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Neighbourhood typologies and associations with body mass index and obesity: a cross-sectional study

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Abstract

Little research has investigated associations between the combined food and physical activity (PA) environment, BMI (body-mass-index) and obesity. Cross-sectional data (n=22,889, age 18-86 years) from the Yorkshire Health Study were used [2010-2013]. BMI was calculated using self-reported height and weight; obesity=BMI≥30. Neighbourhood was defined as a 2km radial buffer; food outlets and PA facilities were sourced from Ordnance Survey Points of Interest (PoI) and categorised into 'fast-food', 'large supermarkets', 'convenience and other food retail outlets' and 'physical activity facilities'. Parks were sourced from Open Street Map. Availability was defined by quartiles of exposure and latent class analysis (LCA) was conducted on these five environmental variables. Linear and logistic regression were then conducted for BMI and obesity respectively for different neighbourhood types. Models adjusted for age, gender, ethnicity, area-level deprivation, and rural/urban classification. A five-class solution demonstrated best fit and was interpretable. Neighbourhood typologies were defined as; low availability, moderate availability, moderate PA, limited food, saturated and moderate PA, ample food. Compared to low availability, one typology demonstrated lower BMI (saturated, b= -0.50, [95% CI= -0.76,-0.23]), while three showed higher BMI (moderate availability, b= 0.49 [0.27,0.72]; moderate PA, limited food, b=0.30 [0.01,0.59]; moderate PA, ample food, b=0.32 [0.08,0.57]). Compared to the low availability, saturated neighbourhoods showed lower odds of obesity (OR=0.86 [0.75,0.99]) while moderate availability showed greater odds of obesity (OR=1.18 [1.05,1.32]). This study supports population-level approaches to tackling obesity however neighbourhoods contained features that were health-promoting and -constraining. Embracing environmental complexity will be an important next step for researchers and policymakers in providing healthy places.

Introduction

One in four adults are currently obese and while recent evidence suggests that long-term trends of increasing body weight is starting to slow, the prevalence remains high (1, 2). Increasingly, research and policy responses are focusing on the environmental contributions for understanding these population-level patterns (3, 4). However, an extensive body of literature has shown inconsistent associations between aspects of the food environment such as supermarkets (5-10) or fast-food outlets (7, 11-14) and obesity. Furthermore, evidence demonstrating a relationship between the physical activity (PA) environment and obesity also remains equivocal (15-19).

Recent research has demonstrated that individual features of obesogenic neighbourhoods may cluster in the same locations (20). It is therefore imperative not to treat each feature in isolation. Developing multi-dimensional measures of both the food and physical activity environments may better represent the wider environmental influences on obesity. Previous studies have used a combined or composite measure to delineate different urban contexts suggesting that individual experiences of neighbourhood context are complex. Composite measures of the environment may lack the appeal of identifying a specific availability point that can be addressed more easily through policy i.e. regulating the growth of just fast-food outlets (21). However, this clustering of neighbourhood features may be a more accurate reflection of the wider influences of the environment on human behaviour within a broader system of environmental features (22).

Despite some evidence to suggest aspects of the food environment may cluster to form neighbourhood typologies, there is no clear pattern of co-occurrence when considering both physical activity and food environments (20). A comprehensive study that virtually audited the built environment using Google Streetview in London, Paris, Ghent and Budapest demonstrated a complex picture (23) with four clusters of neighbourhoods existing. The typologies revealed that neighbourhoods were not always simple linear distinction in their extent of 'obesogenic' features with some clusters containing features that were both potentially obesogenic and non-obesogenic. For example, aesthetically pleasing greener neighbourhoods which may promote physical activity were also those with a low presence of active transport facilities i.e. no bike lanes or foot paths. One limitation of such studies is that they have focused mostly on describing neighbourhood typologies, with less investigation into how different contexts are associated with both body mass index and obesity.

This study uses a large cohort that is specifically designed for informing local-level decision making on weight and weight management. The study first explores how aspects of the food and physical activity environment cluster and second, investigates the association between neighbourhood typologies, body-mass-index and obesity.

Methods

Study Sample

The sample used in this cross-sectional analysis was collected during wave one of the Yorkshire Health Study (formerly the South Yorkshire Cohort Study) which has been reported in detail previously (24). Briefly, the YHS is a longitudinal observational cohort study collecting information on the residents (aged 18-86 years) from the Yorkshire and Humberside region in England. It aims to inform National Health Service (NHS) and local authority health-related decision making in Yorkshire. Data were collected on current and long-standing health, health care usage and health-related behaviours, with a focus on weight and weight management. Wave one data collection contains records on 27,806 individuals (2010-12) from 11 boroughs within the Yorkshire and Humber region. Participants in the cohort are older than in the total South Yorkshire population with a higher proportion of females. The majority of participants were also reported being of White ethnicity (94.1%), which was over representative of the ethnic group (2011 Census; 90.5%). Adults living within the study area with a valid height, weight, postcode, ethnicity and gender were included resulting in 22,889 participants. Ethical clearance was granted by the ethics committee of the Carnegie Faculty, Leeds Beckett University.

Individual-level measures and covariates

The height (cm) and weight (kg) of each participant was self-reported. Body mass index (BMI) was then calculated for each participant as weight (kg)/height^2 (m). In subsequent analyses BMI was used as a scale variable however, participants were also split dichotomously based on their BMI into obese (BMI ≥30) or not obese (BMI <30). Age, gender, ethnicity (White-British and other), deprivation score (Index of Multiple Deprivation) and rural or urban classification were included in all models as covariates. IMD provides a multidimensional measure of deprivation (based on 37 separate indicators, organised across seven distinct domains of; income deprivation; employment deprivation; health deprivation and disability; education, skills and training deprivation; crime; barriers to housing and services; and living environment deprivation) and is commonly used by Local Governments. IMD scores were assigned to the lower super-output area (LSOA) of each individual, as determined by their geocoded postcode. Rural or urban classification of the LSOA was made in line with local government classifications (25).

Neighbourhood level measures

To define neighbourhood, the postcode of each participant was geocoded using home postcode. A neighbourhood boundary was then defined using a radial buffer of 2km centred on these coordinates within ArcGIS 10.4. Neighbourhood was defined as a 2km radial buffer as this is hypothesised as a distance easily accessible when driving (26). The count of facilities or food outlet were then counted within this radial buffer to define availability. It is acknowledged that neighbourhoods are difficult to define as individuals are known to operate outside a radial buffer or administratively defined area (27). However, previous analyses (4) also showed little difference in associations when using 1600m radial buffers which are hypothesised to better reflect walking behaviours (28).

We considered a wide range of food and physical activity neighbourhood characteristics. Data on food outlet locations and physical activity facilities was obtained from The Ordnance Survey (OS), a national mapping agency in the United Kingdom which covers the island of Great Britain. Data were sourced from the Point of Interest (PoI) dataset covering the study area at the time of the data collection (2010-2012) which has been suggested as a viable source of secondary data (REF) and was again mapped in ArcGIS 10.4. Classifications were defined based on a proprietary classification system within the PoI dataset. Food outlets were categorised into three groups of (i) large supermarkets, (ii) fast-food outlets and (iii) convenience or other food retail outlets. Fast-food outlets contained the PoI categories of "fast food and takeaway outlets", "fast food delivery services" and "fish and chip shops"; large supermarket contained "supermarket chains" and convenience and other food outlets contained other food outlets which included but was not limited to "restaurants", "convenience stores", and "bakeries". Physical activity (PA) facilities were included based on proprietary classification of "physical activity facilities". Park data was obtained from Open Street Map. A park was defined as an open, green area for recreation typically open to the public that is in a town or city, national parks were not included in this dataset (29). PoIs and parks falling within and intersecting with the 2km radial buffer were then identified through a point in polygon analysis in ArcGIS 10.4.

Statistical Analysis

To describe the study population and their respective neighbourhoods, means and standard deviations (continuous variables) and percentages (categorical variables) were calculated. Results were presented for both individual-level and area-level variables included within the analysis.

A latent class analysis (LCA) was conducted in STATA MP 14.2 using the five environmental variables (large supermarkets, fast-food outlets, convenience or other food retail, PA facilities and parks). The environment varied considerably between each individual. For instance, some individuals had no food outlets within a 2km buffer and others had 100 (Table 1). However, it is unlikely that an increase from 0-1 fast food outlets is the same as an increase from 101-102 fast food outlets. To account for this and model relative effect, we modelled food outlet data in quartiles using dummy variables (Q1 least exposed, Q4 most exposed). Quartiles were based on population so each quartile contained approximately the same number of participants. Parks were defined as tertiles due to the granularity of the data. LCA is a data driven method that identifies an unobserved or latent construct using the statistical relations among the variables (30). The goal of LCA in our study was to derive meaningful classes from a sample, assign participants to each class and then explore associations with BMI and obesity. LCA derives mutually exclusive classes that maximize between-group variance and minimize within-group variance based on several model fit criteria.

The expectation-maximization (EM) algorithm was used for class derivation and assignment. The LCA operates with an aim of findings participants who are similar on a combination of attributes. To identify the ideal number of classes in the sample solutions of 1 to 10 classes were tested. Models were selected based on model fit statistics of the Bayesian Information Criterion (BIC) statistic, sample sizes per class and usefulness and substantive interpretation (30). Item-response probabilities of classes were then charted for visual interpretation based on each of the five variables which were modelled in quartiles of exposure. Item-response probabilities show the probability of an affirmative response to being part of each derived class (32). Mean values close to 1 indicate a strong degree of homogeneity and classification certainty. The class prevalence and item response probabilities were presented by latent class.

Next, we estimated associations between derived latent neighbourhood patterns (classes), BMI and obesity. All models adjusted for age, gender, ethnicity, area-level deprivation and rural or urban classification of the area. Two separate models were carried out, first, to estimate associations between classes and BMI a linear regression model (b, 95% CI) was used. A binary outcome of obese or not was then created to allow for logistic regression (odds ratios (OR) and 95% CI). Those within 'low availability' neighbourhoods (class 1) were chosen as a reference category. In theory, they would have lower availability to the physical activity environment and although more debatable, poorer availability to all aspects of the food environment which may result in lower physical activity levels and poorer dietary intake due to the lack of availability of all types of food outlets. Due to the high statistical power in the dataset and assumption that data were missing at random (Supplementary Material) missing data were dealt with by listwise deletion. All analyses were undertaken using STATA MP 14.2.

Results

3.1 Latent class analysis

Figure 1 shows model fit criteria based on the raw Bayesian Information Criterion (BIC) score for latent class solutions. A five-class solution was deemed best fit. Any solution above this resulted in smaller gains on model fit criteria and resulted in complex interpretability. The mean maximum posterior probabilities for the 5 classes were 0.90, 0.92, 0.89, 0.93 and 0.87 for classes 1 to 5 respectively, providing evidence of homogeneity for each subgroup.

INSERT FIGURE 1 HERE

Five distinctive neighbourhood typologies were identified (Table 1). Class 1 (18.98% of participants) was labelled as 'low availability' and contained the lowest proportion of all types of neighbourhood amenities. Class 2 (33.32%) was defined as ‘moderate availability’ as it contained a moderate amount of both food outlets, PA facilities and parks. Class 3 (12.15%) was labelled as ‘moderate PA, limited food’ although PA environment availability was moderate, it had lower availability of convenience/other food outlets and large supermarkets and the lowest availability of all classes to fast-food outlets. Class 4 (13.57%) was defined as ‘saturated availability’, with high availability to all types of amenities across the food (particularly fast-food and other food or convenience outlets) and PA environment. Finally, class 5 (21.99%) was defined as ‘moderate PA, ample food’ with moderate access to PA environment and high availability to all food outlets (particularly fast-food and other food or convenience outlets). From this point forward neighbourhood typology name will be referred to rather than class number.

INSERT TABLE 1 HERE

3.2 Composition differences across classes

Table 2 demonstrates that demographic characteristics differed by neighbourhood typology. The percentage of males and females remained consistent however, ‘moderate PA, limited food’ had the oldest population (mean 56.75 years) and ‘saturated’ had the youngest (mean 49.49 years). Ethnicity did vary by neighbourhood type, with the smallest percentage (1.2%) of non-white participants residing with the ‘low availability’, and the largest proportion within the ‘saturated’ typology (10.24%). In terms of rurality, ‘low availability’ was mainly rural (34.28%) and ‘saturated’ were mostly within the urban areas (99.97%). Deprivation varied by neighbourhood typology; neighbourhoods with low availability to food (‘low availability and moderate PA’, ‘limited food’) were typically the least deprived. Typically, as availability to food increases across neighbourhood typologies, deprivation increases, the only exemption is the ‘saturated’ typology which has segments of low deprivation.

3.2 Associations between the combined environment and BMI

Table 3 presents the association between the combined environment and BMI, relative to 'low availability' after adjusting for individual- and area-level covariates. Individuals who resided within 'saturated' neighbourhoods had statistically significant lower BMIs (b= -0.50, 95% CI [-0.76, -0.23]) compared to individuals within 'low availability' neighbourhoods. The other three latent classes of 'moderate availability' (b=0.49, 95% CI 0.27, 0.71]), 'moderate PA, limited food' (b=0.30 [95% CI 0.01, 0.59]) and 'moderate PA, ample food' (b=0.23, [95% CI 0.08, 0.57]) were each found to have significantly higher BMI values compared to 'low availability' neighbourhoods.

INSERT TABLE 3 HERE

3.3 Associations between the combined environment and obesity

Table 4 presents the results of the logistic regression model that examined the association between the combined environment and obesity for each of the environments relative to 'low availability' after adjusting for individual- and area-level covariates. Individuals who resided in neighbourhoods with 'moderate availability' typology were 18% more likely to be obese (OR=1.18 95% CI 1.05,1.32]). Individuals who resided within 'saturated' neighbourhoods were 14% less likely to be obese (OR=0.86 95%CI 0.75,0.99]). The results for residing in the 'moderate PA, limited food' and 'moderate PA, ample food' were not statistically significant for obesity but were in the same direction as associations with body mass index.

INSERT TABLE 4 HERE

Discussion

Our study used latent class analysis to develop a combined measure of the food and physical activity (PA) environment. It then investigated the association between of our typologies of neighbourhood contexts and body mass index (BMI) and obesity. We add to the literature by presenting a more complex and multidimensional picture of contextual neighbourhood factors and their contribution to BMI and obesity. Neighbourhood typologies contained features that may be considered protective of obesity such as, greater availability to PA facilities but also features that may be considered more obesogenic such as increased availability to fast food outlets. It suggests that previous analyses utilising only linear and perhaps more simple measures of neighbourhood context (or treating factors in isolation) will fail to correctly understand the role of neighbourhood context. Policy should explicitly acknowledge that neighbourhoods have availability to multiple features i.e. fast-food outlets, convenience stores and parks that may be both health-promoting and -constraining, rather than focusing on singular aspects such as only fast-food outlets.

To our knowledge, this is one of the first studies that used clusters of neighbourhood environments to study associations with BMI and obesity. In contrast to previous equivocal research, much of which focuses on singular aspects of food or PA environments (12, 16), our results reveal that five neighbourhood typologies were associated with significant and meaningful differences in adult BMI and obesity. This confirms prior work (31) which suggests that accounting for multiple environmental influences, may represent a more accurate reflection of the wider influences of an environmental influence on human behaviour and health (22). This study provides support for population-level approaches to tackling obesity in specific neighbourhood typologies. However, it also acknowledges the complexity of local environments and therefore may accurately reflect the wider environmental influences on human behaviour and obesity.

‘Saturated’ neighbourhoods, characterised by greater availability to the PA and food environment (particularly fast-food and other food or convenience outlets), were associated with reduced BMI and obesity compared to low exposure neighbourhoods. Although several studies have demonstrated the high calorie and nutrient poor content of fast-food (33, 34), this counterintuitive result demonstrates the complex interplay between an individual's built environment and obesity. This importance of moving beyond assessing singular aspects of the environment i.e. just fast food was highlighted by a study which showed that the amount of energy consumed within full service restaurants was equivalent to those who ate at fast food outlets (35). We provide evidence that neighbourhoods are not healthy or unhealthy, but are characterized by neighbourhood features that are both health-promoting and health-constraining (20). We add to evidence by exploring multiple aspects of both the food and PA environments.

'Moderate availability' neighbourhoods were associated with greater odds of obesity and BMI with a meaningful effect despite the relatively wide confidence intervals (18% increase in odds of obesity). Research from the UK (20) and internationally (36) have demonstrated the complex nature of neighbourhoods, however few have extended their analyses to show associations with BMI and obesity. Compared to 'low availability' neighbourhoods and after adjustment for covariates, 'moderate PA, limited food' and 'moderate PA, ample food' also showed statistically significant increases in BMI however, this association did not persist for obesity. Neighbourhood typologies which were related by some type of 'moderate availability' may not be neighbourhoods commonly hypothesised to be at greater risk of both higher BMI and/or obesity. However, it is worth noting that residential neighbourhood context captured within this study may only have a small effect on BMI or obesity and individuals may also have availability outside of their immediate context for instance, at work or when commuting (37).

Neighbourhoods also contain other influential contextual factors not captured within this study such as the quality of the built PA environment or prices within supermarkets which may have exhibited an effect BMI and obesity. For instance, research (38, 39) has demonstrated the importance of the quality of PA spaces in determining PA behaviours. Similarly, other studies have demonstrated that economic i.e. the affordability of supermarkets were important factors in detecting associations with BMI (40, 41). However, this was not captured within this study predominantly due to the difficulty of conducting such research over such a large area on a variety of different environmental variables. Such differences in the quality of built environments in terms of aesthetics, safety, features, price, or choice may be important in determining usage or purchasing behaviours and are important considerations for future research. Although a park may be near a home, it may be unsafe which inhibits its use (42). Without more detailed measures of the food and PA environment, such nuances will continue to reduce the accuracy of statistical models employed and may go some way to explaining the more complex associations seen within this study.

The low exposure neighbourhood typology was used as the reference category (low availability to parks, PA facilities and all types of food outlets). Conceptually, participants would be restricted in their ability to expend energy within parks or PA facilities and the food they can purchase in their immediate residential neighbourhood. Overall, 19.0% of participants resided within low availability neighbourhoods which were also home to slightly older participants relative to other neighbourhood typologies. This neighbourhood typology may be consistent with a design that has been planned around the use of the car. Such designs are conducive to lower PA and higher obesity rates (43).

Implications for policy and practice

Our study adds important local-level analyses which are required to inform local policy on environmental level prevention efforts. The results identified within this study begin to highlight the complexity that local authorities must account for with when making health-related decision making. Neighbourhoods were not wholly unhealthy or healthy but contained a range of features that had varied associations with BMI and obesity. Based on these neighbourhood profiles, population-based interventions to reduce BMI and obesity that are targeted towards specific neighbourhoods show promise. However, policy should be designed to account for the complexity of neighbourhood environments which are composed of a variety of factors that may exhibit complex interactions to influence BMI and obesity. Moving forward both research and policy will benefit by going beyond their silo of professional expertise (i.e. just fast food or physical activity) by working together within multidisciplinary teams.

Limitations

Our study design was cross-sectional restricting our ability to draw out causal effects. The YHS is a self-reported survey and our outcome variable, BMI, may be biased. Furthermore, although we used PoI data which has been suggested as a valid alternative to UK local authority data (44) this was only validated within one local authority. As consistent with many other studies within this area, neighbourhood was defined on the best available evidence, however, it is acknowledged that individuals will inevitably operate beyond their 'neighbourhood buffer' which in this case was only defined based on home postcode (45). We also acknowledge that the placement of food outlets, and PA facilities are not random, determined most likely by property value, land costs, land use and potential customers (population density) to support the service in question (46). Furthermore, the movement of people between neighbourhoods is not random, most likely determined by factors such as income or the affordability of housing in certain areas. Finally, although a range of factors were used to develop the combined environment latent class analysis, perceptive or economic (affordability) based measures could have helped strengthen the notion of a more comprehensive measure of neighbourhood. Future research may benefit from capturing availability beyond the residential environment and by including, actual geocoded measures of dietary and physical activity behaviours. This is a particularly important consideration when investigating associations with the combined environment as it is unreasonable to continue to assume that fast food outlets for instance are a proxy for unhealthy foods without doing in-store audits or measuring actual purchasing and consumption behaviours of individuals.

Conclusion

Our study found evidence of distinct neighbourhood typologies of the food and physical activity environment surrounding individuals that were associated with BMI and obesity.

Policymakers, town planners and local authorities are increasingly engaged with population-based strategies to reduce the prevalence of obesity through improved urban design, regulation of food outlets and increased availability to physical activity facilities or parks. These population-level approaches are supported within this study, in that specific neighbourhood typologies were associated with BMI and obesity. However, these findings also reinforce the notion that neighbourhoods are not wholly unhealthy or healthy, they are characterised by a complex clustering of neighbourhood features that are both health-promoting and -constraining. Given the progress in availability to secondary data on the environment it is now imperative that researchers consider wider environmental influences that include a broad range of environmental factors which include other food outlets, PA facilities, and parks. These findings have international relevance and highlight the need for research and policy to embrace the complex influence of neighbourhoods on health when providing healthy places to improve public health.

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Conflict of Interest

All authors declare no conflicts of interest.

Authorship

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Hannah Jordan	Critical review of paper
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Jim McKenna	Concept of idea, refinement of manuscript

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