | ref | 1.41 (1.19, 1.63)** | 1.77 (1.49, 2.04)** | -
- Overweight (25$\geq$Body mass index<30), OR (95% CI) | ref | 1.79 (1.61, 2.00)** | 2.11 (1.85, 2.42)** | -
- Obese (Body mass index$\geq$30), OR (95% CI) | ref | 1.89 (1.65, 2.16)** | 2.01 (1.71, 2.36)** | -

Data are mean (standard deviation) unless otherwise stated.

** P<0.001.

* Educational attainment, three groups: Lowest=up to 11 years of education; Middle=11 to 13 years of education; Highest=more than 13 years of education.  
** Adjusted for age, sex, household income, car access, smoking status, physical activity energy expenditure, supermarket proximity and exposure to other food outlets with a 1 mile Euclidean radii buffer of the nearest supermarket.
Associations between supermarket proximity and body mass index

Greater distance to the nearest supermarket was associated with significantly greater body weight, with evidence of a dose-response association. In the unadjusted model 1 (Table 2.2.4.2), those with living farthest away from their nearest supermarket were on average 1.07 kg/m² heavier than those living closest (P<0.001). Adjusting for additional individual and neighbourhood level covariates attenuated this association, however those living farthest away remained 0.58 kg/m² heavier on average (P<0.001).

Associations between supermarket proximity, overweight and obesity

Greater distance to the nearest supermarket was associated with significantly greater odds of both overweight and obesity, with evidence of dose-response associations. In the unadjusted model 1 (Table 2.2.4.2), those living farthest away from their nearest supermarket were 1.55 times more likely to be overweight (95% CI 1.40, 1.71) and 1.52 times more likely to be obese (95% CI 1.35, 1.72). Adjusting for additional covariates attenuated these associations, however those living farthest away remained 1.30 times more likely to be overweight (95% CI 1.17, 1.46) and 1.27 times more likely to be obese (1.11, 1.44).

Combined associations of supermarket proximity and education with overweight and obesity

Greater odds of overweight and obesity were associated with supermarket access and educational attainment in combination, in excess of the odds associated with either poorest access or lowest education alone. Table 2.2.4.3 shows adjusted multinomial logistic regression results for each combination of supermarket proximity tertile and level of education. Those living farthest away from their nearest supermarket and lowest educated were 2.40 (95% CI 1.91, 3.03) times more like to be overweight than those living closest and with highest education. Those living farthest away but most educated were 1.29 (95% CI 1.05, 1.58) times more likely to be overweight, while those with lowest education but living closest to their nearest supermarket were 1.61 (95% CI 1.25, 2.07) times more likely to be overweight. For overweight, relative excess risk due to interaction (RERI) was 0.50. Those living farthest away from their nearest supermarket and lowest educated were 4.29 (95% CI 3.20, 5.76) times more likely to be obese; odds in excess of the additive associations of farthest supermarket proximity (OR=1.82, 95% CI 1.37, 2.41) or lowest education (OR=3.10, 95% CI 2.27, 4.23) in isolation. For obesity, RERI was 0.37.
Table 2.2.4.2. Coefficients and odds ratios with 95% confidence intervals of tertiles of distance to the nearest supermarket (physical access) with body mass index, overweight and obesity, as derived from linear and logistic regression analysis (n=9702).

<table>
<thead>
<tr>
<th>BMI</th>
<th>Tertile (range)</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>β</td>
<td>95% CI</td>
<td>β</td>
</tr>
<tr>
<td></td>
<td>Distance to nearest supermarket tertile</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>T1 (0.0-1.1km)</td>
<td>ref</td>
<td>ref</td>
<td>ref</td>
</tr>
<tr>
<td></td>
<td>T2 (1.1-4.9km)</td>
<td>0.84**</td>
<td>0.61; 1.07</td>
<td>0.58**</td>
</tr>
<tr>
<td></td>
<td>T3 (4.9-15.1km)</td>
<td>1.07**</td>
<td>0.84; 1.30</td>
<td>0.71**</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Overweight</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR</td>
<td>95% CI</td>
<td>OR</td>
</tr>
<tr>
<td>Distance to nearest supermarket tertile</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1 (0.0-1.1km)</td>
<td>ref</td>
<td>ref</td>
<td>ref</td>
</tr>
<tr>
<td>T2 (1.1-4.9km)</td>
<td>1.38**</td>
<td>1.25; 1.52</td>
<td>1.29**</td>
</tr>
<tr>
<td>T3 (4.9-15.1km)</td>
<td>1.55**</td>
<td>1.40; 1.71</td>
<td>1.38**</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Obesity</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR</td>
<td>95% CI</td>
<td>OR</td>
</tr>
<tr>
<td>Distance to nearest supermarket tertile</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1 (0.0-1.1km)</td>
<td>ref</td>
<td>ref</td>
<td>ref</td>
</tr>
<tr>
<td>T2 (1.1-4.9km)</td>
<td>1.38**</td>
<td>1.22; 1.56</td>
<td>1.26*</td>
</tr>
<tr>
<td>T3 (4.9-15.1km)</td>
<td>1.52**</td>
<td>1.35; 1.72</td>
<td>1.34**</td>
</tr>
</tbody>
</table>

*P<0.05; **P<0.001.

Model 1 is an unadjusted model | Model 2 adjusts for age, sex, household income, car access, highest educational attainment, smoking status and physical activity energy expenditure (individual level covariates) | Model 3 additional adjusts for exposure to other food outlets with a 1-mile Euclidean radii buffer of the nearest supermarket | T1=tertile with shortest distance to the nearest supermarket | T3=tertile with longest distance to the nearest supermarket.
Table 2.2.4.3. Odds ratios and 95% confidence intervals representing additive interaction terms between access to supermarkets and educational attainment on the likelihood of being overweight or obese, as derived from a single multinomial regression model in the Fenland Study sample (n=9702).

<table>
<thead>
<tr>
<th>Educational</th>
<th>over/normal</th>
<th>OR (95% CI)</th>
<th>over/normal</th>
<th>OR (95% CI)</th>
<th>over/normal</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest</td>
<td>541/793</td>
<td>ref</td>
<td>315/427</td>
<td>1.04 (0.85, 1.26); P=0.75&lt;sup&gt;d&lt;/sup&gt;</td>
<td>322/345</td>
<td>1.29 (1.05, 1.58); P=0.01&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Middle</td>
<td>509/483</td>
<td>1.52 (1.26, 1.82); P&lt;0.001&lt;sup&gt;d&lt;/sup&gt;</td>
<td>677/511</td>
<td>1.95 (1.64, 2.34); P&lt;0.001&lt;sup&gt;d&lt;/sup&gt;</td>
<td>711/564</td>
<td>1.74 (1.46, 2.08); P&lt;0.001&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Lowest</td>
<td>196/185</td>
<td>1.61 (1.25, 2.07); P&lt;0.001&lt;sup&gt;d&lt;/sup&gt;</td>
<td>326/249</td>
<td>2.11 (1.70, 2.63); P&lt;0.001&lt;sup&gt;d&lt;/sup&gt;</td>
<td>311/199</td>
<td>2.40 (1.91, 3.03); P&lt;0.001&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Educational</th>
<th>obese/normal weight</th>
<th>OR (95% CI)</th>
<th>obese/normal weight</th>
<th>OR (95% CI)</th>
<th>obese/normal weight</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest</td>
<td>152/793</td>
<td>ref</td>
<td>124/427</td>
<td>1.32 (1.00, 1.75); P=0.05&lt;sup&gt;d&lt;/sup&gt;</td>
<td>138/345</td>
<td>1.82 (1.37, 2.41); P&lt;0.001&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Middle</td>
<td>276/483</td>
<td>2.63 (2.05, 3.36); P&lt;0.001&lt;sup&gt;d&lt;/sup&gt;</td>
<td>384/511</td>
<td>3.64 (2.86, 4.62); P&lt;0.001&lt;sup&gt;d&lt;/sup&gt;</td>
<td>450/564</td>
<td>3.48 (2.74, 4.42); P&lt;0.001&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Lowest</td>
<td>129/185</td>
<td>3.10 (2.27, 4.23); P&lt;0.001&lt;sup&gt;d&lt;/sup&gt;</td>
<td>202/249</td>
<td>4.02 (3.04, 5.31); P&lt;0.001&lt;sup&gt;d&lt;/sup&gt;</td>
<td>183/199</td>
<td>4.29 (3.20, 5.76); P&lt;0.001&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Measure of interaction on an additive scale (RERI) for overweight = 0.50; for obesity = 0.37. RERI scores >0 suggest positive interaction and departure from additivity.

ORs are adjusted for age, sex, household income, smoking status, car access, physical activity energy expenditure and exposure to other food outlets within a 1km Euclidean buffer of the nearest supermarket.

<sup>a</sup>T1=tertile with shortest distance to the nearest supermarket – T3=tertile with longest distance to the nearest supermarket  |  <sup>b</sup>Educational attainment, three groups: Lowest=up to 11 years of education; Middle=11 to 13 years of education; Highest=more than 13 years of education  |  <sup>c</sup>Single reference group; those highest educated and with shortest distance to the nearest supermarket  |  <sup>d</sup>ORs and P values relative to single reference group (ref).
Discussion

In previous studies, socioeconomic status has been consistently associated with diet and body weight. By providing access to a range of healthy foods at a variety of price points, it has also been suggested that access to a supermarket is important for maintaining a healthy diet and weight. In our study, both lower educational attainment and greater distance to the nearest supermarket were independently associated with higher body weight and odds of both overweight and obesity, with evidence of dose response relationships. Importantly, the combined associations of lowest supermarket access and lowest education with likelihood of both overweight and obesity were substantially in excess of the additive associations between these weight status outcomes and having either of these risk factors in isolation. The magnitude of these relationships, with combined lowest supermarket access and lowest education associated with a fourfold greater likelihood of obesity, provides further cause for public health concern.

Despite a marked increase in the number of studies examining the environmental determinants of body weight over the past decade, recent systematic reviews have illustrated mixed results, and a particular lack of clarity with regards the importance of supermarkets for health. A review of North American studies found that greater supermarket access was associated with lower body weight in only 23% of the 93 associations tested.[8] While one study in the Republic of Ireland found that supermarket proximity was related to eating a healthy diet,[25] we are unaware of any observational UK studies addressing the relationship between supermarket access and weight. The international literature linking supermarket access to diet is similarly equivocal.[7,26] By demonstrating associations between supermarket proximity and body weight in a large sample of UK adults, we have begun to address this knowledge gap, and to build upon the international research that has demonstrated this association.[27-30]

Moreover, through evaluating the interaction of the environment with individual level socioeconomic status, we have observed the generation of an excess risk of both overweight and obesity in the presence of both poor supermarket access and low socioeconomic status.[16,31]

Potential Mechanisms

Although an understanding of precise mechanisms bears further research, previous research findings suggest explanations. Established behavioural, psychosocial and economic attributes, which have been linked to socioeconomic gradients in obesity, may also confer increased environmental vulnerability and therefore exaggerate the effects of poor supermarket access.[13,28] In areas with poorer access to supermarkets, individuals may be more likely to purchase food from other types of food outlets.[32] For example, consumers may rely more heavily on foods prepared for them outside of the home at takeaway (‘fast food’) outlets.[33] These food outlets typically sell large portions of less healthy food than can be prepared at home,[34] and increased patronage of such outlets has been associated with weight gain over time.[35,36] Within these outlets, the price sensitivity of low income, low-socioeconomic status consumers may result in the selection of energy-dense products that are perceived to offer value for money.[37,38] Individuals with poor nutrition knowledge (strongly linked to low socioeconomic status) may make less-healthy choices,[39] further disadvantage them by comparison to their counterparts in higher socioeconomic groups. Research has previously
demonstrated how individuals in lower socioeconomic groups are more likely to choose less healthy takeaway food options, compared to those in higher socioeconomic groups.[40]

Alternatively, evidence suggests that individuals are often compelled in areas with poorer access to supermarkets to rely more heavily on convenience stores for their grocery shopping.[32] Convenience stores are typically more expensive than supermarkets, offering more limited product lines,[41] while qualitative reports suggest that healthy foods are also more hidden, often among marketing and promotional materials for less healthy foods in particular.[32] These in-store attributes may especially disadvantage groups of low socioeconomic status, who spend less per calorie than any other social group;[25,26] perceive healthy food to be expensive;[42] may be less equipped to cook healthy meals from scratch from a limited grocery selection;[43] may be more susceptible to unhealthy food marketing and unhealthy product placement;[44] and whom may not value their own health sufficiently enough to “hunt” for healthy options in a within-store environment that encourages unhealthy purchases.[32,45] Moreover, in the absence of accessible supermarkets, reliance on these other types of food outlet near to home may be further exaggerated in groups of low socioeconomic status through unemployment,[46] low levels of car access[47] and restricted time budgets,[48] which serve to limit and constrain daily mobility. In a UK study, the median distance to a participant’s main grocery store was 63% greater among those with car access as opposed to no car access.[14]

Our study was also motivated to better understand the magnitude in odds of overweight and obesity associated with combined poorest supermarket access and lowest education (most ‘at risk’), relative to those with greatest access and highest education (least ‘at risk’). We hypothesised that if we have access to a neighbourhood supermarket resource, which we choose to use and use well (choices constrained by socioeconomic status), we might have a very different weight, relative to those who lack supermarket access and are less-equipped (constrained by socioeconomic status) to make healthy choices. We have successfully illustrated just how different the odds of both overweight and obesity would be on average between these groups, observing a fourfold greater likelihood of being obese among those disadvantaged both socioeconomically and in terms of supermarket access. The magnitude of such compounding helps us to understand how socioeconomic health inequalities may, to some extent, be generated and perpetuated in the UK. Moreover, it is notable that in this study – although not in any previous UK study[13-15] – those least educated were the most disadvantaged in terms of supermarket access. Our findings are consistent with international studies that have observed similar compound deprivation effects associated with takeaway (‘fast-food’) food,[49] and green space access.[50]

**Implications for policy**

The observed association between supermarket access and body weight is of policy importance, possibly lending support for improvements in public health by improving access to supermarkets. In the US, government initiatives and farmers markets in particular have helped to improve healthy food retail in areas where supermarkets were unable to locate.[51] In the UK, the emergence and growing popularity of small format chain supermarket stores[41] may help to facilitate this ‘supermarket solution’.[52] However, as others have previously suggested,[14,53] our results stress a second important point of intervention at the level of the individual, in order to maximise the success of any new neighbourhood healthy food retail.[32] Experimental studies evaluating the introduction and failure of a new neighbourhood supermarket (in isolation) to deliver meaningful dietary change have
concluded similarly.[7,31,32] Specifically, targeting those with poor geographic supermarket access and lowest education with interventions at multiple levels could yield large benefits for public health. While individual level interventions such as those targeting improvements in cooking skills (Jamie Oliver’s Ministry of Food programme being a high profile example)[54] have historically been problematized for relying heavily on individual agency alone for their success,[55] structural barriers to intervention uptake are often poorly understood and improvements in cooking skills might only be sustained within a supportive neighbourhood food environment. This hypothesis is supported by the results of a recent US study, where the effects of a weight loss intervention for those with metabolic syndrome were greatest among participants with the best neighbourhood grocery store access.[56]

Although much more research will be required to understand the combined effects of interventions at multiple levels to improve diet and health, the identification of this ‘at risk’ group will also be a major challenge. Unlike in the US,[12] the notion of ‘food deserts’ in the UK, where whole neighbourhoods suffer from both poor socioeconomic and geographic access to healthy foods, has become contextually outdated.[57] However, Cambridgeshire supermarket access in this study was unequal, ranging from zero to fifteen kilometres. Understanding and identifying address-level differences in supermarket access UK-wide, in conjunction with socioeconomic data, and tracking these differences over time in response to neighbourhood supermarket interventions, would represent important first steps in addressing extreme access disparities and monitoring their reduction.

Methodological considerations and limitations

Supermarket access exposure misclassification could have resulted from the assumption that study participants would shop at the closest supermarket to their home. Although supermarket exposure was not constrained to an arbitrary researcher- or administratively-defined neighbourhood ‘container’, we had no information on where or at which supermarket participants actually shopped for food. A US study showed that only one in seven food shoppers chose to patronise the supermarket closest to their home.[58] It should be noted however that this ‘uncertain geographic context problem’ is not limited to this study.[59] Furthermore, while supermarkets may be accessed from non-home locations, previous UK research highlighted proximity to home as a major contributor to supermarket choice,[14] while 92% of shoppers in one US study reported leaving from home to conduct their grocery shopping.[33] Although our local authority food outlet location data was not ground-truthed for locational accuracy, we have shown previously that this data represents the most accurate of its kind in the UK,[19] minimising further potential risk of exposure misclassification. Temporal mismatch may have resulted in misclassification as our exposures (supermarket locations) and outcomes (body weight, overweight, obesity) were measured at different time points (2011 and 2005-2014, respectively). However, growth in the UK supermarket sector has historically been slow.[13] Our study was based on observational, cross-sectional data, which limits inference on causal relationships. Finally, our study utilised a representative sample of the Cambridgeshire population that was more highly educated and less ethnically diverse than the wider UK, which may limit generalisability.
Conclusions

This study used a large and unique UK dataset, containing both individual level geographic and well characterised socioeconomic information, combined with accurate neighbourhood environment data, to examine independent and combined associations of geographic supermarket access and highest level of education with body weight, likelihood of being overweight and obese. The study showed strong associations between poorer supermarket access as well as lower education, with higher body weight, greater odds of overweight and obesity, and with evidence of dose response relationships. The study also established exaggerated risk of overweight and obesity, associated with poorest supermarket access and lowest education, above and beyond the level of additive risk associated with experiencing each of these risk factors in isolation. Moreover, the fourfold level of risk associated with having poorest supermarket access and lowest education, compared to having the greatest supermarket access and highest education, is a matter of public health concern with implications for how we understand health inequalities and interventions to improve them.

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2.2
Chapter 2.2.5 Exploring the relation of spatial access to fast food outlets with obesity


Submitted

Abstract

We examined whether perceived availability and usage of fast food outlets, and consumption of fast food, mediated the association between spatial access to fast food outlets and obesity. Data from 5,084 SPOTLIGHT survey participants, residing in five European urban regions, were analyzed. Direct associations and mediating effects of spatial access to fast food outlets, perceived availability and usage of fast food outlets, fast food consumption and self-reported weight status were explored using multilevel logistic and multinomial regressions, adjusted for socio-demographics, presence of other food outlets and residential self-selection. Living in a neighborhood with most spatial access to fast food outlets was associated with perceived availability and usage of fast food outlets (RRR=3.30, 95%CI=1.71; 6.34), but not with fast food consumption or obesity. Perceived availability and usage of fast food outlets was associated with greater reported consumption (OR=1.55, 95%CI=1.05; 2.28). The notion of usage appears central in the food environment-obesity relation.