Title:

Assessing the Obesogenic Environment of North East England

Abstract

This study examines the influence of the environment (defined as ‘walkability’, food availability and deprivation), alongside individual factors, on body mass index (BMI) and fruit and vegetable consumption. The aim of this unique study was to objectively scrutinise the concept of the obesogenic environment in the North East of England.

A set of theoretical obesogenic indices based on the availability of food to consume within and outside of the home, residential density, street connectivity and land use mix were created for North East England. A pooled sample of 893 individuals (aged 16+) over three years (2003, 2004, 2005) from the Health Survey for England (HSE) was isolated for further analysis and correlation with the obesogenic indices.

Results suggest that few elements of both walkability and food availability are significantly associated with BMI and fruit and vegetable intake. Some methodological concerns are highlighted, such as the appropriateness of walkability calculations for rural areas. The study concludes by strongly recommending a multi-faceted approach be taken when trying to tackle current levels of obesity.

Key words

Obesogenic environments, walkability, GIS, Environmental equity, Food environment.

Introduction

Levels of obesity have increased three-fold in the last twenty years and predictions for the future of the obesity problem are becoming ever more pessimistic (Foresight 2008a). A recent report for the Department of Health found that 65% of men and 56% of women are currently overweight in the United Kingdom, with one third of all UK adults recognised as clinically obese (Zaninotto *et al* 2006). Foresight models of future trends suggest that by 2050 “60% of adult men, 50% of adult women and about 25% of all children under 16 could be obese” (Foresight 2008b). The consequences of this will have an impact across society. This predicted rise in Body Mass Index (BMI) by 2050 will be associated with increases in diseases attributable to obesity including 30% increase for stroke, 20% for coronary heart disease and greater than 70% increase in type 2 diabetes (McPherson *et al* 2007).

BMI as a measure is not without its weaknesses; amongst these criticisms, it is inappropriate for assessing weight status in children, the elderly, the pregnant, and those with a notable amount of muscle tissue, for example. However the World Health Organisation (WHO) commends the use of BMI as a suitable measure of adiposity (World Health Organisation 2000), and it is one of the most commonly used assessments of weight status implemented in study designs as a result.

Driven by the increased availability of food and ever more sedentary lifestyles, this proliferation in levels of obesity is often referred to as the obesity ‘epidemic’ (Banwell *et al* 2005). Foresight emphasise the need to curtail this epidemic by acting now and being proactive as opposed to taking no action and being reactive (Jeffery & Sherwood 2008; Swinburn & Egger 2002); preventing obesity is much more effective than treating it. The efficacy of ‘treating’ a rooted obesity problem is not the only issue for the government to remain aware of; in 2002 the estimated total annual cost of overweight and obesity was nearly £7 billion, by 2050 the anticipated wider costs of elevated BMI per annum is £49.9 billion with £6.1 billion of this as predicted extra NHS costs of obesity alone (McPherson *et al* 2007). In theory the cause of obesity is simple: greater energy consumption than expenditure leads to weight gain. This said, the true aetiology of obesity is very much open to debate and although genetics are known to play a part, the possible effect of the environment upon our BMI is regularly suggested (World Health Organisation 2000). It has thus been suggested that a "neighbourhood based approach could add to traditional individual level obesity interventions, which often ignore the environmental context that shapes our behaviours, especially when healthy foods or opportunities for physical activity are unavailable" (Black & Macinko 2008, 2).

Fundamentally, "obesity results from an energy imbalance that occurs when energy consumption exceeds energy expenditure" so whilst examining the availability of food and its impact upon health, we must also investigate the role of the environment in encouraging or precluding energy expenditure through physical activity (Papas *et al* 2007, 129). This is particularly important as "some individuals can avoid obesity in un-supportive [obesogenic] environments by maintaining a pattern of healthy behaviours" (Hill & Peters 1998, 1371). The negative effects of the environment upon individual level health is often referred to as the 'obesogenic environment', a concept led by the notion that our surroundings can drive an "automatic, unconscious influence…[upon] behaviour" (Brug *et al* 2006, 528). Moreover, changing geographies mean that the obesogenicity of the environment is unlikely to be uniform and as a result it may be necessary to examine this variation in obesogenic 'exposure' within a framework of 'environmental justice'. It is possible that some populations are actually unfairly predisposed to being obese simply because of the 'obesogenic' environment in which they happen to live (Sexton & Adgate 1999). Despite the apparent poignancy of applying environmental justice to the study of obesogenic environments, no such explicitly focussed work exists in the field thus far

(Bowen 2002). Where such a serious health outcome as obesity is concerned however, we should rightly act to investigate these potential injustices (Bowen 2002; Cutts *et al* 2009).

The environment is defined here as “all that is external to the individual”, with the term ‘built environment’ referring to “aspects of a person’s surroundings which are human-made or modified” (Papas *et al* 2007, 129-130). This definition of the built environment often includes the availability of unhealthy food (such as fast food which is frequently of a higher calorific value than food produced in the home), the socio-economic status of the neighbourhood (which may affect the quality of retail food outlets), and the extent to which an individual’s surroundings may encourage physical activity through walking - the ‘walkability’ of the environment (Lopez-Zetina *et al* 2006). Individually, these factors have been significantly associated and dissociated with outcomes such as BMI and food consumption in recent years, both in the UK and the global context (see Maddock 2004; Mehta & Chang 2008; Smith *et al* 2005; Pearce *et al* 2008; Cummins *et al* 2005; Frank *et al* 2004; Ewing *et al* 2003; Leslie *et al* 2005; Ellaway *et al* 1997; Matheson *et al* 2008; Burgoine *et al* 2009). However research has delivered little consensus as to what features of the built environment are having the greatest effects upon our health; despite convincing hypotheses, no factors have been *proven* to *consistently* affect our behaviours in a specific way. Furthermore, very few studies (if any) have attempted to address aspects of our environment that both influence consumption and physical activity (Townshend & Lake 2009). Additionally, there are few studies in this field situated in the UK context, a setting that is believed to be radically different to that found in the US and Australia, thus necessitating further research (Townshend & Lake 2009; Lake & Townshend 2006).

This study builds upon existing work by understanding the multitude of factors that constitute our ‘environment’ and examining how these factors act collectively upon BMI (overweight and obese), and fruit and vegetable intake. Both overweight and obesity are considered within this research as those that are overweight are more ‘at risk’ of obesity. A case study based approach was employed here, which utilised both primary and secondary data to create a set of theoretical maps of varying obesogenic environments. These indices allowed us to link the physical environment of the North East of England with the individuals (and their recorded behaviours) who resided there and to subsequently scrutinise this relationship. The hypotheses are four-fold: increased walkability will be negatively associated with overweight/obesity; increased food availability will be positively associated with overweight/obesity; increased food available to purchase out of the home will be positively associated with increased levels of fruit and vegetable intake; increased levels of food available to consumed out of the home will be negatively associated with increased levels of fruit and vegetable intake.

Methods

Obesogenic indices were created for the study area, which was delimited to the North East of England. The indices were as follows:

- availability of food that is generally consumed outside of the home;
- availability of food that is generally consumed (or at least prepared) within the home;
- residential density;
- street connectivity;
- land use mix.

The latter three are common components in deducing theoretical 'walkability', the extent to which our surroundings may encourage physical activity through walking. These measures have been chosen primarily because there has been limited research linking them to obesity in the UK context, although they have been shown on numerous occasions to relate to obesity in other countries and settings. Socio-economic status was assessed at the area level by means of the 2004 IMD (Index of Multiple Deprivation), provided with the Health Survey for England (HSE) data. IMD is a composite measure of deprivation that summarises information on employment, living environment, crime, health, education, income and housing at the small area level throughout England (Noble *et al* 2004; Cummins *et al* 2005). The above indicators were calculated at the Lower Super Output Area (LSOA) level – a statistical area below that of the electoral ward level, containing approximately 1500 individuals - using boundary data available from the EDINA Digimap collections (edina.ac.uk/digimap). Overall, LSOAs were deemed the most appropriate for this study as they allowed a sufficient level of detail to be achieved whilst still allowing for the analysis of larger patterns and trends. The steps involved in calculating these measures are detailed as follows.

Assessing the foodscape

Data on the foodscape was sourced from the 2007 Yellow Pages using methods described in detail in Burgoine *et al* (2009) and Lake *et al* (2010). The street addresses for all food retail outlets were noted systematically for the entire North East England region and full postcodes were subsequently obtained using Yell.com (all addresses were matched to a full postcode). Food outlets were classified as either 'food to be consumed out of the home' ('pizza delivery and takeaway', 'takeaway' and 'restaurant' Yellow Pages categories combined) or 'food bought out of the home' ('supermarkets' and 'greengrocers and convenience stores' Yellow Pages classifications combined) based on the likely site of preparation/consumption of the food.

The locations of the food vendors were geocoded and mapped using ArcGIS 9.2 (ESRC Inc., Redlands, CA). Only 3 of 1463 postcodes (0.2%) were unable to be matched to a geographical location. Due to many LSOAs containing no food outlets, the number of food outlets was subsequently aggregated at the larger Middle Super Output Area (MSOA) level. Population data for MSOAs was sourced from the 2001 UK census and a ratio of food outlets per thousand of population was calculated. The results of this calculation were then ranked and divided into quintiles – precedent for the use of quintiled environmental data has already been set in the literature (Wheeler & Ben-Shlomo 2005; Pearce *et al* 2010). Five groupings (quintiles) were chosen, as this would allow accurate trend identification (Wheeler 2004). The environmental indicators had to be categorised in this way in order to be a candidate for 'matching' with HSE data by the National Centre for Social Research, NatCen (see later section on data sources for more information on the 'matching' process). Whilst the use of deciles, for example, would have allowed a more detailed picture of potential obesogenicity throughout the study area, this was not possible. The anonymity of HSE participants is of paramount importance, and the use of deciles on this number of environmental indicators would mean that each matched record (each individual) would contain a potentially geographically disclosive combination of decile scores. To elaborate, if deciles were used, some areas would be undoubtedly attributed unique combinations of decile scores, which would subsequently allow a deduction of where certain individuals (those who had been matched with these unique scores) are located. These principles of maintaining confidentiality are also the reason why continuous environmental indicator data could not be matched to individuals.

Quintile scores at the MSOA were subsequently attributed to each of the LSOAs contained within them so as to have a fair representation of food outlet scores at the lowest geographical areas. Whilst this method of allocation may be flawed in rural areas where statistical areas (such as MSOAs and LSOAs) are much larger in physical size, it is thought to work well in urban settings where these areas are smaller. In urban areas, the smaller MSOAs and LSOAs extend the food environment of an individual to a distance that the average adult would likely walk in order to obtain food.

Calculating residential density

Highly populated neighbourhoods are usually thought to include mixed-use development, and an increased variety and choice of retail activities that are necessarily in close proximity. Importantly, this is hypothesised to result in "shorter, [more] walkable distances between complementary shops and restaurants", which, confounded by the amplified difficulty in car parking is thought to increase walkability

(Leslie *et al*., 2007, 117). Residential density was calculated based on the work of Leslie *et al* (2007) as the number of household spaces divided by the total area of domestic buildings (m^2), per administrative area. The total number of household spaces in any given LSOA was sourced from the 2001 UK census, and the information on the total area of domestic buildings was sourced from the Generalised Land Use Database (GLUD), available through the official UK Office for National Statistics website (neighbourhood.statistics.gov.uk).

Calculating street connectivity

Areas that are highly connected possess a large number of street intersections, increasing the probability that a direct route will be available between two points and thus potentially increasing convenience and the propensity to walk (Frank & Engelke 2005). Connectivity was calculated using an OS Meridian map (scale 1:50000) available from the EDINA Digimap collections (edina.ac.uk/digimap). The number of street intersections was summed within each LSOA (see figure 1), and then standardised by the size of the respective administrative area (m^2).

Figure 1. An illustration of how OS Meridian highlights road interconnections within one LSOA

Calculating land use mix

An increasingly varied mixture of land uses within an area is usually related to "shorter distances between residences and destinations such as stores and workplaces" (Owen *et al* 2007, 388). This improved proximity between origin and destination is hypothesised to encourage an individual to walk rather than consider other forms of transport. Furthermore, research suggests that "the more varied the land use mix, the more varied and interesting the built-form" and the more walkable the environment (Leslie *et al* 2007, 117). Land use mix was determined here using the GLUD, which divides LSOAs into land parcels, areas of land that share a common use. The entropy formula proposed by Leslie *et al* (2007) was applied:

$$-\frac{\sum_{k}(p_k \ln p_k)}{\ln N}$$

whereby, k is the type of land use, p is the proportion of the LSOA devoted to that specific land use, and N is the total number of land use categories. Three types of land use were considered here, 'residential', 'non-residential' and 'green' spaces. Precedent for incorporating these land uses is given in the literature (Kockelman 1991; Frank *et al* 2004), however there is no consensus as to the most appropriate number of land uses to include in such an entropy calculation. The resultant entropy scores range between the (theoretical) values of 0 implying "homogeneity, wherein all land uses are of a single type" and 1 implying "heterogeneity, wherein developed area is equally distributed among all land use categories" (Cervero & Kockelman 1997, 207).

Health Survey for England (HSE) Data on individuals

The National Centre for Social Research (NatCen) conducts the HSE annually in order to assess the state of the nation's health (Higgins 2007). Geographical referencing from the HSE is unavailable at geographical levels below the district health authority (DHA) due to confidentiality constraints, but data at the DHA level is unsuitable for this analysis due to lack of detail. As a result, the final obesogenic indices were sent to NatCen to facilitate further analysis in a safe setting. A 'record matching' process carried out by NatCen resulted in individuals' identification codes returned alongside obesogenic indices for the area in which these people live, but no geographical referencing of the actual area. As a result, the geographical locations of the individuals themselves remained strictly concealed to protect confidentiality. The obesogenic indicators were calculated and provided in quintiles (as opposed to continuous variables) in order to facilitate this 'record matching' process and ensure that HSE participants remained unidentifiable throughout the analysis. Three years' worth of HSE individual records were matched (2003, 2004, 2005, covering England's North East region) in order to boost the sample size and improve the power of the statistical analysis. Although more annual datasets could have been requested, salient outcome variables were not available or compatible for other years, which would have limited their usefulness. The consistency of the HSE data across these years was assessed by examining key variables over time. No significant changes that could have reflected a difference in data collection methods or a markedly different sample for example were reported, thus the data was deemed fit for use. Those under the age of 16 years were removed from the sample due to the fact that younger people are generally not as free as over 16-year-olds to interact fully with their environments and also because BMI scores would require different coding and further interpretation (Cole *et al* 2000).

Statistical Analyses

Correlation analysis was used to examine the relationship between environmental indices. Descriptive statistics were used to describe the demographics of the HSE sample, and to compare the HSE sample to the complete study population. For obesity/overweight as an outcome variable, logistic multinomial regression was used to examine all potential determinants, and environmental and individual level determinants separately. Urban/rural status was not controlled for in the model as sample sizes were insufficient and singularities common; it was instead included into the models as an independent variable. Furthermore, correlation, chi-square and ANOVA were used (where appropriate due to data demands) to examine individual associations between potential determinants of weight and BMI. For fruit and vegetable consumption as an outcome variable, ANOVA was again used to assess associations with potential individual and environmental level determinants. Analysis was performed using SPSS for Windows, version 15.0 (SPSS Inc., Chicago, 2006).

Results

The Geography of the Study Area

Whilst discussion of the obesogenic patterns found within the study area does not fall within the remit of this paper, suffice to say that rural areas (as defined by the Commission for Local Communities) were deemed significantly and uniformly more obesogenic in terms of walkability than urban areas. Food environment indicators however jilted this urban/rural divide and demonstrated a much more varied distribution across the entire study area (Commission for Rural Communities 2004). Predominantly urban areas, such as the wider area of Tyne and Wear, were generally much more varied in terms of their overall obesogenicity. Overall, levels of correlation were very high between indices, with Bartlett's test of sphericity indicating significant levels of correlation between the variables ($p<0.001$).

Sample Description

Table 1 shows the distribution of HSE participants (n=893, aged 16+) in the North East across the variables that were utilised in the analysis. There are a higher percentage of obese residents (21.3%) compared with national HSE levels of obesity, which stands at 20.5%. There are also more women (56.3%) within the study area than men (43.7%), alongside a greater proportion of those living in urban areas (82.2%). Our HSE sample is largely representative of the national dataset, where 54.4% were women, 45.6% were men, and 78.8% lived in urban areas. There were sufficient numbers across quintiles in all obesogenicity indicators to facilitate further analysis.

Table 1. Distribution of HSE participants in the North East (n=893) across variables utilised in the analysis

Variable	People aged 16-90*		
Survey year		**Reported total fruit and veg portions**	
2003	396 [44.3]	Yes	811 [90.8]
2004	196 [21.9]	Missing	82 [9.2]
2005	301 [33.7]	**Food to consume out of the home**	
IMD2004 score for LSOA		1 Least Available (least obesogenic)	145 [16.2]
1 (least deprived)	63 [7.1]	2	179 [20.0]
2	146 [16.3]	3	164 [18.4]
3	176 [19.7]	4	139 [15.6]
4	234 [26.2]	5 Most Available (most obesogenic)	266 [29.8]
5 (most deprived)	274 [30.7]	**Food to purchase out of the home**	
BMI category		1 Least Available (least obesogenic)	132 [14.8]
Underweight	6 [0.7]	2	176 [19.7]
Normal	286 [32.0]	3	162 [18.1]
Overweight	306 [34.3]	4	202 [22.6]
Obese	190 [21.3]	5 Most Available (most obesogenic)	221 [24.7]
Missing	105 [11.8]	**Residential density Quintile**	
Socio-economic Status (SES)		1 High density (least obesogenic)	166 [18.6]
Manual	411 [46.0]	2	185 [20.7]
Non-manual	447 [50.1]	3	198 [22.2]
Missing	35 [3.9]	4	175 [19.6]
Supermarket accessibility		5 Low density (most obesogenic)	169 [18.9]
Very easy	395 [44.2]	**Street connectivity Quintile**	
Fairly easy	281 [31.5]	1 Highly connected (least obesogenic)	192 [21.5]
Fairly difficult	28 [3.1]	2	152 [17.0]
Very difficult	10 [1.1]	3	171 [19.1]
Missing	179 [20.0]	4	164 [18.4]
Problem of vandalism		5 Least connected (most obesogenic)	214 [24.0]
Very big problem	65 [7.3]	**Land use mix Quintile**	
Fairly big problem	172 [19.3]	1 Highly mixed (least obesogenic)	221 [24.7]
Not a very big problem	361 [40.4]	2	152 [17.0]
Not a problem at all	115 [12.9]	3	146 [16.3]
Missing	180 [20.3]	4	166 [18.6]
Urban / Rural category		5 Least mixed (most obesogenic)	208 [23.3]
Urban	734 [82.2]		
Rural	159 [17.8]		
Sex			
Male	390 [43.7]		
Female	503 [56.3]		
Ethnicity			
White	874 [97.9]		
Non-white	19 [2.1]		

* Percentages shown in brackets

The mean age for the North East cohort was 51.4 years, compared with an average age of 50.6 years when looking at the entire national dataset. Results are similar when looking at mean BMI within this sample (27.2), slightly above the national average of 27.1. Within our study cohort, the modal social class was ‘non-manual’, and the modal ethnicity was ‘white’.

BMI as an Outcome Variable

A multinomial regression model was developed with ‘normal’ weight, ‘overweight’ (which includes those who are obese) and ‘obese’ as the outcome variables for the examination of individual and environmental influences upon BMI. The only statistically significant results are noted in table 2. With regards to the risk of being overweight the combined effects of the predictor variables help to explain 16.2% of the variance using the Nagelkerke (pseudo) R Square value, a large amount of variance to be explained by such a relatively limited array of factors in the model when it is generally accepted that multiple factors contribute to weight (Vandenbroeck *et al* 2007). It is also evident that some of the estimated odds ratios show trends that were anticipated. For example, increasing age is associated with weight gain (table 2). Those aged 40-59, 60-74 and 75+ were found to have a significant 124.0%, 248.8% and 303.4% increase in the chances of being overweight respectively, compared to those in the 16-24 age group. Those aged 40-59 and 60-74 were found to have a significant 237.1% and 376.8% increase in the risk of obesity respectively, relative to those in the 16-24 age group, also. Men possess a significantly (p=0.002) greater 85.6% risk of overweight than women (table 2).

Decreased residential density (increased obesogenicity) is associated with a generally increased risk of overweight, although with high significance (p=0.037) only in areas of the very lowest residential density (table 2). This implies that people in more walkable areas may be increasingly likely to walk, helping them to maintain a 'normal' weight status (complementing previous findings). However, food availability was not found to be significantly associated with BMI (overweight or obesity) in this regression model, and so does not contribute towards this explained variance in body mass index. Importantly, it should be noted that very few odds ratios in the model are significant at the 95% confidence level. This said, amalgamating overweight with obesity (as opposed to treating overweight as 'normal') leads to a greater number of significant results, however this is most likely because of the elevated sample numbers present when the two categories are combined.

Table 2. Notable odds ratios by predictor variables on the chance of becoming obese and overweight (includes obese)

Variable	**Overweight**			**Obese**		
	Odds Ratio	**Significance**	**95% Confidence Intervals**	**Odds Ratio**	**Significance**	**95% Confidence Intervals**
Residential Density 1 (least obesogenic)	1	-	-	1	-	-
Residential Density 2	1.422	0.302	0.729, 2.774	1.153	0.723	0.525, 2.532
Residential Density 3	1.424	0.372	0.655, 3.094	1.830	0.185	0.749, 4.470
Residential Density 4	1.613	0.246	0.719, 3.622	1.560	0.342	0.623, 3.906
Residential Density 5 (most obesogenic)	2.704	0.037	1.062, 6.885	2.220	0.143	0.764, 6.454
Age (16-24)	1	-	-	1	-	-
Age (25-39)	1.860	0.080	0.928, 3.728	1.438	0.407	0.610, 3.390
Age (40-59)	2.240	0.016	1.159, 4.328	3.371	0.002	1,545, 7.355
Age (60-74)	3.488	0.001	1.668, 7.291	4.768	0.000	2.009, 11.316
Age (75+)	4.034	0.004	1.543, 10.547	2.502	0.138	0.744, 8.415
Sex (women)	1	-	-	1	-	-
Sex (men)	1.856	0.002	1.253, 2.750	1.259	0.322	0.798, 1.987

The complete regression model was furnished with the following variables: residential density, street connectivity, land use mix, food available to purchase and consume out of the home, social class, urban/rural, index of multiple deprivation, perceived vandalism and access to shops, consumption of fruit and vegetables, age, sex and ethnicity.

Further multinomial regression analysis between strictly 'environmental' and 'individual' predictor variables exhibited a lack of significant results (not shown here). Correlation, ANOVA and chi-square (used where appropriate, depending on data type) also revealed little individual co-variance between pairs of individual/environmental factors and BMI (table 3). However age was found to be a highly significant predictor variable ($p<0.001$), with a weak yet significant positive correlation with BMI, a recurring result that is not surprising. An individual's gender, as well as their urban/rural placement were also expectedly found to be associated with BMI, with BMIs in rural areas roughly one (BMI) unit higher than in urban areas. Food availability was not found to have a significant relationship with BMI.

Table 3. Correlation, ANOVA and Chi-square analysis between BMI and predictor variables

Variable	**BMI Continuous**				**BMI Categorised**	
	Pearson's Correlation		*ANOVA*		*Chi-square*	
	r_p	**Significance**	**F**	**Significance**	**X^2**	**Significance**
Continuous						
Age	0.158	0.000	-	-	-	-
Vegetable Consumption	-0.027	0.467	-	-	-	-
Fruit Consumption	0.048	0.198	-	-	-	-
Categorical						
IMD 2004	-	-	1.676	0.154	0.906	0.624
Social Class	-	-	0.108	0.743	3.999	0.262
Access to Shops	-	-	0.193	0.901	3.655	0.933
Vandalism	-	-	0.849	0.467	8.850	0.451
Urban/Rural	-	-	4.739	0.030	3.391	0.335
Sex	-	-	0.026	0.872	14.229	0.003
Age Categorised	-	-	8.101	0.000	37.231	0.000
Ethnicity	-	-	1.517	0.218	2.126	0.547
Food Consumed Out of the Home	-	-	0.601	0.662	12.785	0.385
Food Bought Out of the Home	-	-	1.305	0.266	11.168	0.515
Residential Density	-	-	2.369	0.051	12.206	0.429
Street Connectivity	-	-	1.599	0.173	8.878	0.713
Land Use Mix	-	-	1.003	0.405	13.622	0.326

Fruit and Vegetable Consumption as an Outcome Variable

Fruit and vegetable consumption (recorded by the HSE as the number of portions consumed in the 24 hours before the survey was delivered) was then examined as an outcome variable, however, the nature of the variables involved precluded the use of more sophisticated analytical techniques, such as multinomial logistic regression, which can pool the effects of several independent variables upon a single dependent variable. Therefore, ANOVA was utilised, despite that fact that the relationships found exclude the impact wielded by other variables.

Table 4 shows the results of this ANOVA. Socio-economic position had a significant association with the amount of fruit and vegetables consumed, with those of a manual occupation consuming 0.54 portions of fruit less on average per day than those of a non-manual occupation (deduced from means plots, not shown; $p<0.001$). Furthermore, an interesting trend emerged when examining the means plots for age (figure 2) whereby the average daily consumption of fruit and vegetables rapidly declines for those over the age of 75. This drop follows an increased average intake of fruit by age since the age group of 16-24 years, a trend that is not mirrored in the average portions of vegetables consumed.

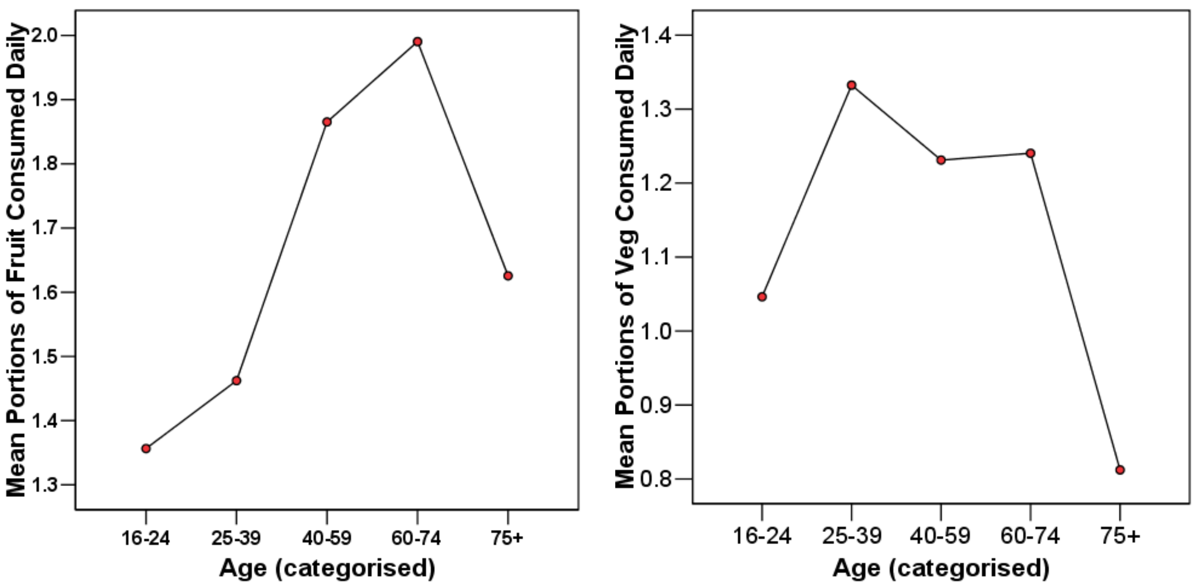

Figure 2. Mean portions (~80g per portion) of fruit (left) and vegetables (right) consumed daily by age group.

Gender was associated with levels of fruit consumed, with women consuming an extra 0.30 portions of fruit per day on average (p=0.032). Furthermore, ethnicity was associated with the consumption of vegetables on a daily basis, with those classed as non-white consuming an extra 1.24 portions of vegetables per day on average (p<0.001), although the non-white sample size was very small (n=19).

Table 4. ANOVA results between fruit and vegetable consumption (number of portions consumed daily) and environmental and individual level predictor variables

Variable	Consumption of Fruits		Consumption of Vegetables	
	F	**Significance**	**F**	**Significance**
Environmental				
IMD 2004	4.318	0.002	1.673	0.154
Residential Density	5.725	0.000	3.040	0.017
Street Connectivity	0.253	0.908	1.551	0.186
Land Use Mix	0.241	0.915	1.249	0.288
Food Consumed Out of the Home	0.037	0.997	3.062	0.016
Food Bought Out of the Home	0.183	0.947	1.756	0.136
Individual				
Social Class	20.080	0.000	4.735	0.030
Ethnicity	1.077	0.300	23.489	0.000
Age Categorised	3.536	0.007	3.596	0.006
Sex	4.610	0.032	1.470	0.226
Access to Shops	0.741	0.528	0.889	0.447

In terms of environmental factors (results shown in table 4), area level deprivation (IMD 2004) was associated significantly (p=0.002) with the portions of fruit consumed, with people in the most deprived areas consuming 0.28 less portions of fruit per day compared to those in the most affluent areas, on average. An increasing number of opportunities to consume food out of the home was also significantly linked to an elevated daily consumption of vegetables (p=0.016); if people are indeed choosing to utilise the opportunities to purchase and consume food out of the home within their neighbourhood, they may not always be making unhealthy choices. Despite this, increased opportunities to purchase food out of the home did not lead to elevated levels of fruit and vegetable consumption. Residential density was significantly linked to the eating of both fruit (p=<0.001) and vegetables (p=0.017); those living in areas of low residential density (high obesogenicity) were found to consume significantly more fruit on a daily basis (figure 3).

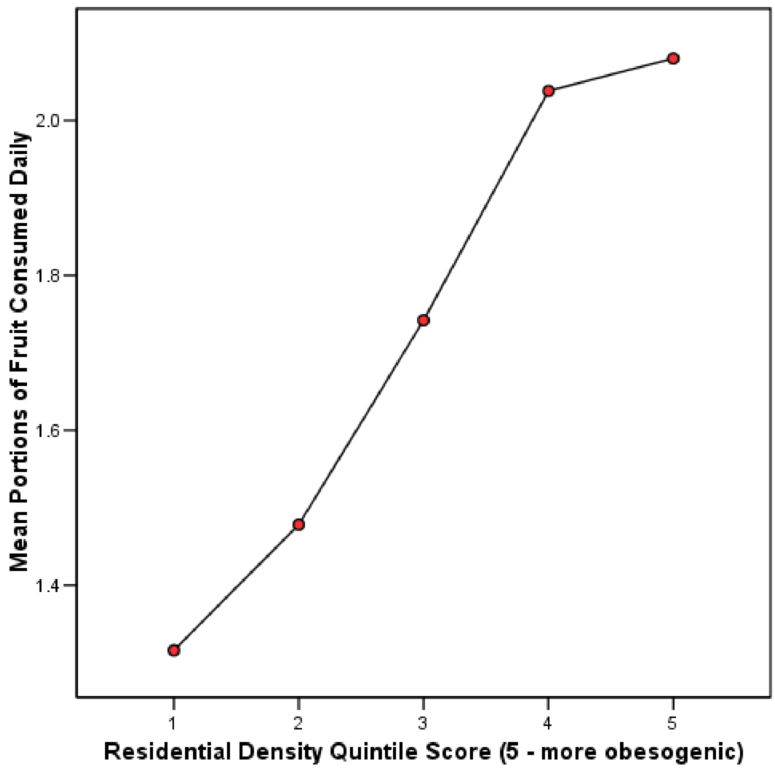

Figure 3. Mean portions (~80g per portion) of fruit consumed daily within each residential density quintile. Quintile 5 is the least dense, most obesogenic quintile.

Discussion

This is the first UK study to objectively explore environmental factors on both sides of the energy balance equation and their relationship with BMI and dietary behaviour (fruit and vegetable intake). It is worth noting the varied obesogenicity of North East England, a disparity which overall, manifested itself across the urban/rural divide in this research. This division remained evident when ‘walkability’ was considered as a separate entity, however largely dissipated when obesogenicity due to the availability of food was evaluated. This is as expected due to methodological concerns regarding the accuracy of the walkability metric in rural areas; this said, there is continued debate surrounding the ‘actual’ level of walkability in rural areas. Those individuals who reside in areas of high street connectivity were also more likely to be exposed to the most all-round obesogenic environments in terms of walkability and food availability.

This disparity in obesogenicity has been linked here to levels of BMI and particularly overweight, and fluctuations in fruit and vegetable intake, as expected, however with only one environmental determinant found to be particularly influential. In general, few significant associations were discovered between potential ‘determinants’ and weight status/ fruit and vegetable intake. Decreased residential density was found to increase the risk of overweight (although this was not a dose-response relationship), implying that people in less walkable areas are increasingly unlikely to walk, contributing to their weight status and thus complementing previous US work by Frank *et al* (2004) and Ewing *et al* (2003). Despite strong correlations between residential density, street connectivity and land use mix, the latter two factors failed to exhibit an association with BMI, thus contradicting previous work in the field, mainly from the US. Food availability was not found to have a significant relationship with BMI, contradicting the popular suggestion that higher food outlet density correlates with higher BMIs, irrespective of booming numbers of food outlets in recent decades (Burgoine *et al* 2009; Maddock 2004). This contradiction in findings may exist because of the contextual differences between recent US studies and the UK focus of our study. It is possible that cultural differences and differential attitudes towards food consumption are different across these settings (Lake & Townshend 2006), leading to differences in research findings. Furthermore, a relatively large number of studies choose to focus specifically on the relationship between 'fast food' and health and emerge with findings that this study is unable to address directly due to a focus here on the wider unhealthy food environment. However, increased availability of food to consume out of the home was found to be linked with elevated vegetable consumption – a result that may seem paradoxical in a climate where restaurants and fast food outlets are commonly imagined as wholly negative (Zenk & Powell 2008) . This finding contradicts the findings of Kamphuis *et al* (2007), who found that the increased availability of food to consume out of the home was perceived to lessen consumption of fruit and vegetables. Increased availability of food to purchase out of the home did not have a 'positive but modest' increase in the consumption of fruit and vegetables as found in the UK work of Smith *et al* (2005). Socio-economic disparities in fruit intake were observed. Those residing in more affluent areas were found to have an average increased consumption of 0.28 portions of fruit per day. Perhaps this is because of the prohibitively high prices of fruit compared to less healthy options.

It was important that individual level factors be examined alongside environmental factors, and in general, they were more strongly associated with weight and consumption outcomes. Increased age, for example, was shown to substantially increase the chances of overweight and obesity, as would be anticipated (Craig & Shelton 2007). Conversely, fruit intake (as a proxy for a healthy diet) was found to increase significantly with age (up to 75 years). Gender was found to contribute significantly towards the chances of overweight, with women having lower risk of overweight and consuming significantly more fruit on a daily basis. Associations were found between fruit intake and socio-economic position and between ethnicity and vegetable intake. Although sample numbers here were very small, the impact of ethnic diversity upon diet certainly warrants further study.

This study provides us with some interesting research findings that exhibit the potential to both reaffirm and importantly challenge our comprehension of the obesogenic environment. Food availability, as it was measured here, was found to yield little tangible impact upon our sample (however the use of a different metric of food availability may have presented us with a different 'reality'), yet equally, factors such as area level deprivation and elements of walkability have offered contributions towards BMI. The real strength of this research though has been the inclusion of both environmental and individual predictor variables to a study of obesity along with the volume of each of these factors that have been included. Rutt and Coleman (2005, 832) proposed that whilst the built environment may facilitate an effect upon BMI, body mass index may simply be "magnified by confounding factors such as socio-economic status…or intake of fruit and vegetables", a notion that has compelled this work and subsequently been reinforced. Although the extensive range of variables considered within this research remains noteworthy, the vast array of factors that truly impact upon our health should be born in mind for future research (Keith *et al* 2006). Examining BMI as an outcome variable in the UK has addressed a current gap in the literature, whilst the inclusion of fruit and vegetable intake alongside BMI as outcomes should not be underestimated in terms of importance. Despite weak results, this research has provided evidence to further warrant the inclusion of obesogenic environments into discussions of environmental justice. Those living in less residentially dense areas were generally susceptible to increased levels of overweight, and so whilst environmental justice touts the need for our surroundings to remain 'fair' and 'nurturing', for residents of these regions, the factors influencing energy imbalance within individual's environments requires further exploration (Sexton & Adgate 1999).

There are several methodological issues that need to be considered when interpreting the results presented here. Firstly, it would have been preferable to verify the locations of all food vendors sourced from the Yellow Pages using primary data collected in the field, as phone directories are very prone to under-reporting the realities of the food environment (Lake *et al* 2010). It would have been desirable to collate foodscape data from different time points (2003, 2004, 2005, corresponding with the HSE data utilised), however time constraints and the difficulties of sourcing retrospective Yellow Pages data deemed this unfeasible (Burgoine *et al* 2009; Wang *et al* 2006). The geographical scale and ease of availability offered by Yellow Pages was the deciding factor in its selection for this research, and its use to date is not without precedent (Burdette & Whitaker 2004; Maddock 2004; Simmons *et al* 2005). This said, more accurate sources of food outlet data for the UK need to be considered for future research (Brownson *et al* 2009; Paquet *et al* 2008), and have been considered by our research group (Lake *et al* 2010).

We should also question how typical the individuals in the sample are with regards to how they interact with their various environments, although in truth, this information would be very difficult to ascertain without collecting information on individual's lifestyle patterns. It is also essential to remember that this study makes considerable assumptions about the purchasing behaviour of individuals, and the extent to which proximity truly affects choice. The dangers of modifiable areal units, whether administrative or statistical are also acknowledged (Fotheringham & Wong 1990). However, this is a spatial problem to which there is genuinely no answer because of data recording and availability limitations that constrained our ability to examine the indices at varying spatial resolutions (Daras & Alvanides 2006). Analysis was occasionally limited by the categorical nature of our data which restricted the theorisation of a direction of causation, a limitation which is frequently associated with this type of research (Sexton & Adgate 1999). The categorical nature of our indices may also be to the detriment of significant results, however because data were matched to HSE records the use of continuous data was not an option, due to confidentiality concerns. Whilst there was potential for the use of multilevel modelling in this research, the expertise required for such an analysis was not present at the time. Multilevel modelling proper will be utilised in future work. Assessing the foodscape for larger areas (MSOAs) and then attributing this assessment to smaller areas (LSOAs) may have also created an inaccuracy that could tangibly affect our results and account for the generally understated relationship between outcome variables and food availability. A more accurate method of assessing the foodscape over small area geographies should be considered for future research. Further, although attempting to apply walkability to rural areas should be regarded as a strength of this research, extended refinement of the calculation is probably required before we can be totally sure of its efficacy in this context (both rural, and in fact, UK); such work is being undertaken in our research group, examining footpath availability and green space availability amongst other measures. As it stands, we cannot be entirely confident that the walkability differences observed between urban/rural areas are not a product of the metric used rather than the reality; the dataset did not allow us to control for urban/rural status adequately. It would have been desirable to have data on the frequency and intensity of physical activity undertaken to correlate with variables such as walkability and importantly BMI/fruit and vegetable intake; this data was only available for a single HSE survey year and was thus sadly omitted. In ensuing studies, other sources of such information should be considered. These methodological inadequacies will need to be addressed for future work, however it should be noted that these techniques are adequate for the analysis undertaken here and have been used previously by others as aforementioned.

It has become abundantly clear that the relationship between an individual and their environment is complex and this work emphasises the complexity of the obesity issue, which cannot be attributed neatly to a single factor or defined group of factors. Instead, the theoretical obesogenicity of the study area (which undeniably varies through space) combines and works in tandem with a range of individual level predictor variables in order to ultimately determine our BMI and fruit and vegetable intake. Interestingly, evidence from this analysis suggests that although our surroundings are likely to have a small influence on our behaviours, individual level factors such as age and gender may in fact hold a much stronger influence on our energy balance than our environment.

Conclusion

This study has succeeded in strengthening the research base with regards the existence/non-existence of the obesogenic environment (via the methods used here at least), yet has not by-passed individual level factors that have been shown to mediate the interaction between an individual and their surroundings. This said, further research is needed to include the plethora of unaccounted for environmental, individual and social (perhaps household) level factors that truly compose our surroundings and that influence our health behaviours. These findings reaffirm the suggested viewpoint that the obesity epidemic cannot be subdued by addressing the physical and built environment alone – attention needs to be turned against this growing (mis)conception to address the way that each individual chooses to behave within, interact with and react to, the diverse range of environments.

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