

The Food Environment and Obesity: A Systematic Review and Meta-analysis

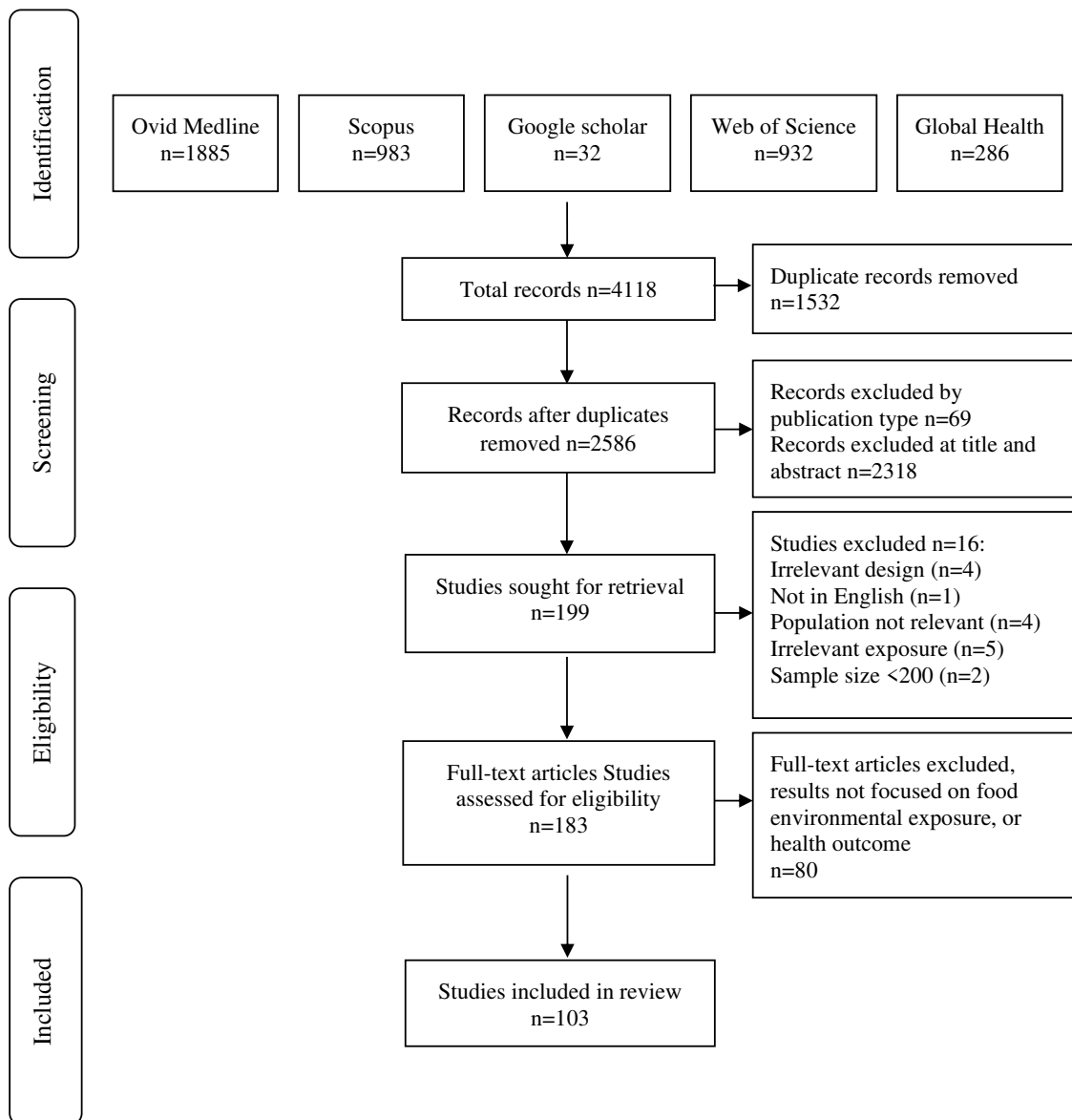
Supplementary Material

Contents

| | |
|---|----|
| Supplementary Material | 1 |
| 1. PRISMA Flow Diagram..... | 2 |
| Included | 2 |
| Eligibility | 2 |
| Screening | 2 |
| Identification | 2 |
| 2. Eligibility criteria..... | 3 |
| Table S1. Eligibility criteria for publications relevant to the review using PICO | 3 |
| 3. Risk of bias | 4 |
| 4. General characteristics of reviewed studies..... | 5 |
| 5. Risk of bias assessment..... | 19 |
| 6. Food outlet density and proximity and its association with BMI | 24 |

1. PRISMA Flow Diagram

Figure S1. PRISMA Flow Diagram



2. Eligibility criteria

Table S1. Eligibility criteria for publications relevant to the review using PICO

| | |
|---|--|
| <u>P</u>opulation | General adult population, excluding populations with comorbidities. |
| <u>I</u>ntervention/ exposure | Assessment of the retail food environments at any geographical level (e.g., census tract area, postal code, county, city, etc) |
| <u>C</u>ontrol | Not applicable/areas with no food environment |
| <u>P</u>rimary <u>O</u>utcomes | Obesity related outcomes (e.g., BMI, obesity prevalence, adiposity, etc.) |

3. Risk of bias

Table S2. Risk of bias and quality criteria assessment for reviewed studies

| Criterion | Meeting criteria (Score 1) | Not meeting criteria (Score 0) |
|-----------------------------|---|--|
| Population | Population was randomly selected, and proper sampling methods were undertaken to select a representative population according to the study's aims. | Population was selected using telephone surveys. |
| Outcome (BMI) | Measured weight and height or validated data. | Self-reported or non-validated data used. |
| Exposure (food environment) | > 2 types of food establishments were studied. | ≤ 2 types of food establishments were studied |
| Food outlet data source | Validated or trustworthy source (e.g., up-to-date government database) used or ground truthing was undertaken). | Data were not validated. |
| Spatial analysis method | ≥ 2 methods were employed. | Only one method. |
| Physical activity (PA) | PA or walkability was considered in the model. | Neither PA nor walkability considered. |
| Study design | Longitudinal studies. | Cross-sectional or ecological design |
| Statistical method | Use of Moran's I, multilevel analysis, geographic weighted regression analysis or any other method that considered space or clustering as an important variable of influence. | Linear regression methods which do not consider space or clustering. |
| Data temporality | Health and food outlet data were from same year. | Health and food outlet data varied in collection time. |

4. General characteristics of reviewed studies

Table S3. General characteristics and descriptive summary of reviewed studies

| Reference | Country | Sample population | Physical activity consideration | Statistical Method | Significant findings |
|--------------------------------|-----------|-------------------|---------------------------------|---|----------------------|
| Cross-sectional studies | | | | | |
| Abbott et al., 2014 | Australia | 1,819 | Yes | Linear regression model | Yes |
| Adachi-Mejia 2017 | USA | 2,025 | Yes | Multiple regression models | Mixed |
| Ahern et al., 2011 | USA | USA population | Yes | Linear regression | Yes |
| Albalawi et al., 2020 | UK | 456,079 | No | Multiple linear regressions | No |
| Backes et al., 2019 | Brazil | 1,096 | No | Multilevel Poisson regression models (with robust standard error) | No |
| Bodor et al., 2010 | USA | 3,925 | Yes | Hierarchical linear models | Yes |
| Burgoine 2017 | UK | 9,702 | Yes | Multiple linear regression | Yes |
| Burgoine 2018 | UK | 51,361 | Yes | Multivariable linear and binomial logistic regression | Yes |
| Cerin et al., 2011 | USA | 274 | Yes | GLM with binomial variance and logit link functions | Yes |
| Chaparro et al., 2017 | USA | 1,041 | No | Multilevel logistic regression | No |
| Chen et al., 2010 | USA | 844,187 | No | OLS spatial diagnostic test on regression residual of non-spatial model | Yes |
| Chen et al., 2013 | USA | 3,550 | Yes | OLS | Yes |
| Chen et al., 2016 | USA | 25,023 | No | Multilevel | Yes |
| Chen et al., 2019 | USA | 20,897 | Yes | Ordinary least squares linear regression (evaluated by Moran's I index) global ordinary least squares regression local geographically weighted regression | Yes |
| Chen et al., 2020 | USA | 20,897 | No | Path analysis | Yes |

| Reference | Country | Sample population | Physical activity consideration | Statistical Method | Significant findings |
|------------------------------|------------|------------------------|---------------------------------|--|----------------------|
| Christian et al., 2012 | USA | 121 | Yes | Multivariate logistic regression | No |
| Conroy et al., 2018 | USA | 102,906 | Yes | multivariable linear regression multivariable multinomial logistic regression | No |
| Cooksey-Stowers et al., 2017 | USA | 3,108 | Yes | OLS | Yes |
| Crawford et al., 2008 | Canada | 684 | Yes | Bivariate logistic regression | No |
| Dake et al., 2016 | Ghana | 657 | Yes | Multilevel | Yes |
| Drewnowski et al., 2012 | USA | 1,304 | No | Modified Poisson regression | No |
| Drewnowski et al., 2014a | USA-France | 9,291 | No | Modified Poisson regression w/ robust error variance | No |
| Dunn et al., 2012 | USA | 1,019 | No | Probit regression | Yes |
| Fan et al., 2014 | USA | 403,305 | No | Multilevel regression models | Yes |
| Frankenfeld et al., 2015 | USA | USA population | No | Linear regression | Yes |
| Fuller et al., 2013 | USA | 1,440 | Yes | Bivariate linear regression | No |
| Gartin 2012 | Paraguay | 126 | No | Linear regression no GIS analysis | No |
| Ghosh-Dastidar et al., 2014 | USA | 1,214 | No | Multivariate logistic regression | Yes |
| Hanibuchi et al., 2011 | Japan | 39,765 | No | Multiple linear regression logistic regression | Yes |
| Hattori et al., 2013 | USA | 97,678 | Yes | Negative binomial regression OLS and logistic regression | Yes |
| Hobbs 2017 | UK | 4,723 | No | Single-level linear regression linear multilevel | No |
| Hobbs et al., 2019 | UK | 22,889 | No | Binary logistic regression | No |
| Hobbs et al., 2019 | UK | 7,544 | No | Structural equation modelling | No |
| Hollands et al., 2013 | Canada | 1,269 geographic areas | Yes | OLS and spatial auto-regressive error | Yes |

| Reference | Country | Sample population | Physical activity consideration | Statistical Method | Significant findings |
|-------------------------------|---|------------------------------------|---------------------------------|--|----------------------|
| Hollands et al., 2014 | Canada | 84,341 | Yes | Multivariable regression analyses | Yes |
| Hosler et al., 2009 | USA | Columbia and Greene counties in NY | No | Bivariate correlations | No |
| Inagami et al., 2009 | USA | 2,156 | No | Multilevel modelling | Yes |
| Jeffery et al., 2006 | USA | 1,033 | Yes | Logistic regression | No |
| Jilcott et al., 2011 | USA | USA population | Yes | Multilevel linear models | Yes |
| Kruger et al., 2014 | USA | 1,345 | No | Stepwise linear regressions | Yes |
| Laxy et al., 2015 | USA | 1,570 | Yes | Multivariate linear and logistic regression | No |
| Li et al., 2008 | USA | 1,221 | Yes | Linear and logistic regression | No |
| Li et al., 2009b | USA | 1,145 | Yes | Multilevel Poisson regression | Yes |
| Li et al., 2009c | USA | 1,145 | Yes | Multilevel | Yes |
| Liese 2017 | USA | 459 | Yes | Multivariable/hierarchical linear regression | Yes |
| Lopez 2007 | USA | 15,358 | No | Multilevel logistic regression | Yes |
| Macdonald et al., 2011 | Scotland | 991 | No | Multilevel | Yes |
| Mackenbach 2019 | Belgium France Hungary Netherlands and the United Kingdom | 5,076 | No | Logistic and linear regressions | No |
| Mackenbach 2019 | Netherlands | 2,812 | No | Linear and multinomial logistic regression | Yes |
| Maddock 2004 | USA | USA population | Yes | Logistic regression and multinomial regression | Yes |
| Mason 2018 | UK | 40,1435 | Yes | Multilevel linear regression | Yes |

| Reference | Country | Sample population | Physical activity consideration | Statistical Method | Significant findings |
|----------------------------------|-------------|--|---------------------------------|---|----------------------|
| Mazidi and Speakman 2017 | USA | 2,996 counties. 3,138 counties USA population~ 170 million adults | Yes | Linear regression | No |
| Mehta and Chang 2008 | USA | 876,091 | Yes | Bivariate correlation hierarchical multiple regression | Yes |
| Mejia et al., 2015 | USA | 5,185 | Yes | Multilevel analysis Two-level hierarchic regression models | Yes |
| Mendes et al., 2013 | Brazil | 3,404 | No | Negative binomial | Yes |
| Michimi and Wimberly 2010 | USA | 1,477,828 | No | Poisson regression model in a single level | No |
| Michimi and Wimberly 2015 | USA | 300,933 | No | Latent class analysis | Yes |
| Morland et al., 2006 | USA | 10,763 | Yes | Multilevel logistic regression | Yes |
| Murphy 2017 | Australia | 3,218 | No | Generalised estimating equations | Yes |
| Murphy 2018 | Australia | 3,141 | Yes | Generalized estimating equations models | Yes |
| Mylona 2020 | USA | 20,927 | Yes | Multivariate logistic regression | Yes |
| Oexle et al., 2015 | USA | 838 | No | Multilevel logistic regression | Yes |
| Oka et al., 2013 | USA | 5,485 | Yes | Multilevel modelling binomial regression | Yes |
| Patel et al., 2017 | India | 1,782 | Yes | Logistic regression | Yes |
| Pearce et al., 2009 | New Zealand | 12,529 | No | Multinomial Logistic regression | No |
| Pineda et al., 2021 | Mexico | 37,969 | Yes | Multilevel linear regression | Yes |
| Polsky et al., 2016 | Canada | 10,199 | Yes | logistic regression stratified linear regression | Yes |
| Polsky et al., 2016 | Canada | 10,199 | Yes | Multilevel modelling | No |

| Reference | Country | Sample population | Physical activity consideration | Statistical Method | Significant findings |
|---------------------------------|---------|-------------------|---------------------------------|---|----------------------|
| Pouliou and Elliott 2010 | Canada | 115,548 | Yes | Two-level logistic regression multilevel | Yes |
| Prince et al., 2012 | Canada | 4,727 | Yes | Logistic and linear regression | Yes |
| Pruchno et al., 2014 | USA | 5,688 | No | Multivariate analysis | No |
| Richardson et al., 2015 | USA | 5,114 | Yes | Binomial multivariate multilevel model | Yes |
| Rundle et al., 2009 | USA | 13,102 | Yes | Multilevel structural equation | Yes |
| Salois 2012 | USA | 3,051 counties | Yes | Structural equation model | Yes |
| Singleton et al., 2016 | USA | 3,135 | No | Linear regression | Yes |
| Slack et al., 2014 | USA | 3,109 counties | Yes | Multilevel analysis | Yes |
| Spence et al., 2009 | Canada | 2,900 | No | Robust regression MM estimator regression | Yes |
| Stark et al., 2013 | USA | 48,482 | Yes | OLS spatial regression | No |
| Tung et al., 2016 | USA | 267 | Yes | Linear regression | No |
| Viola et al., 2013 | USA | 48,014 | Yes | Weighted logistic regression models | Yes |
| Walker 2020 | Canada | 8,076 | Yes | Logistic regression | Yes |
| Wang et al., 2007 | USA | 7,595 | Yes | Multilevel Pearson correlation coefficients | Yes |
| Xu and Wang 2015 | USA | 328,156 | Yes | Bayesian ecologic approach for spatial prediction | Yes |
| Yan et al., 2015 | USA | 3,041 | No | Multilevel | No |
| Yenerall 2017 | USA | 784 | No | Logistic regression model | No |
| Zhang 2019 | USA | 8,365 | No | Generalised linear regression and logistic regression | No |
| Zhang 2020 | China | 170,872 | Yes | Five-level logistic regression models | Yes |
| Zick et al., 2009 | USA | 898,387 | Yes | Multilevel Logistic model | Yes |
| Jaime et al., 2011 | Brazil | 2,122 | Yes | Correlation analyses Pearson | No |

| Reference | Country | Sample population | Physical activity consideration | Statistical Method | Significant findings |
|------------------------------------|-----------|-------------------|---------------------------------|--|----------------------|
| | | | | correlation coefficient | |
| Longitudinal studies | | | | | |
| Block et al., 2011a | USA | 3,113 | No | Cross-classified multilevel model | No |
| Boone-Heinonen et al., 2013 | USA | 4,092 | Yes | Regression with fixed effects for individuals | Yes |
| Burgoine et al., 2011 | England | 893 | Yes | Correlation ANOVA and Chi-square analysis | No |
| Burgoine et al., 2016 | UK | 2,039 | Yes | Linear and logistic regression | Yes |
| Carroll 2020 | Australia | 2,253 | Yes | Spearman rank correlation latent variable growth models | Yes |
| Du et al., 2014 | China | 24,396 | Yes | Random intercept-slope growth model | Yes |
| Dubowitz et al., 2012 | USA | 60,775 | Yes | Logistic regression multivariate regression models with random effects | Yes |
| Gibson et al., 2011 | USA | 27,825 | Yes | OLS | Yes |
| Hobbs 2019 | UK | 8,864 | No | Multilevel linear regression | No |
| Jilcott Pitts et al., 2015 | USA | 205 | No | Multiple linear and logistic regression | No |
| Meyer et al., 2015 | USA | 14,397 | Yes | OLS logistic regression | No |
| Rummo 2017 | USA | 12,174 | Yes | Instrumental-variables regression | No |
| Xu et al., 2013 | China | 28,063 | Yes | Bayesian hierarchical regressions multilevel | Yes |
| Zenk 2017 | USA | 219 | No | Hierarchical linear regression | No |

GLM: General linear model, OLS: ordinary least squares regression, ANOVA: analysis of variance

Table S4. Food environment characteristics and methods of the reviewed studies

| Reference | Geographic unit of observation | Store type | Spatial food store measure | Buffer size | Food outlet source |
|------------------------------------|--------------------------------|---|----------------------------|---|--------------------------------------|
| Abbott et al., 2014 | Suburbs | Green grocers, supermarkets, FF | Density | NA | NA |
| Adachi-Mejia 2017 | Neighbourhood | FF, restaurant, GS, supermarket | Density and proximity | 1 km street-network | Government and commercial |
| Ahern et al., 2011 | County | Direct-to-consumer farms, GS, restaurants, FF, CS | Density | NA | Government |
| Albalawi 2020 | Postcode district (PD) | FF, restaurants, delivery, takeaways, pubs, and cafes | Density | Postcode district | Government and Commercial databases |
| Backes 2019 | residential address | Supermarkets, GC, CS | Density | 400m radius buffer around residential locations | Systematic survey |
| Block et al., 2011a | CTA | FF, restaurants, bakeries/coffee shops, supermarkets, GS, CS | Proximity (driving time) | NA | Government, Yellow pages, Commercial |
| Bodor et al., 2010 | CTA | Supermarkets, medium food stores, small food stores, CS, general merchandise stores, FF | Density | 2km | Government |
| Boone-Heinonen et al., 2013 | Census block group | FF, supermarkets, CS | Proximity | 1km Euclidean | Commercial |
| Burgoine 2017 | Residential address | Supermarkets | Proximity | Street network proximity | Government |
| Burgoine 2018 | Residential address | FF | % | 1-mile straight-line radius (circular) residential address | Government |
| Burgoine et al., 2011 | LSOA | FF, supermarkets, greengrocer, CS, pizza delivery, takeaway | Density | NA | Yellow pages |
| Burgoine et al., 2016 | residential and work address | FF, supermarkets | Density | 1-mile straight-line radius (circular) buffers, centered on home and work addresses | Government |
| Carroll 2020 | Census collection districts | FF; RFEI | Density, RFEI | 1600m road-network proximity buffers from participants' residence | Government and commercial databases |

| Reference | Geographic unit of observation | Store type | Spatial food store measure | Buffer size | Food outlet source |
|---------------------------------|--------------------------------|--|--------------------------------------|---|---|
| Cerin et al., 2011 | CTA | FF, CS, restaurants, gas/non gas food marts | Density, proximity, diversity | 1km residential, 1km network | Government, Yellow Pages, online business, directories, and ground-truthing |
| Chaparro et al., 2017 | CTA | FF, CS, LS | Density | NA | Government |
| Chen et al., 2010 | County | Chain grocers | Density | 1-mile | Government |
| Chen et al., 2013 | CTA | Restaurants, FF | Density, proximity | 0.5 mile | Government |
| Chen et al., 2016 | County, food desert tract | Supermarkets, GS, clubs and supercentres, CS, specialty food stores, pharmacies, restaurants | Density | NA | Government |
| Chen 2019 | CTA | mRFEI | mRFEI | None | Government |
| Chen 2020 | CTA | mRFEI | mRFEI | None | Government |
| Christian, 2012 | CTA | Supermarkets, CS, FV markets, limited-service restaurants | Density | 0-50 miles Euclidian | Government |
| Conroy 2018 | Census block group | REI, RFEI | REI, RFEI | 1-6 km pedestrian network | Government and commercial databases |
| Crawford et al., 2008 | State | FF chains | Proximity, density | 2km | Yellow pages, commercial/online |
| Crawford et al., 2008 | Residential address | FF | Density, proximity | 2km | Government |
| Dake et al., 2016 | Enumeration areas | Out-of-home cooked food, CS, FV | Density | NA | Ground truthing |
| Drewnowski et al., 2012 | County and block group code | Supermarkets | Network proximity (3 types, driving) | NA | Field work |
| Drewnowski et al., 2014a | County | Supermarkets | Network proximity | Buffers centered on each study participant's residence. | Government |
| Du et al., 2014 | Neighbourhood | FF, indoor restaurants, and | Density | NA | Community questionnaire |

| Reference | Geographic unit of observation | Store type | Spatial food store measure | Buffer size | Food outlet source |
|------------------------------------|--|--|---|--|---------------------------------------|
| | | fixed outdoor food stalls | | | , community leader |
| Dubowitz et al., 2012 | Tract and metropolitan statistical area | GS, supermarkets, FF | Density | 0.75, 1.5, and 3.0 miles | Yellow pages, commercial |
| Dunn et al., 2012 | CTA | FF | Density | 1, 3 miles | Ground-truthing |
| Fan et al., 2014 | Census block group, CTA, zip code, 1 km buffer around residential address. | GS, CS, restaurants | Density | 1km | Commercial |
| Frankenfeld et al., 2015 | Block group | FF, CS and pharmacies, GS, and specialty food stores | Ratio unhealthy: healthy food outlets, k-mean cluster | NA | Commercial |
| Fuller et al., 2013 | CTA | Primary food stores | Road network proximity | NA | Commercial and participant survey |
| Gartin, 2012 | Census block group | Open-air markets, CS, supermarkets | Proximity | 0.5-1 miles | Ground-truthing |
| Ghosh-Dastidar et al., 2014 | CTA | Supermarkets, specialty grocery stores, discount grocery stores, supercentres, meat/seafood markets, wholesale clubs | Network proximity | NA | Geocoded from participant's interview |
| Gibson, 2011 | Zip code | GS, CS, restaurants | Density | NA | Government |
| Hanibuchi et al., 2011 | Block | CS, FF, supermarkets | Radial proximity based on street network | 500m | Yellow pages |
| Hattori et al., 2013 | Residential address | FF, restaurants, CS, small food stores, GS, supermarkets | Density, Euclidian proximity within walking proximity | 0.25, 0.5, 1-, 1.5-, and 3-miles circular buffers | Commercial |
| Hobbs 2017 | Residential address | Supermarkets, takeaways, CS | Density | 800m and 2000m) residential address; LSOA (km ²) | Government and commercial databases |

| Reference | Geographic unit of observation | Store type | Spatial food store measure | Buffer size | Food outlet source |
|----------------------------|--------------------------------|--|-------------------------------|--|---------------------------------------|
| Hobbs 2019 | Residential postcode | FF, LS, CS, and restaurants | Density | 2km | Commercial database |
| Hobbs 2019 | Residential postcode | FF | Density | 2km radial buffers around home postcode | Commercial database |
| Hobbs 2019 | Cluster of food outlets | FF, LS, restaurants, CS, independent supermarkets, specialty, café | Density | 1600m Euclidean radial buffer | National database |
| Hollands et al., 2013 | Forward sortation area | FF, coffee outlets, restaurants | Density | NA | Commercial |
| Hollands et al., 2014 | Forward sortation area | FF, restaurants | Density | NA | Commercial |
| Hosler, 2009 | Census block group | Food stores, farmer's markets | Density, Euclidian proximity | NA | Research centre |
| Inagami et al., 2009 | CTA | FF | Density | NA | Government |
| Jaime et al., 2011 | Sub-municipality | Supermarket, GS, FV, FF chains | Density | NA | Government and commercial |
| Jeffery et al., 2006 | Not defined | FF, restaurants | Proximity, density, frequency | Radio of 0.5 miles, 1 mile and 2 miles (home and work addresses) | Government and commercial |
| Jilcott et al., 2011 | County | Farmers' markets, GS, supermarkets, supercentres | Density | NA | Government |
| Jilcott Pitts et al., 2015 | County | Farmers' market | Network proximity | NA | Ground truthing |
| Kruger et al., 2014 | County | FF | Proximity | NA | Yellow pages and internet |
| Laxy et al., 2015 | Neighbourhood | FF, CS, supermarkets | Network proximity | NA | Commercial |
| Li et al., 2008 | Census block group | FF | Density | NA | Commercial |
| Li et al., 2009b | Census block group | FF | Density | NA | Government and commercial |
| Li et al., 2009c | Census block group | FF | Density | NA | Government and commercial |
| Liese 2017 | Residential address | Supermarkets, supercentre, or warehouse club | Proximity | None | Ground-truthing survey and government |

| Reference | Geographic unit of observation | Store type | Spatial food store measure | Buffer size | Food outlet source |
|-----------------------------------|--------------------------------|--|--------------------------------------|--|--------------------------------------|
| Lopez, 2007 | Zip code | Supermarkets, FF, general retail | Density | NA | Government and commercial |
| Macdonald et al., 2011 | Postal code | Supermarkets, independent food stores and chain outlets, FV | Network Proximity | 500m and 1000m | Government |
| Mackenbach 2019 | Neighbourhood | FF | Spatial access | 300m Euclidean buffer around selected residential neighbourhoods | Commercial database |
| Mackenbach 2019 | Residential address | FF | Spatial access | 300m Euclidean buffers around participants' home addresses | Commercial database |
| Maddock, 2004 | State | FF | Square miles per food outlet | NA | Yellow pages and online verification |
| Mason 2018 | Residential address | FF | Street-network Proximity | 500m, 500–999m, 1000–1999m, 2000m from residential address | National database |
| Mazidi and Speakman, 2017 | County | FF and restaurants | Density | NA | Government |
| Mehta and Chang, 2008 | County | FF | Density | NA | Government |
| Mejia et al., 2015 | Neighbourhood | FF, CS, small food stores, GS, supermarkets. | Density, Euclidian proximity | 0.25, 0.5, 1, 1.5, and 3 miles | Commercial |
| Mendes et al., 2013 | Postal code | Supermarkets, hypermarkets | Presence, health vulnerability index | NA | Commercial |
| Meyer et al., 2015 | Neighbourhood | CS, coops/natural food stores, specialty markets, supermarkets, GS, FF, food stances/cafeterias, restaurants | Density | 3km | Commercial |
| Michimi and Wimberly, 2010 | County | Supermarkets and supercentres other grocery stores (except convenience stores), and warehouse clubs | Euclidian proximity | NA | Government |

| Reference | Geographic unit of observation | Store type | Spatial food store measure | Buffer size | Food outlet source |
|-----------------------------------|--------------------------------|---|------------------------------------|--|---|
| Michimi and Wimberly, 2015 | County | Supermarkets, snack/coffee shops, restaurants, FF, CS | Factor analysis | NA | Government |
| Morland et al., 2006 | CTA | Supermarkets, grocery stores, or smaller non-corporate-owned food stores, CS, restaurants, FF, and limited-service restaurant | Density | NA | Government |
| Murphy 2017 | Residential address | Supermarkets | Density, proximity | 800, 1000, 1600, 2000 and 3000m network | Government, commercial, and ground truthing |
| Murphy 2018 | Residential address | FF, supermarkets | Density, proximity | 800m, 1000m, 1600m, 2000m, and 3000m network | Government and commercial |
| Mylona 2020 | Residential address | FF | kernel Density | 3-1 km | Commercial database |
| Oexle et al., 2015 | County | FF | Count, proximity | 1 mile | Ground truthing |
| Oka et al., 2013 | CTA | Food markets, CS, grocers, restaurants, pizza stores, gyms | Principal component analysis | NA | Government |
| Patel et al., 2017 | census enumeration blocks | FF, restaurants | Density | 1-km | Ground truthing |
| Pearce et al., 2009 | Census mesh block | Multinational/local FF | Travel proximity | NA | Yellow pages |
| Pineda et al., 2021 | CTA | FF, restaurant, CS, supermarkets | Density | NA | Government and ground truthing |
| Polsky et al., 2016 | Census block group | FF, restaurants | Absolute density, relative density | 720m along the street network | Commercial |
| Polsky et al., 2016 | Dissemination blocks | Restaurants | Absolute and relative Density | 720m | Commercial |
| Pouliou and Elliott, 2010 | Postal code | FF, CS, GS, supermarkets | Density | 1km | Government |
| Prince et al., 2012 | Neighbourhood | GS, CS, specialty food stores, FF, restaurants | Density | NA | Another study |

| Reference | Geographic unit of observation | Store type | Spatial food store measure | Buffer size | Food outlet source |
|--------------------------------|---|---|---|--|---------------------------|
| Pruchno et al., 2014 | CTA | FF, store fronts, supermarkets, GS, CS | Density | NA | Government |
| Richardson et al., 2015 | Residential address | FF, restaurants, supermarkets, CS | Density | 3 and 8km Euclidean | Commercial |
| Rummo 2017 | Residential address | FF, restaurants, CS, GS, supermarkets | percentage of CS, GS, and S out of sum of them, percentage of FF and FSR out of the sum of them | 1-km street network proximity from respondents' residences | Commercial database |
| Rundle et al., 2009 | Network buffer around residential address | Supermarkets, FV markets, FF, pizzerias, bakeries, and candy and nut stores | Density | 805m network | Commercial |
| Salois, 2012 | County | Restaurants, FF, supermarkets, GS, gas-based CS, no-gas CS, super centre/warehouse club stores, farmers' markets | Density | NA | Government |
| Singleton et al., 2016 | County | GS, CS, farmer's markets, supercentres, supermarkets, FF, restaurants | Density | NA | Government |
| Slack et al., 2014 | County/food desert tract | FF | Density | NA | Government |
| Spence et al., 2009 | Postal code | Supermarkets, FF, specialty food stores, CS | Count, ratio, Retail Food Environment Index (RFEI) | 800m and 1600m | Government and commercial |
| Stark et al., 2013 | Zip code | GS, supermarkets, national/local FF, pizza restaurants, CS, Food outlets were categorized, bodegas, bakeries, candy and nut stores, meat markets, restaurants, GS, fish markets and specialty food stores | Density, relative concentration (proportion), diversity | NA | Commercial |
| Tung et al., 2016 | Neighbourhood | GS | Euclidian Proximity | NA | Self-reported |

| Reference | Geographic unit of observation | Store type | Spatial food store measure | Buffer size | Food outlet source |
|---------------------------|-----------------------------------|---|---|---|---------------------------|
| Viola et al., 2013 | Postal code | FF, pizzerias, supermarkets | Density, Network Proximity | ¼ miles | Commercial |
| Walker 2020 | Residential postcode | FF, restaurants, pubs to liquor stores, markets | ratio (FF/FSR, pubs/liquor stores); Count (markets) | 500m | Ground-truthing survey |
| Wang et al., 2007 | Census tracts and/or block groups | FF, food retail stores | Density, Euclidian Proximity | 0.5 miles | Government and commercial |
| Xu and Wang, 2015 | County | FF and restaurants | Ratio FF:Restaurants | NA | Government |
| Xu et al., 2013 | Street committee | FF, restaurants | Density | 720m street network | Government |
| Yan et al., 2015 | County | Supercentres, GS, CS, specialized food stores | Density | NA | Government |
| Yenerall 2017 | Residential address | GS | accessibility (network Proximity) | None | National database |
| Zenk 2017 | Census block group | CS, small GS, large GS, liquor stores | availability (Count) | 0.5-mile radial buffer around participants' census block centroid | Ground-truthing survey |
| Zhang 2019 | CTA | mRFEI | mRFEI | 0.5 miles | Commercial database |
| Zhang 2020 | Subdistrict/town | FF, restaurants, small GS, LS | Density | NA | National database |
| Zick et al., 2009 | Census block group | Healthy grocery stores, CS, restaurants, FF, multiple retail food options | Density, diversity, and design | NA | Government and commercial |

CS: convenience store, FF: fast-food outlet, FV: fruit and vegetable store, GS: grocery store, LS: liquor store, RFEI: retail food environment index, mRFEI: modified retail food environment index. NA: not available/not applicable

5. Risk of bias assessment

Table S5. Risk of bias and quality assessment of reviewed studies

| Reference | Population sampling | Outcome | Exposure (food environment) | Food outlet data source | Spatial analysis method | PA | Study design | Statistical Method | Data temporality/ time match | Score |
|-----------------------------|---------------------|---------|-----------------------------|-------------------------|-------------------------|------|--------------|--------------------|------------------------------|-------|
| Abbott et al., 2014 | Low | High | Low | High | High | High | High | High | High | 2 |
| Adachi-Mejia et al., 2017 | High | High | Low | Low | Low | Low | High | High | High | 4 |
| Ahern et al., 2011 | Low | High | Low | High | High | Low | High | High | High | 3 |
| Albalawi 2020 | High | Low | Low | Low | High | High | High | High | High | 3 |
| Backes 2019 | Low | High | Low | Low | High | High | High | High | Low | 4 |
| Block et al., 2011a | Low | Low | Low | High | High | High | Low | Low | Low | 6 |
| Bodor et al., 2010 | High | High | Low | Low | High | High | High | High | Low | 3 |
| Boone-Heinonen et al., 2013 | Low | Low | Low | High | High | Low | Low | High | Low | 6 |
| Burgoine 2017 | Low | Low | High | Low | High | Low | High | High | High | 3 |
| Burgoine 2018 | Low | Low | Low | Low | High | Low | High | High | High | 4 |
| Burgoine et al., 2011 | Low | High | Low | High | High | Low | Low | High | Low | 5 |
| Burgoine et al., 2016 | Low | Low | High | Low | Low | High | High | High | Low | 5 |
| Carroll 2020 | Low | Low | Low | Low | Low | Low | Low | High | Low | 7 |
| Cerin et al., 2011 | Low | High | Low | Low | Low | Low | High | Low | High | 6 |
| Chaparro et al., 2017 | Low | High | High | High | Low | High | High | Low | Low | 4 |
| Chen et al., 2010 | Low | High | High | Low | High | High | High | Low | High | 3 |
| Chen et al., 2013 | High | High | High | Low | Low | Low | High | Low | Low | 5 |
| Chen et al., 2016 | Low | High | High | High | High | High | High | Low | High | 2 |
| Chen et al., 2019 | High | Low | Low | Low | High | High | High | Low | High | 4 |
| Chen et al., 2020 | High | Low | High | Low | High | High | High | High | High | 2 |

| Reference | Population sampling | Outcome | Exposure (food environment) | Food outlet data source | Spatial analysis method | PA | Study design | Statistical Method | Data temporality/ time match | Score |
|-------------------------------------|---------------------|---------|-----------------------------|-------------------------|-------------------------|------|--------------|--------------------|------------------------------|-------|
| Christian, 2012 | High | High | Low | Low | High | High | High | High | Low | 3 |
| Conroy 2018 | High | High | Low | Low | High | High | High | High | High | 2 |
| Cooksey-Stowers et al., 2017 | Low | High | Low | High | Low | Low | High | High | Low | 5 |
| Crawford et al., 2008 | High | High | High | High | High | Low | High | High | High | 1 |
| Dake et al., 2016 | High | Low | Low | High | Low | Low | High | Low | Low | 6 |
| Drewnowski et al., 2014b | High | High | High | Low | High | High | High | Low | Low | 3 |
| Drewnowski, 2012 | High | High | High | Low | High | High | High | High | Low | 2 |
| Du et al., 2014 | Low | Low | Low | High | Low | Low | Low | High | High | 6 |
| Dubowitz et al., 2012 | Low | Low | Low | Low | High | Low | Low | High | High | 6 |
| Dunn et al., 2012 | Low | High | High | Low | High | High | High | Low | Low | 4 |
| Fan et al., 2014 | Low | High | Low | High | High | High | High | High | High | 2 |
| Frankenfeld et al., 2015 | Low | High | Low | High | High | High | High | High | High | 2 |
| Fuller et al., 2013 | High | High | High | Low | High | Low | High | Low | Low | 4 |
| Gartin, 2012 | High | Low | Low | Low | High | High | High | High | Low | 4 |
| Ghosh-Dastidar et al., 2014 | Low | Low | Low | Low | Low | High | High | High | Low | 6 |
| Gibson, 2011 | Low | Low | Low | Low | High | High | High | High | Low | 5 |
| Hanibuchi et al., 2011 | Low | High | Low | High | High | High | High | High | High | 2 |
| Hattori et al., 2013 | Low | High | Low | High | Low | Low | High | Low | High | 5 |
| Hobbs 2017 | High | High | Low | Low | Low | High | High | High | Unclear | 3 |
| Hobbs 2019 | High | High | Low | Low | High | High | Low | Low | High | 4 |
| Hobbs 2019 | High | High | High | Low | High | High | High | High | High | 1 |
| Hobbs 2019 | High | High | High | Low | High | High | High | High | Unclear | 1 |

| Reference | Population sampling | Outcome | Exposure (food environment) | Food outlet data source | Spatial analysis method | PA | Study design | Statistical Method | Data temporality/ time match | Score |
|----------------------------|---------------------|---------|-----------------------------|-------------------------|-------------------------|------|--------------|--------------------|------------------------------|-------|
| Hollands et al., 2013 | High | High | Low | Low | High | Low | High | Low | Low | 5 |
| Hollands et al., 2014 | Low | High | High | Low | High | Low | High | Low | Low | 5 |
| Hosler, 2009 | Low | High | High | Low | High | High | High | High | High | 2 |
| Inagami et al., 2009 | Low | High | High | Low | High | High | High | Low | High | 3 |
| Jaime et al., 2011 | Low | High | Low | Low | High | Low | High | High | Low | 5 |
| Jeffery et al., 2006 | Low | High | High | High | Low | Low | High | High | High | 3 |
| Jilcott et al., 2011 | Low | High | Low | Low | High | Low | High | Low | High | 5 |
| Jilcott Pitts et al., 2015 | High | High | High | Low | Low | High | High | High | Low | 3 |
| Kruger et al., 2014 | High | High | High | High | High | High | High | High | High | 0 |
| Laxy et al., 2015 | Low | Low | Low | High | Low | Low | High | High | Low | 6 |
| Li et al., 2008 | Low | High | High | High | High | Low | High | Low | Low | 4 |
| Li et al., 2009c | Low | High | High | High | High | Low | High | Low | Low | 4 |
| Li et al., 2009c | Low | High | High | High | High | Low | High | Low | Low | 4 |
| Liese 2017 | High | Low | Low | Low | High | Low | High | High | Low | 4 |
| Lopez, 2007 | Low | High | Low | High | High | High | High | Low | High | 3 |
| Macdonald et al., 2011 | Low | High | Low | Low | High | High | High | High | High | 3 |
| Mackenbach 2019 | High | High | High | Low | Low | High | High | Low | High | 3 |
| Mackenbach 2019 | High | High | High | Low | High | High | High | High | Low | 2 |
| Maddock, 2004 | Low | High | High | High | High | Low | High | Low | High | 3 |
| Mason 2018 | High | Low | High | Low | High | Low | High | High | Unclear | 2 |
| Mazidi and Speakman, 2017 | Low | High | High | Low | Low | Low | High | High | Low | 5 |
| Mehta and Chang, 2008 | Low | High | High | High | High | High | High | High | Low | 2 |

| Reference | Population sampling | Outcome | Exposure (food environment) | Food outlet data source | Spatial analysis method | PA | Study design | Statistical Method | Data temporality/ time match | Score |
|-----------------------------------|---------------------|---------|-----------------------------|-------------------------|-------------------------|------|--------------|--------------------|------------------------------|-------|
| Mejia et al., 2015 | High | High | Low | Low | Low | Low | High | High | High | 4 |
| Mendes et al., 2013 | High | High | High | High | High | High | High | High | High | 0 |
| Meyer et al., 2015 | High | Low | Low | High | High | Low | Low | High | High | 4 |
| Michimi and Wimberly, 2010 | High | High | Low | High | High | High | High | High | Low | 2 |
| Michimi and Wimberly, 2015 | High | High | Low | Low | High | High | High | Low | Low | 4 |
| Morland et al., 2006 | Low | Low | Low | High | High | Low | High | Low | High | 5 |
| Murphy 2017 | High | High | High | Low | High | High | High | Low | Low | 3 |
| Murphy 2018 | High | High | High | Low | High | Low | High | Low | Unclear | 2 |
| Mylona 2020 | High | Low | High | Low | High | Low | High | Low | Unclear | 3 |
| Oexle et al., 2015 | High | High | High | Low | Low | High | High | High | High | 2 |
| Oka et al., 2013 | Low | Low | Low | High | High | Low | High | Low | High | 5 |
| Patel et al., 2017 | Low | Low | High | Low | Low | Low | High | High | High | 5 |
| Pearce et al., 2009 | Low | Low | High | High | High | High | High | Low | High | 3 |
| Pineda et al., 2021 | Low | Low | Low | Low | Low | Low | High | Low | High | 7 |
| Polsky 2016 | High | High | Low | Low | Low | Low | High | High | High | 3 |
| Polsky et al., 2016 | Low | Low | High | High | High | Low | High | High | High | 3 |
| Pouliou and Elliott, 2010 | Low | High | Low | High | High | Low | High | High | High | 3 |
| Prince et al., 2012 | Low | High | Low | High | High | Low | High | Low | High | 4 |
| Pruchno et al., 2014 | High | High | Low | High | High | High | High | Low | Low | 3 |
| Richardson et al., 2015 | High | Low | High | High | High | Low | Low | Low | Low | 5 |
| Rummo 2017 | High | Low | Low | Low | High | Low | Low | High | Low | 5 |
| Rundle et al., 2009 | Low | Low | Low | High | High | Low | High | Low | High | 5 |

| Reference | Population sampling | Outcome | Exposure (food environment) | Food outlet data source | Spatial analysis method | PA | Study design | Statistical Method | Data temporality/ time match | Score |
|-------------------------------|---------------------|---------|-----------------------------|-------------------------|-------------------------|------|--------------|--------------------|------------------------------|-------|
| Salois, 2012 | Low | High | Low | High | High | Low | High | High | Low | 4 |
| Singleton et al., 2016 | High | High | Low | Low | Low | High | High | High | High | |
| Slack et al., 2014 | Low | High | High | High | High | Low | High | Low | High | 3 |
| Spence et al., 2009 | High | High | Low | High | Low | High | High | High | High | 2 |
| Stark et al., 2013 | High | High | Low | High | Low | Low | High | Low | Low | 5 |
| Tung et al., 2016 | High | Low | High | High | High | Low | High | High | Low | 3 |
| Viola et al., 2013 | High | High | Low | High | Low | Low | High | Low | Low | 5 |
| Walker 2020 | High | Low | Low | Low | Low | Low | High | Low | Unclear | 5 |
| Wang et al., 2007 | Low | High | Low | High | Low | Low | High | Low | High | 5 |
| Xu and Wang, 2015 | Low | High | High | High | High | Low | High | Low | Low | 4 |
| Xu et al., 2013 | High | High | High | Low | Low | Low | Low | Low | Low | 6 |
| Yan et al., 2015 | High | High | Low | High | High | High | High | High | High | 1 |
| Yenerall 2017 | Low | High | High | Low | High | High | High | High | Unclear | 2 |
| Zenk 2017 | High | Low | Low | Low | High | High | Low | High | Low | 5 |
| Zhang 2019 | High | Low | Low | Low | High | High | High | High | High | 3 |
| Zhang 2020 | High | Low | Low | Low | High | Low | High | High | Low | 4 |
| Zick et al., 2009 | High | High | Low | High | Low | Low | High | Low | High | 4 |

A high score represents a lower risk of bias while a low score indicates a higher risk of bias. The maximum possible score was 9.

6. Food outlet density and proximity and its association with BMI

Figure S2. Fast-food outlet density and proximity and its association with BMI

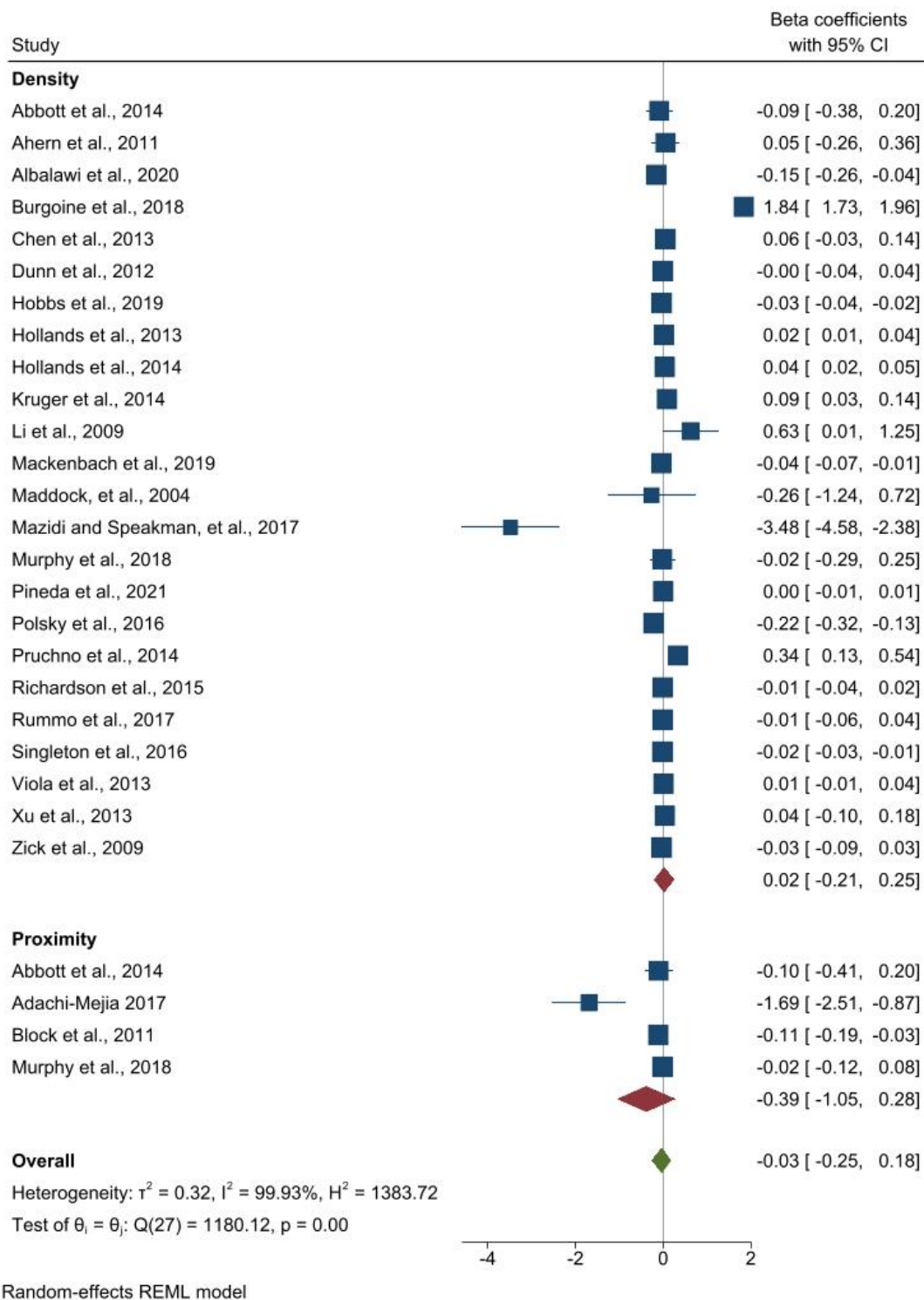


Figure S3. Restaurant density and its association with BMI.

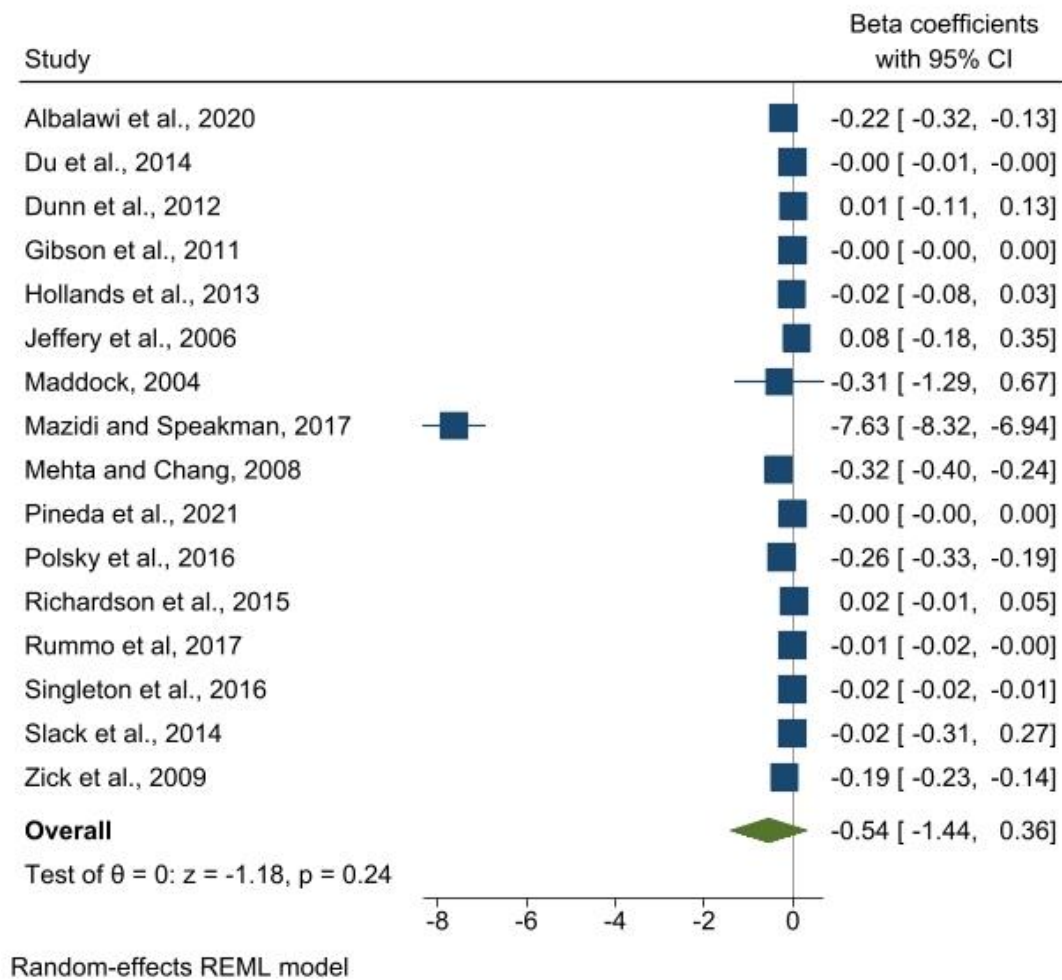


Figure S4. Convenience store density and proximity and its association with BMI.

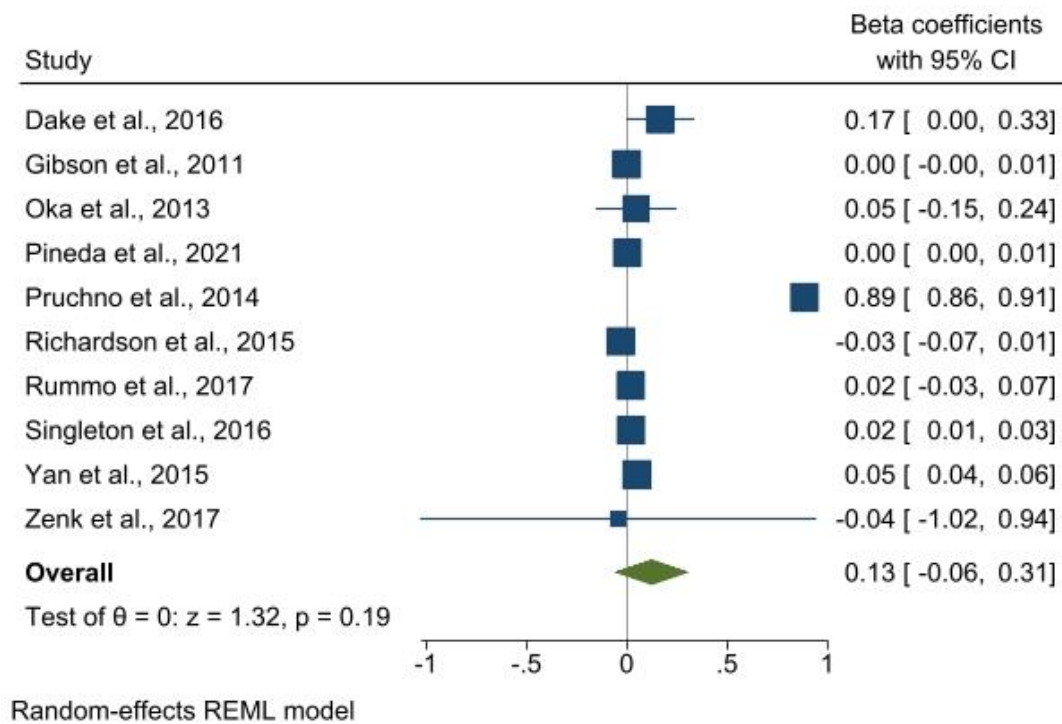


Figure S5. Supermarket density and proximity and its association with BMI.

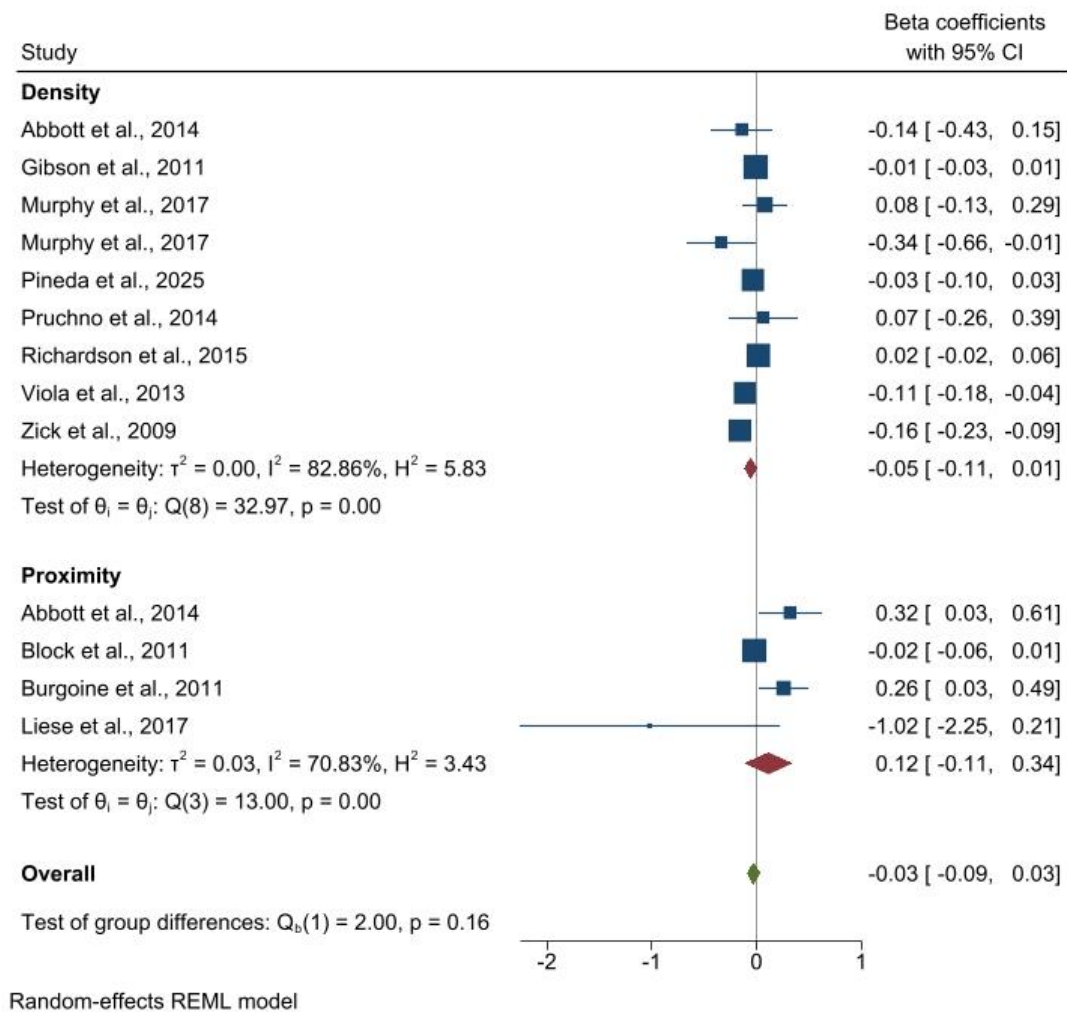


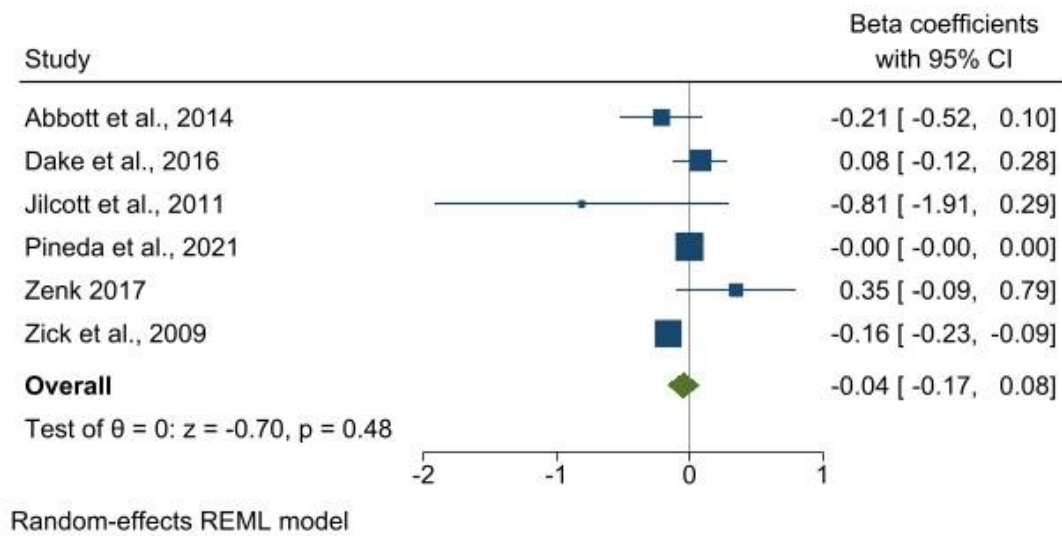
Figure S6. Fruit and vegetable store density and its association with BMI.

Figure S7. Retail food environment index (RFEI) and its association with BMI.