Quantifying the Impact of Supermarket Distance on Childhood Obesity in Greater London, UK: Exploring Different Access Measures and Modification Effects of Transportation

Elzbieta Titis, MS

Abstract

Background: Healthy food access may be relevant for predicting trends in childhood obesity. The goal was to determine associations between childhood overweight (including obesity) and distance to three nearest supermarkets stratified by transportation modes (walking, cycling, driving).

Methods: Bivariate and multivariate linear regressions examine the relationship with obesity, including interacting active and inactive modes.

Results: Proximity to at least three supermarkets shows small but significant positive association with obesity. Walking mode showed higher obesity rates than driving, and distance was not related to the mode of travel.

Conclusions: Disparities in healthy food access may not contribute meaningfully to childhood obesity, as other individual factors may be largely at play.

Keywords: childhood obesity; food access; supermarket; transportation

Introduction

Obesity continues to rise in the United Kingdom (UK), mirroring global trends and threatening to become a grave public health threat because of its associated health and economics consequences. The current obesity crisis may be driven by qualities of the environment that promote both excess energy consumption and inadequate energy expenditure. Healthy food access may therefore be relevant for predicting trends in childhood obesity in restricted environments; for example, this restriction in access and availability of low-cost healthful food may occur in areas limited by public transportation, higher cost of nutritious foods, or where fast-food restaurants or convenience stores dominate. The presence of a supermarket is often viewed as the “gold standard” in food access research, as supermarkets typically offer lower prices, increased quantity, and improved quality of food items.
compared with smaller food venues, such as convenience stores, therefore are thought to have a generally preventive effect on obesity, encouraging more healthful eating.

Systematic reviews and meta-analyses confirm rather mixed relationship between weight-related behaviors/outcomes among children and adolescents and food environments, which may be owing to various theoretical and methodological constructs being used in relation to the choice of dataset, definition of healthy vs. unhealthy food outlets, food neighborhood definition (e.g., residential, school), or the choice of measure (e.g., proximity, density) and buffer cutoffs. In addition to impacting associations with obesity, this ongoing heterogeneity in measuring food access has been found to increase likelihood of conclusions with either type 1 errors or type 2 errors, contribute to a conflicting evidence base and confusing policy messages, and impair evidence synthesis and translation when measurement differences are overlooked. Consequently, to better understand associations between food access and obesity, researchers have called for better designed studies and following an intuitive approach based on convergence of results. In this study, I further examine this sensitivity of the association to the metric used; Euclidean distance, which represents the shortest distance between two points, is also considered for comparison with literature, as it could be a reasonable surrogate for true distances, including all real-life applications of the vehicle routing problem.

Transportation systems are important in understanding links between food access and diet-related health outcomes because they can affect which food sources consumers can reach, thus moderating healthy eating. Evidence shows that mode choice varies according to trip purpose and distance. Moreover, those living below the poverty line rely on walking, bicycling, public transportation, or shuttle service for food provisioning. The limited literature also suggests that motor vehicle ownership may buffer the effect of poor access to high-quality neighborhood food environments. It is also possible that food environment may influence dietary intake by demanding an extra transportation burden for low-income populations. Others found that greater dependence on passive forms of transportation could promote obesity, which may be owing to "increased inactivity by reducing the need for more active forms of transportation," as opposed to active travel (i.e., walking and cycling) that could lower obesity rates by increasing levels of physical activity. For example, some argue that walking to public transit helps meeting PA recommendations, with one systematic review concluding that increased level of access to public transport may prevent the development of childhood obesity. Moreover, another systematic review and meta-analysis has demonstrated effects of air pollution, which is secondary to motorized transit, on obesity in children.

Limited evidence also shows that reductions of distances between homes and grocery stores could lead to less driving for grocery shopping, whereas larger distances were predictive of using car as the major transportation mode for grocery shopping. Similarly, others found that commuting to a distant workplace increases the risk of obesity; however, the mediating effects of mode of transport may be subject to reverse causality. What remains unclear, however, is how the growing distance to food stores may influence childhood obesity depending on travel modes (e.g., cycling as opposed to driving), and whether encouraging continued dependence on active forms of transportation for daily grocery shopping may help reduce obesity. To the best of author’s knowledge, this is the first study to look directly at the impact of motorized and non-motorized transportation on childhood obesity, while accounting for the effect of distance to healthy foods.

The main purpose was to determine associations between childhood overweight (including obesity) and healthy food access as approximated by distance to three nearest supermarkets in Greater London, United Kingdom. Both proximity and density-based measures are used to capture different aspects of food environments; for example, proximity measures food choice influence through food cost and availability, whereas density accounts for differences in price, quality, and selection. The latter can also be quantified by proximity to additional nearest outlets (i.e., second and third) because the distance to additional nearest shops gives a sense of the amount of choice consumers have and the amount of competition the nearest store faces.

Specifically, this study examines: (1) which access measure best defines access to healthy food for various transportation profiles; and (2) whether the relation between distance and overweight changes given the nonmotorized/active (walking, cycling) versus motorized/inactive (driving) transportation. Moreover, secondary aim includes (3) examining whether the relationship between active-inactive transportation and childhood overweight changes depending on distance that needs to be travelled. Greater London was chosen as a suitable case study because the city has the highest rates of childhood obesity of any global city, as well as a good variation in the type of transportation used. Results are relevant to the United Kingdom and other countries because the factors debarring access to a healthy diet operate in broadly similar ways in many developed nations besides the United Kingdom.

Data and Methods

The analysis uses publicly available data by the National Child Measurement Programme (NCMP) and Open Route Service, the latter which provided database of road distances for various transport modes. A geospatial database that was created includes street network distances between 312,000 postcode centroids and three closest of total 1,600 supermarkets. The sample includes older children aged 10–11 years. The unit of analysis is the Middle Super Output Area (MSOA) level, which is a geographic hierarchy in England and Wales with the minimum population of 5000 (or 2000 households) and the mean of 7200 (or 4000 households). The final dataset includes 983
observations for each transport profile; nine observations were missing owing to data confidentiality. In the next sections, I describe the data in more detail.

**Data**

**Dependent variable.** Proportion of children that are overweight (including obese) by the NCMP constituted the dependent variable. The NCMP program measures the height and weight of children in Reception (aged 4–5) and year 6 (aged 10–11) to assess overweight and obesity levels in children within primary state schools. Heights and weights are used to calculate a BMI percentile by dividing weight (in kilograms) by the square of height (in meters); children are classified as overweight (including obese) if their BMI is on or above the 85th centile of the British 1990 growth reference (UK90) according to age and sex.\(^\text{38}\) The measurement process is overseen by trained health care professionals. The data for all the geographic areas are based on the child’s Lower Super Output Area (LSOA) of residence, which is the second smallest level of geography published in England and Wales and has an average population of \(\sim1500\) residents or \(650\) households. LSOA data, using 2011 LSOA codes, were aggregated to 2011 MSOA geographies using an LSOA to MSOA lookup and data averaged across three consecutive years 2013/14, 2014/15, and 2015/16.\(^*\)

**Explanatory variables.** Locations of supermarkets belonging to major UK supermarket chains (Tesco, Sainsbury’s, ASDA, Morrisons, Waitrose, Aldi, and Co-operative)\(^\text{39}\) were sourced from Ordnance Survey Points of Interest, which is the most comprehensive, location-based directory of all public and privately owned businesses, education, and leisure services across the United Kingdom.\(^\text{40}\) In total, 16 different food access measures were estimated, including proximity (road network and Euclidean distances) and density of supermarkets (the number of outlets within various Euclidean thresholds for different travel modes); averaged and transformed distances (second order) were also calculated to account for variability around the data and explore polynomial models, respectively. Buffer cutoffs (upper and inner) have been informed by the policy and literature or based on data exploration (percentiles); for example, in the UK context, \(500\) m walking distance away from the closest supermarket defines threshold for limited accessibility to healthful food (Beverley Hughes, Minister for Local Government and Regions, July 12, 2000).\(^\text{41}\) Table 1 provides the classification of measures as used in this study; for detailed description of measures and how the geospatial database was built (Supplementary File S1).

In addition, the following socioeconomic factors thought to be associated with the childhood obesity prevalence were collated from UK Census 2011 and Office for National Statistics: population density,\(^\text{42}\) non-White ethnicity,\(^\text{43}\) unemployment level,\(^\text{44}\) household income level,\(^\text{45,46}\) and educational level.\(^\text{47,48}\) Finally, because certain demographic factors would further affect demand for mobility and access, for example, the availability of a car, being full-time employed, or having dependents would increase demand for driving as opposed to walking or cycling\(^\text{48,49}\); these additional covariates were also sourced from the UK Census and entered in the models.

Table 2 lists all the variables used in the study, including description and source, level of analysis and years covered, and descriptive statistics; statistical descriptions for all the distance measures, including transformations applied and distances to the nearest outlet, are given in Supplementary File S2. At the time of conducting the analysis, the most recent data were used. Temporal mismatch between the data could not be avoided because of data availability issues; however, as the purpose of this research is not to study causal links, this should not impact interpreting results and drawing conclusions.

---

\(^*\)The data is freely available from NHS Digital NCMP: https://digital.nhs.uk/services/national-child-measurement-programme/
**Table 2. Descriptive Statistics (Mean ± Standard Deviation) for the Variables in the Study Including Base for England**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Euclidean distance (third)</td>
<td>Postcode, 2018</td>
<td>82 ± 0.37</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Walking distance (third)</td>
<td>Postcode, 2018</td>
<td>84 ± 0.28</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Cycling distance (third)</td>
<td>Postcode, 2018</td>
<td>1.55 ± 0.62</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Driving distance (third)</td>
<td>Postcode, 2018</td>
<td>1.4 ± 0.7</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Income</td>
<td>MSOA, 2018</td>
<td>52,889.73 ± 8910.52</td>
<td>43,857.36 ± 9720.05</td>
<td>42,128.2 ± 8897.22</td>
</tr>
<tr>
<td>Population density</td>
<td>LSOA, 2018</td>
<td>94.01 ± 49.51</td>
<td>41.64 ± 36.30</td>
<td>33.05 ± 24.08</td>
</tr>
<tr>
<td>Non-White ethnicity</td>
<td>LSOA, 2011</td>
<td>2.08 ± 2.39</td>
<td>0.26 ± 0.35</td>
<td>0.18 ± 0.27</td>
</tr>
<tr>
<td>Unemployment level</td>
<td>LSOA, 2011</td>
<td>3.78 ± 0.92</td>
<td>0.33 ± 0.07</td>
<td>0.34 ± 0.07</td>
</tr>
<tr>
<td>Education level</td>
<td>LSOA, 2011</td>
<td>7.09 ± 4.02</td>
<td>0.23 ± 0.08</td>
<td>0.24 ± 0.08</td>
</tr>
<tr>
<td>Car availability</td>
<td>LSOA, 2011</td>
<td>402.07 ± 101.66</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Having no children</td>
<td>LSOA, 2011</td>
<td>0.14 ± 0.04</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Part-time job</td>
<td>LSOA, 2011</td>
<td>0.26 ± 0.06</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

aProportion of overweight children (incl. obese) for MSOAs in England and Wales, NCMP 2013–2016 ORS 2018.
bStraight line distance between postcode centroid and third nearest supermarket, designed measure, ORS 2018.
cWalking distance between postcode centroid and third nearest supermarket, designed measure, ORS 2018.
dCycling distance between postcode centroid and third nearest supermarket, designed measure, ORS 2018.
eDriving distance between postcode centroid and third nearest supermarket, designed measure, ORS 2018.
fEstimates of total annual household income for MSOAs in England and Wales, ONS 2018.
gNumber of persons per hectare as a measure of density, ONS 2018.
hProportion of households from the non-White group, ethnic group classification, UK Census 2011.
iProportion of households with adults not in employment, UK Census 2011.
jProportion of households with the highest level of qualification, UK Census 2011.
kProportion of households with one or more cars, UK Census 2011.
lProportion of households with no dependent children, UK Census 2011.
mProportion of households in part-time employment, UK Census 2011.

LSOA, Lower Super Output Area; MSOA, Middle Super Output Area; NCMP, National Child Measurement Programme; ONS, Office for National Statistics 2018; ORS, Open Route Service.

**Statistical Analysis**

Controls for levels of unemployment and education were initially removed owing to multicollinearity with income; other highly correlated (>0.7) variables were not removed as this could cause omitted-variable-bias (e.g., car availability is highly correlated with density, but the former is associated with the probability to walk or cycle while the latter is a strong predictor of childhood obesity). Variables for ethnicity, cycling, and driving were positively skewed thus transformed to normality, which is recommended for parametric statistics, using the `gladder` function in Stata showing the quantiles of transforms according to the ladder of powers against the quantiles of a normal distribution.

Stepwise semi-automatic approach was used to guide the choice of explanatory variables, and bivariate and multivariate linear regressions examined their relationship with childhood obesity, including effect modification with distance stratified by transportation mode. In addition, the effect modification was examined by interacting non-motorized (combined walking and cycling profiles) and motorized (driving) travel modes. Initially the results were obtained for nontransformed distance to the third nearest supermarket, followed by sensitivity analyses using transformed distance and distances to the nearest store (Supplementary File S3). The research was conducted with ArcGIS for building the service area, R for building the origin–destination cost matrix solver, and Stata 16 for performing statistical analyses.

**Results**

The unadjusted and adjusted regression models with road network distance to the third nearest supermarket as the primary exposure variable are given in Table 3;
Euclidean distance is also given for comparison. In both the bivariate and multivariate analyses, slight differences in childhood overweight were found between road and Euclidean measures, both showing proportion of overweight children and supermarket distance tend to increase in the same direction. When considering distance in multivariate association, both measures become strongly significant.

The adjusted results from the linear and interaction regressions with overweight stratified by transportation mode (including active vs. inactive transportation) to the third nearest supermarket are given in Table 4. All profiles showed that childhood overweight increases with growing distance and association were significant; however, the interaction term was not significant.

Regressions with best candidate measures per transport mode are given in Table 5. Overall, distance to the third nearest store was best approximation for all the profiles. Results of the sensitivity analyses did not change the interpretation of the results (except results for cycling to the nearest store were sensitive to the transformation applied but these were not statistically significant) but further highlighted that distance to the third nearest supermarket is stronger predictor of childhood overweight than distance to the nearest supermarket.

Discussion

The objective of this study was to examine different measures of healthy food access stratified by nonmotorized vs. motorized transportation mode in relation to childhood overweight outcome. Results show that distance to at least three closest supermarkets is important for explaining obesity rates. This could be explained by the context of a densely populated metropolis where high-volume transportation networks enable faster commute between food outlets located in relatively near proximity to each other. It is also possible that people do not shop for their groceries at the closest store because other factors may influence their shopping preference, such as cost and perceived value for money, brand loyalty, the store layout or atmosphere, or whether a store offers certain facilities or not. Walking profile shows higher obesity rates than driving, which contradicts simulation evidence that “local walkability interventions can achieve measurable declines in childhood obesity rates.” Walking and cycling are beneficial not only in terms of PA, health outcomes (including childhood obesity), and all-cause mortality but also sustainable mobility; on the contrary, active modes are also associated with health risks related to pollution exposure and injury, which may outweigh the benefits of PA.

One systematic review and meta-analysis also argues that bike lane access is associated with children and adolescents’ PA; still, others contest these results, and the relationship with obesity is unclear. The mix of neighborhood-level barriers and facilitators of weight-related health behaviors is likely leading to additional difficulties in disentangling their associations with adolescent obesity.
When interacting active–inactive transportation distance, results show that people may not substitute one for the other when distance changes. This contrasts with the evidence suggesting distance would be related to the mode of travel,\textsuperscript{18,32,67,68} and as such requires further examination. For example, it was found that reductions of distances between homes and grocery stores could lead to less driving for grocery shopping.\textsuperscript{32} In another study, children who lived farther from school were less likely to walk, which was partly attributed to certain features within neighborhoods.\textsuperscript{67} Similarly, Nelson et al.\textsuperscript{68} argue that inactive commuting to schools for children is mainly owing to distance and time constrains, not the bike lane access,\textsuperscript{68} and that the relationship depends on the intensity of PA.\textsuperscript{69} It is also possible that more advanced models could identify patterns in the data that measures used in this study have missed. For example, a model using the floating catchment area approach and integrating residential transportation mode choices probabilities and the travel friction coefficient has been shown to get closer to the reality of transportation, including multiple mode representation, than traditional estimations of accessibility.\textsuperscript{70}

**Limitations and Directions for Further Research**

This research accounts for measures of healthy food access to supermarkets only; future research could consider adding other food retailers in addition to supermarkets, including unhealthy food outlets. Public transportation should also be considered in the future as those living below the poverty line and without ready access to a vehicle rely on it for accessing healthy food. Obesity is measured using high-quality, aggregated indicators, which may be useful for policy that is already based on the same level data; however, individual data may better capture people’s actual behaviors, feelings, and thoughts (e.g., about food and diet or traveling). Future research could also look at different thresholds of tolerance for nonmotorized travel to stores and investigate disparities in food access between inner and outer London boroughs to account for differences in urban arrangement (e.g., public

<p>| Table 4. Associations between Childhood Overweight, Distance to the Third Nearest Supermarket Stratified by Travel Modes, Including Interaction between Active and Passive Modes, and Other Covariates in a Sample of 974 Middle Super Output Areas, Greater London |</p>
<table>
<thead>
<tr>
<th>Dependent variable: BMI</th>
<th>i, Walking, β (SE)</th>
<th>ii, Cycling, β (SE)</th>
<th>iii, Active, β (SE)</th>
<th>iv, Driving, β (SE)</th>
<th>v, Active#, driving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking distance</td>
<td>2.33*** (0.49)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Cycling distance</td>
<td>—</td>
<td>0.75*** (0.21)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Active distance</td>
<td>—</td>
<td>—</td>
<td>1.55*** (0.34)</td>
<td>—</td>
<td>0.82 (0.61)</td>
</tr>
<tr>
<td>Driving distance</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.88*** (0.19)</td>
<td>0.41 (0.56)</td>
</tr>
<tr>
<td>Interaction</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.04 (0.2)</td>
</tr>
<tr>
<td>Income</td>
<td>—0.00*** (0.00)</td>
<td>—0.00*** (0.00)</td>
<td>—0.00*** (0.00)</td>
<td>—0.00*** (0.00)</td>
<td>—0.00*** (0.00)</td>
</tr>
<tr>
<td>Density</td>
<td>0.01 (0.00)</td>
<td>0.00 (0.00)</td>
<td>0.01 (0.00)</td>
<td>0.01 (0.00)</td>
<td>0.01 (0.00)</td>
</tr>
<tr>
<td>Ethnicity (log-10)</td>
<td>—1.58 (0.9)</td>
<td>—1.34 (0.91)</td>
<td>—1.36 (0.9)</td>
<td>—1.62 (0.9)</td>
<td>—1.48 (0.9)</td>
</tr>
<tr>
<td>Car availability</td>
<td>—0.01*** (0.00)</td>
<td>—0.01*** (0.00)</td>
<td>—0.01*** (0.00)</td>
<td>—0.01*** (0.00)</td>
<td>—0.01*** (0.00)</td>
</tr>
<tr>
<td>Having no children</td>
<td>—28.65*** (7.15)</td>
<td>—27.23*** (7.2)</td>
<td>—26.32*** (7.17)</td>
<td>—28.11*** (7.12)</td>
<td>—26.86*** (7.19)</td>
</tr>
<tr>
<td>Part-time job</td>
<td>—18.04*** (3.67)</td>
<td>—15.29*** (3.65)</td>
<td>—15.66*** (3.62)</td>
<td>—16.82*** (3.61)</td>
<td>—16.14*** (3.64)</td>
</tr>
</tbody>
</table>

*\(p<0.05\), *\(p<0.01\), ****\(p<0.001\).

*Walking and cycling distances combined and averaged.

Interaction between active and inactive (driving) mode of travel.

Total annual household income.

Number of persons per hectare.

Proportion of households from the non-White group, the base 10-logarithm transformation.

Proportion of households with one or more cars.

Proportion of households with no dependent children.

Proportion of households in part-time employment.

BMI, body mass index; SE, standard error.
transport provision, areas’ resilience to retail environmental changes), including sociodemographic inequities in accessing active transportation.

A further limitation to this study’s overall approach exists with regard to its sample, including children aged 10–11 years. Children rely on their caregivers to provide them with nutritious food; however, older children may be more independent in their food decisions than their younger counterparts, as well as more mobile in terms of travelling around their own neighborhood or city without adult supervision. For example, recent evidence shows that during the COVID pandemic parents were more likely to eat with their younger children, providing more structure around meals and restricting snacks, whereas older children tended to have unrestricted access to unhealthy snacking. Therefore, in addition to the distance and food access, future studies could look at how independently older children are allowed to make their own food choices and how much may this affect their weight status, while accounting for personal, environmental, and macrosystem factors. In addition, as obesity and travel behavior are related to gender, gender differences should be considered, especially when inconsistent results have been reported between men and women.

### Table 5. Associations between Childhood Overweight and Best Candidate Measures Per Transport Mode in a Sample of 974 Middle Super Output Areas, Greater London

<table>
<thead>
<tr>
<th>Dependent variable: BMI</th>
<th>i, Walking, β (SE)</th>
<th>ii, Cycling, β (SE)</th>
<th>iii, Driving, β (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road distance to the third store</td>
<td>1.84*** (0.54)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Euclidean distance to the third store</td>
<td>0.94* (0.47)</td>
<td>1.64*** (0.42)</td>
<td>—</td>
</tr>
<tr>
<td>Average distance to the three closest stores</td>
<td>—</td>
<td>—</td>
<td>0.99*** (0.23)</td>
</tr>
<tr>
<td>Income*</td>
<td>—0.00*** (0.00)</td>
<td>—0.00*** (0.00)</td>
<td>—0.00*** (0.00)</td>
</tr>
<tr>
<td>Densityb</td>
<td>0.01 (0.00)</td>
<td>0.01 (0.00)</td>
<td>0.01 (0.00)</td>
</tr>
<tr>
<td>Ethnicity (log-10)c</td>
<td>—1.42 (0.9)</td>
<td>—1.25 (0.9)</td>
<td>—1.64 (0.9)</td>
</tr>
<tr>
<td>Car availabilityd</td>
<td>—0.01*** (0.00)</td>
<td>—0.01*** (0.00)</td>
<td>—0.01*** (0.00)</td>
</tr>
<tr>
<td>Having no childrene</td>
<td>—26.74*** (7.15)</td>
<td>—26.77*** (7.19)</td>
<td>—28.74*** (7.12)</td>
</tr>
<tr>
<td>Part-time jobf</td>
<td>—18.46*** (3.61)</td>
<td>—17.95*** (3.63)</td>
<td>—16.68*** (3.61)</td>
</tr>
<tr>
<td>N</td>
<td>974</td>
<td>974</td>
<td>974</td>
</tr>
<tr>
<td>Adj R²</td>
<td>0.413</td>
<td>0.407</td>
<td>0.408</td>
</tr>
</tbody>
</table>

*p < 0.05, **p < 0.01, ***p < 0.001.
*Total annual household income.
bNumber of persons per hectare.
cProportion of households from the non-White group, the base 10-logarithm transformation.
dProportion of households with one or more cars.
eProportion of households with no dependent children.
fProportion of households in part-time employment.
BMI, body mass index; SE, standard error.

### Conclusions

This research tested a real-world network analysis approach to approximate walkability to three nearest supermarkets, in addition to operationalizing cycling and driving distances to realistically consider population level exposures to healthy foods and their associations with childhood obesity. Walking mode showed higher obesity rates than driving, and distance was not related to the mode of travel. The results can be extrapolated to other densely populated cities and metropolitan areas. Tackling nutritional inequality and encouraging continued dependence on active forms of transportation to reduce obesity rates may require individual approaches, in addition to relocating road space and creating new routes for safer walking and cycling.

### Impact Statement

The results provide a better understanding of supermarket access and transportation disparities in childhood overweight prevalence in the context of large metropolis, including effects of active versus inactive modes and consideration for whether distance moderates their relationship with childhood overweight.
Acknowledgments

Building the geospatial database has proved particularly challenging in terms of data collection speed, and I am most thankful to the developers at the Institute of Geography of Heidelberg University, Germany, who have provided extended quotas on the API request. The author likes to acknowledge the work of Henry Cosby who has been involved in initial liaising with the Institute and data acquisition, including revising the data sampling approach. Finally, this article and the research behind it would not have been possible without support of my supervisors, Prof. Rob Procter and Jessica Di Salvatore.

Authors’ Contributions

Conception and design of the work; acquisition, analysis, and interpretation of data. Author gave her final approval for the version to be published and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Funding Information

E.T. is supported by a PhD studentship from the Engineering and Physical Sciences Research Council (EPSRC) Centre for Doctoral Training in Urban Science (EP/L016400/1).

Author Disclosure Statement

The author declares no conflict of interest.

Supplementary Material

Supplementary File S1
Supplementary File S2
Supplementary File S3

References


67. Larsen K, Buliung RN, Faulkner GEJ. School travel how the built and social environment relate to children’s walking and independent mobility in the Greater Toronto and Hamilton Area, Ontario, Canada. Transp Res Rec 2015;2513:80–89; doi: 10.3141/2513-10


Address correspondence to:
Elzbieta Titis, MS
Warwick Institute for the Science of Cities
Mathematical Sciences Building, 4th Floor
The University of Warwick
Coventry CV4 7AL
United Kingdom

E-mail: e.titis@warwick.ac.uk