Dietary quality in children and the role of the local food environment

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ABSTRACT

Diet is a modifiable contributor to many chronic diseases including childhood obesity. The local food environment may influence children's diet but this area of research is understudied. This study explores if distance to and the number of supermarkets and convenience stores in the local area around households are associated with dietary quality in nine year olds whilst controlling for household level socio-economic factors. This is a secondary analysis of Wave 1 (2007/2008) of the Growing Up in Ireland (GUI) Child Cohort Study, a sample of 8568 nine year olds from the Republic of Ireland. Dietary intake was assessed using a short, 20-item parent reported food frequency questionnaire and was used to create a dietary quality score (DQS) whereby a higher score indicated a higher diet quality. Socio-economic status was measured using household class, household income, and maternal education. Food availability was measured as road network distance to and the number of supermarkets and convenience stores around households. Separate fixed effects regression models assessed the association between local area food availability and dietary quality, stratified by sex. The DQS ranged from −5 to 25 (mean 9.4, SD 4.2). Mean DQS was higher in those who lived furthest (distance in quintiles) from their nearest supermarket (p < 0.001), and in those who lived furthest from their nearest convenience store (p < 0.001). After controlling for socio-economic characteristics of the household, there was insufficient evidence to suggest that distance to the nearest supermarket or convenience store was associated with dietary quality in girls or boys. The number of supermarkets or convenience stores within 1000 m of the household was not associated with dietary quality. Food availability had a limited effect on dietary quality in this study. Issues associated with conceptualising and measuring the food environment may explain the findings of the current study.

Introduction

Poor diet is an important modifiable contributor to many chronic diseases including childhood obesity (Han, Lawlor, & Kimm; World Health Organization, 2004). Understanding the determinants of dietary behaviour during childhood is important as poor dietary behaviours track from childhood to adulthood (Craigie, Lake, Kelly, Adamson, & Mathers, 2011). Children's diet is influenced by individual preferences as well as the wider shared family, social and physical environment, as highlighted by ecological models of health behaviour (Bronfenbrenner, 1997). The contribution of the local food environment to a poor diet is a relatively new area of research. To date, findings are inconsistent and this may be due to conceptual and methodological issues associated with measuring the food environment (Caspi, Sorensen, Subramanian, & Kawachi, 2012; Feng, Glass, Curriero, Stewart, & Schwartz, 2010; Holsten, 2009; Mackenbach et al., 2014).

The food environment is multidimensional (Glanz, Sallis, Saelens, & Frank, 2005) and the availability of food outlets is one important aspect of the local food environment. Research has found that smaller food outlets including convenience stores tend to stock a higher proportion of processed foods, a smaller range of fruit and vegetables, and charge higher prices for food than supermarkets, especially in poorer areas (Kaufman, MacDonald, Lutz, & Smallwood, 1997; MacDonald & Nelson, 1991; Rose & Richards, 2004). Shorter distances to a supermarket and a higher number of local supermarkets are consistently associated with a higher dietary quality in North America, particularly among low income households (Rose & Richards, 2004). Evidence from Europe and Australia is less consistent

(Black, Moon, & Baird, 2013) with recent studies finding no difference in food availability between better and worse off communities (Cummins & Macintyre, 1999, 2002), particularly for supermarkets (Maguire, Burgoine, & Monsivais, 2015).

Research on the association between the food environment around children's homes and diet is sparse and inconclusive. Engler-Stringer, Le, Gerrard, and Muhajarine (2014) conducted a systematic review which examined the influence of location and accessibility of food outlets on children's diet (Engler-Stringer et al., 2014). Though there was much heterogeneity between studies, the review found some moderate evidence to suggest that the local food environment around households may influence children's diet. However, the effect sizes in many of the included studies were small (Engler-Stringer et al., 2014). For example, a study from the UK reported that increasing distance to a convenience store was associated with a slightly lower intake of foods such as chocolate and crisps (Skidmore et al., 2010). Furthermore, in the UK, availability of 'unhealthy' food outlets was associated with a higher body mass index (BMI) which is a more distal outcome than diet (Jennings et al., 2011). Leung, Gregorich, Laraia, Kushi, & Yen, 2010 reported an inverse association between the prevalence of food/retail destinations in the neighbourhood environment and total energy intake in girls aged 6–8 years from the USA (Leung et al., 2010). However, there have also been null findings for the association between the local food environment and diet in children (An & Sturm, 2012).

Increasingly, policymakers recognise the potential role of the food environment to curb chronic diseases including obesity and also to encourage healthy eating. Thus, a better understanding of the relationship between local area food availability and dietary quality in children is needed. In 2007, 89% of all eating occasions for Irish children aged 5–12 years occurred at home (Burke et al., 2007) suggesting that food availability around households is important. For the current paper, we hypothesised that greater access to food outlets (closer proximity and the number of supermarkets) would be associated with a higher dietary quality in children. As children may have limited autonomy over food purchase and eating behaviours, we control for family level socio-economic factors to capture aspects of the shared home environment. This paper explores if distance to and the number of food outlets (supermarkets and convenience stores) in the local environment around households are associated with dietary quality in a nationally representative sample of nine year old children controlling for family level socio-economic factors.

Methods

Study design and subjects

This is a secondary analysis of the Child Cohort of the Growing Up in Ireland (GUI) study. Details of the study have been described elsewhere (Williams et al., 2009). Briefly, this is a nationally representative study of 8568 nine year old children living in the Republic of Ireland. Wave 1 of the study was conducted in 2007/2008. A two-stage cluster based sampling process was used, with a random sample of primary schools selected as the primary sampling unit. Age eligible children from participating schools were then invited to partake. Data collection took place within the home and included parent questionnaires. Trained researchers conducted the computer assisted personal interviews. A primary caregiver (the parent who spent most time with the study child) was nominated as the primary respondent (98% mothers) for the parental questionnaires.

Written informed consent was obtained from a parent/guardian prior to the study commencing. Ethical approval was granted by the Research Ethics Committee (REC) of the Health Research Board, Dublin, Ireland.

Outcome variable

Dietary quality

As there is some evidence to suggest that children under ten are unable to accurately estimate their dietary intake (Magarey et al., 2011), we used a brief parent reported 20-item food frequency questionnaire (FFQ) to estimate each child's diet. The FFQ was an adapted version of a Sallis Amherst questionnaire (Layte & McCrory, 2011; Sallis, Taylor, Dowda, Freedson, & Pate, 2002). Twenty food/drinks items were listed. The parents reported whether each food or drink item was consumed (1) not at all, (2) once, (3) more than once, or (4) don't know over the previous 24 h. As a low number of parents reported 'don't know' (N=77), these responses were coded as missing.

In Ireland, it is recommended that children consume plenty of bread, cereal (preferable wholemeal) and potatoes, fruit and vegetables; have a moderate consumption of dairy (preferable low fat), lean meats, poultry and fish; and limit consumption of foods high in sugar, fat and salt (Flynn et al., 2012). An un-weighted dietary quality score (DQS) was constructed to generally reflect current Irish dietary guidelines. Each food or drink item was defined as 'healthy' or 'unhealthy'. Fourteen food or drink items were defined as healthy and six as unhealthy. Healthy foods and drinks included fresh fruit, vegetables, meat, eggs, bread, cereals, potatoes, dairy products, and water. Unhealthy items included meat pie, hot chips, crisps, biscuits, and soft drinks (see Additional file 1 for full FFQ). For consumption of each healthy item, a value of 0 for not eaten at all, 1 for eaten once and 2 for eaten more than once were assigned. Unhealthy items were given a value of −2 for eaten more than once, −1 for eaten once and 0 for not eaten at all (Perry et al., 2015). A continuous DQS was produced by summing the individual items whereby a higher score indicated a higher diet quality. The score ranges from −5 to 25 in the participating children.

Exposure variables

Food environment

The structure of the food environment and types of food outlets in Ireland have been explained elsewhere (Competition Authority, 2008; Layte et al., 2011). Briefly, supermarkets have the largest share of the market. Similar to the UK, the Irish grocery sector can be divided into three groups as (1) supermarkets, (2) a retail brand or franchise, or (3) an independent retailer including newsagents. Similar to previous Irish research (Layte et al., 2011), food outlet type was coded as either a supermarket or convenience store (a retail brand or franchise or an independent retailer). This categorisation was used as supermarkets are commonly deemed as 'healthier' than convenience stores (Kaufman et al., 1997; MacDonald & Nelson, 1991; Rose & Richards, 2004).

The trained researchers used handheld GPS devices during field-work to record the co-ordinates of each participating child's household. A complete database of residential and commercial addresses (https://www.geodirectory.ie/) was used to document the co-ordinates of all supermarkets and convenience stores located in the Republic of Ireland at the time of data collection. The GeoDirectory is the primary source of business address data in the Republic of Ireland and is continually updated and validated by a dedicated unit. Using the precise spatial co-ordinates of households and food outlets (supermarkets and convenience stores), network-based travel distances were calculated using the Network Analyst extension in Geographic Information Systems (GIS), ArcGIS, v.9.3.1. Network analysis is a GIS technique used to calculate the distances covered and/or times taken in making a journey on a 'network', such as the road network. It facilitates a 'route analysis' to derive the optimal route from a specified start point (e.g. an individual's residence) to a specified end point (e.g. a supermarket). Given that road network density tends to differ significantly across Ireland, road network travel distances are generally preferable to standard Euclidean measures of distance when measuring proximity

(O'Donoghue, Hynes, & Cullinan, 2008).

For this paper, similar to previous Irish research (Layte et al., 2011), network-based 'route analysis' was undertaken for each household to the nearest supermarket and to the nearest convenience store to calculate nearest distance with a high level of accuracy. Comparable to other research (Caspi et al., 2012; Charreire et al., 2010), radii of 500, 1000 and 2000 metres (m) were used to create concentric rings to calculate the number of supermarkets and convenience stores which surrounded each household.

Independent predictor and control variables

Family level socio-economic status

Family level socio-economic status (SES) measures and child's sex (boy/girl) were parent reported. Mother's current age was coded as < 30, 30–39, 40–49 and 50+. Highest level of maternal education was coded as lower secondary or less, higher secondary, post-secondary, or third level. Household class was measured using the Irish Central Statistics (CSO) Social Class Schema (1996) produced by aggregating occupations classified using the CSO's Standard Classification of Occupations. In two-parent families where both parents were economically active and in different classes, the higher social class was assigned to the family (Williams et al., 2009). Household class was coded as professional managers, managerial and technical, non-manual, skilled manual, semi-skilled and unskilled, and unclassified. Parent reported net income was adjusted for household composition and size. An equivalence scale was used to allocate a weight to each person in the household (1 to the first adult, 0.66 to other adults aged 14+, and 0.33 to each child aged < 14). Each household was summed to calculate the household size in adult equivalents. Household equivalised income was calculated as disposable household income divided by the equivalised household size. Continuous equivalised net income was imputed to reduce missing data (N=626) using the UVIS multiple imputation command in Stata. For descriptive analysis, the income variable was divided into quintiles. For multivariate analysis, the imputed continuous variable was log transformed as it was not normally distributed.

Population density

A parent reported population density variable was used and is coded as in open country (rural areas), in a village (N=200–1499), in a town (N=1500–9999), in a town (N=10,000+), in a city (not Dublin) or in Dublin City.

Sample cluster variable (electoral divisions)

The electoral division (ED) that each household was located in was used as the sample cluster for regression analysis. EDs are small legally defined administrative areas for which small area population statistics are calculated. There are currently 3440 EDs in Ireland, ranging in size from 0.05 to 126.0 km^2 (Central Statisics Office).

Statistical analysis

Statistical analysis was carried out in Stata 12 IC (StataCorp LP, USA). As there was evidence of a non-linear relationship between dietary quality and the road network distance to the nearest supermarket and convenience store, the distance variables were explored using different parameterisations including log transformations and by categorising the distance variables to decide on the most appropriate approach to present the data. For multivariate analysis, the distance variables are presented in quintiles.

Descriptive analysis was performed. Mean DQS by each independent predictor variable were calculated. Mean differences were tested using independent samples t-tests and one-way analysis of variance. A survey weight was applied to the descriptive analysis to account for the complex sampling design.

A fixed effects approach was used to estimate the effect of local area food availability (distance to and number of supermarkets and convenience stores) on dietary quality. The fixed effects approach allows us to assess the association between food availability and dietary quality 'within' each geographical cluster (ED). This removes the effect 'rurality' would have on our estimates if we simply estimated the effect of distance to food outlets at the household level. Using a fixed effects approach, the mean deviation of the child's DQS from the mean DQS within their local area (ED) was regressed on the mean deviation of the exposure and independent predictor variables within each local area. Equation one below displays the fixed effects estimator:

$$\hat{y} = (y_{ij} - \bar{y}_j) = \alpha + \beta(\chi_{ij} - \bar{\chi}_j) + \varepsilon_{ij}$$

In this equation y_{ij} is the DQS of child i in local area j, $\bar{y}_j$ is the mean DQS within local area j, χ_{ij} is a vector of predictor variables, $\bar{\chi}_j$ is the mean value of the predictor variables and ε_{ij} is the individual residual. Using this method, we confined the analysis to the association between food availability and dietary quality *within* sample clusters (EDs).

As the strength of the associations between distance and sex varied in the regression models, we present our regression analysis stratified by sex. Separate regression models for the nearest supermarket and convenience store to each household were used to assess the association between distance to the nearest food outlets and dietary quality. The number of supermarkets and convenience stores within concentric rings (500 m, 1000 m and 2000 m) of each household were modelled using the same method as the distance models. All predictors and control variables (family level SES and population density) were included in the regression analysis and variance inflation factor testing was used to test for possible multicollinearity. Population density was controlled for in the regression models as clusters (EDs) vary in the average distance to food outlets. P-values < 0.05 were deemed statistically significant.

Results

Sample characteristics

Overall, 82% of invited schools and 57% of children and parents participated in the study. Of the participating children (N=8561), 48.8% were boys. Nearly twenty percent (17.2%) of children's mothers were educated to a lower second level or less and 30.2% were educated to a third level. Mean distance to the nearest supermarket from the home was 5444 m (95% CI, 5308–5579 m). Mean distance to the nearest convenience store was 2356 m (95% CI, 2299–2413 m). Two in five (37.3%) children had at least one supermarket within 1000 m of their home. Overall, 67.1% of children who lived in Dublin had at least one supermarket within 1000 m of their home compared to 1.9% of children who lived in open country. Three in five (58.6%) children had at least one convenience store within 1000 m of their home. Of children who lived in Dublin, 89.8% had at least one convenience store within 1000 m of their home compared to 8.7% of children who lived in open country.

Mean dietary quality by each descriptive characteristic are presented in Table 1. The DQS ranged from −5 to 25. Mean DQS was 9.4 (SD 4.2). Mean DQS was not significantly different between boys and girls (p=0.3). For each of the family level SES indicators, children from higher socio-economic groups had higher mean dietary quality than those from lower socio-economic groups (p-trend < 0.001 for mother's current age, household class, income quintiles and maternal education). Children who had the shortest distance (quintile 1) to travel to their nearest supermarket had a lower mean DQS compared to children who lived furthest from their nearest supermarket (9.0 v 9.6, p < 0.001). Children who lived closest to their nearest convenience store had a lower mean DQS (quintile 1 v quintile 5, 9.1 v 9.7, p < 0.001) than those who lived furthest from their nearest convenience store. Children with at least one supermarket within 1000 m of their home

Table 1
Descriptive characteristics and mean dietary quality of nine year old children in the Growing Up in Ireland Study (Wave 1).

Total N=8561					
	Unweighted N=8561	%	Mean DQS 9.4	SD 4.2	P-value[*]
Sex					
Girl	4399	48.8	9.4	4.2	0.3
Boy	4162	51.2	9.5	4.2	
Mother's current age					
< 30	383	6.6	8.5	4.3	< 0.001
30–39	3432	43.4	9.3	4.2	
40–49	4505	46.8	9.7	4.2	
50+	241	3.2	9.0	4.3	
Household class					
Professional workers	1171	8.4	10.6	3.8	< 0.001
Managerial and technical	3314	33.9	10.1	4.1	
Non-manual	1685	19.2	9.1	4.1	
Skilled manual	1195	16.9	9.4	4.1	
Semi- skilled and unskilled	738	11.2	8.6	4.2	
Unclassified class	409	10.4	8.4	4.2	
Equivalised household annual income (quintiles)					
Highest	2244	20.0	10.3	4.0	< 0.001
4th	1941	20.0	9.8	4.2	
3rd	1711	20.2	9.6	4.2	
2nd	1474	20.0	9.0	4.0	
Lowest	1164	19.9	8.6	4.3	
Highest level of maternal education					
Third level	2235	30.2	11.0	3.9	< 0.001
Post-secondary	2122	36.7	10.4	4.2	
Higher secondary	2695	15.9	9.4	4.0	
Lower secondary/ less	1509	17.2	8.1	4.1	
Population density					
In open country	2768	31.4	9.9	4.1	< 0.001
In a village (< 1500)	802	10.4	9.3	4.0	
In a town (1500– 9999)	1045	12.9	9.0	4.1	
In a town (10,000+)	1414	16.5	9.2	4.2	
In a city (not Dublin)	600	6.8	9.8	4.1	
In Dublin City	1913	22.1	9.3	4.4	
Distance to nearest supermarket from households					
Shortest	1713	20.8	9.0	4.3	< 0.001
2nd	1712	19.6	9.5	4.3	
3rd	1712	18.5	9.4	4.1	
4th	1712	19.4	9.7	4.0	
Longest	1712	21.8	9.6	4.1	
Distance to nearest convenience store from households					
Shortest	1713	20.8	9.1	4.3	< 0.001
2nd	1712	20.4	9.3	4.3	
3rd	1712	19.4	9.5	4.1	
4th	1712	18.6	9.7	4.0	
Longest	1712	20.8	9.7	4.2	
Supermarket within 1000 m of household					
Yes	3110	37.3	9.1	4.3	< 0.001
No	5451	62.7	9.6	4.1	
Convenience store within 1000 m of household					
Yes	4953	58.6	9.3	4.2	< 0.001
No	3608	41.4	9.7	4.1	

[*] P-values are for differences in the dietary quality score between groups. Household

class refers to the social class of the family. The mean equivalised household annual income in each quintile is: €36974, €21959, €16886, €12650, €8180 (from Q5-Q1 respectively).

had a lower mean DQS than children with no supermarket within 1000 m of their home (9.1 v 9.6, p < 0.001). Children with at least one convenience store within 1000 m of their home had a lower mean DQS when compared to children without a convenience store within 1000 m of their home (9.3 v 9.7, p < 0.001) (Table 1).

Food availability in the local area and dietary quality

Fixed effects models assessing the association between distance (in quintiles) to the nearest supermarket and convenience store, and dietary quality by sex are presented in Table 2. The models in Table 2 are adjusted for family level socio-economic factors and population density. There was an inverse, non-significant association between distance to the nearest supermarket and diet quality for girls. For boys, distance to the nearest supermarket was not associated with dietary quality. Lower maternal education was significantly associated with a lower DQS in girls and boys.

Table 3 presents models assessing the association between the number of supermarkets and convenience stores within a 1000 m radius of the household and dietary quality, adjusting for family level socio-economic factors and population density. The number of super-markets within 1000 m of the household was not associated with dietary quality in girls or boys. The number of convenience stores within 1000 m of the household was associated with dietary quality in girls though the effect size was small (there was a similar finding for the 2000 m radius), but not in boys. The number of supermarkets and convenience stores within a 500 m radius of the household was not associated with dietary quality (data not shown). Lower maternal education was consistently significantly associated with a lower DQS in girls and boys (Table 3).

Discussion

This study examined if distance to and the number of supermarkets and convenience stores in the local area around households was associated with dietary quality in a large, nationally representative sample of nine year old children. Some small differences were observed in this study whereby children with greater distances to the nearest supermarket and convenience store from the household had a higher mean DQS than children with shorter distances to travel. Furthermore, children who did not have a convenience store within 1000 m of their household had a higher mean DQS than children without a convenience store within 1000 m of the household. Unexpectedly, similar patterns were observed for supermarkets. In the final regression analyses which accounted for household socio-economic characteristics, there was insufficient evidence to suggest that food availability around households was associated with dietary quality in nine year old children. The economic resources of the household were more consistently associated with dietary quality, particularly maternal education. Some consideration should be given to the limitations of study when interpreting the findings. Further, it should be noted that our finding may not be generalisable to children of all ages.

Our findings suggest that household socio-economic characteristics may be more important predictors of dietary quality in children, rather than the availability of supermarkets and convenience stores around households. Lower household socio-economic indicators were associated with a lower dietary quality in this study. From an ecological model perspective (Bronfenbrenner, 1997), the food environment is a distal factor associated with diet and dietary behaviours. Individual and family level factors also influence food behaviours (Penney, Almiron-Roig, Shearer, McIsaac, & Kirk, 2014) and this may help explain our findings. SES can impact on nutritional knowledge, health conscious-

Table 2

Fixed effects (within sample cluster) ordinary least squares models of dietary quality by food outlet type (supermarkets and convenience stores) in nine year old children in the Growing Up in Ireland Study, stratified by sex.

	Supermarkets				Convenience stores			
	Girls		Boys		Girls		Boys	
	Coefficient	95% CI	Coefficient	95% CI	Coefficient	95% CI	Coefficient	95% CI
Road network distance (in quintiles) Nearest	ref	–	ref	–	ref	–	ref	–
2nd	−0.35	−0.81 to 0.11	0.64	0.15 to 1.12	−0.14	−0.57 0.29	0.23	−0.25 to 0.70
3rd	−0.19	−0.71 to 0.32	0.09	−0.45 to 0.64	0.11	−0.34 to 0.57	0.37	−0.15 to 0.89
4th	−0.58	−1.41 to 0.25	0.38	−0.48 to 1.24	−0.12	−0.68 to 0.44	0.31	−0.31 to 0.93
Furthest	−0.83	−2.09 to 0.43	0.53	−0.82 to 1.87	−0.30	−1.12 to 0.52	0.86	−0.03 to 1.75
Mother's current age < 30	ref	–	ref	–	ref	–	ref	–
30–39	0.53	−0.12 to 1.17	0.52	−0.27 to 1.30	0.53	−0.12 to 1.17	0.53	−0.26 to 1.31
40–49	0.79	0.13 to 1.45	0.53	−0.26 to 1.33	0.78	0.13 to 1.44	0.55	−0.25 to 1.34
50+	0.63	−0.48 to 1.74	0.63	−0.62 to 1.88	0.63	−0.48 to 1.74	0.69	−0.56 to 1.94
Household class Professional workers	ref	–	ref	–	ref	–	ref	–
Managerial and technical	0.22	−0.24 to 0.67	−0.16	−0.62 to 0.30	0.22	−0.24 to 0.67	−0.18	−0.64 to 0.27
Non-manual	−0.46	−0.99 to 0.08	−0.48	−1.02 to 0.06	−0.45	−0.99 to 0.09	−0.48	−1.03 to 0.06
Skilled manual	−0.12	−0.70 to 0.48	−0.65	−1.27 to −0.03	−0.10	−0.69 to 0.48	−0.68	−1.30 to −0.06
Semi- skilled and unskilled	0.08	−0.58 to 0.74	−1.00	−1.70 to −0.24	0.07	−0.59 to 0.73	−0.96	−1.68 to −0.23
Unclassified class	−0.32	−1.11 to 0.47	−1.22	−2.07 to −0.36	−0.32	−1.11 to 0.47	−1.21	−2.06 to −0.35
Log of equivalised household annual income	0.27	−0.01 to 0.55	0.13	−0.21 to 0.47	0.28	−0.01 to 0.56	0.13	−0.21 to 0.47
Highest level of maternal education Third level	ref	–	ref	–	ref	–	ref	–
Post-secondary	−0.59	−1.01 to −0.18	−0.53	−0.96 to −0.11	−0.60	−1.01 to −0.18	−0.53	−0.96 to −0.11
Higher secondary	−1.00	−1.41 to −0.59	−1.22	−1.66 to −0.80	−1.01	−1.42 to −0.60	−1.22	−1.65 to −0.79
Lower secondary/less	−2.16	−2.66 to −1.65	−1.89	−2.44 to −1.35	−2.15	−2.66 to −1.65	−1.89	−2.43 to −1.34
Population density In open country	ref	–	ref	–	ref	–	ref	–
In a village (< 1500)	−0.56	−1.19 to 0.08	−0.41	−1.08 to 0.27	−0.56	−1.21 to 0.10	−0.30	−1.00 to 0.40
In a town (1500–9999)	−0.47	−1.12 to 0.17	−0.45	−1.17 to 0.27	−0.43	−1.09 to 0.22	−0.32	−1.05 to 0.41
In a town (10,000+)	−0.56	−1.28 to 0.16	−0.25	−1.05 to 0.55	−0.52	−1.24 to 0.20	−0.14	−0.93 to 0.66
In a city (not Dublin)	−1.16	−2.54 to 0.22	−0.33	−1.83 to 1.17	−1.06	−2.44 to 0.32	−0.23	−1.73 to 1.28
In Dublin City	−1.79	−2.99 to −0.60	−0.71	−1.93 to 0.50	−1.73	−2.92 to −0.54	−0.57	−1.79 to 0.65
Constant	8.71	5.65 to 11.78	9.22	5.55 to 12.88	8.31	5.27 to 11.34	9.09	5.44 to 12.74
Individuals (N)	–	4340	–	4099	–	4340	–	4099
Areas (N)	–	1347	–	1329	–	1347	–	1329
R2 within	–	0.05	–	0.05	–	0.05	–	0.05
R2 between	–	0.06	–	0.04	–	0.05	–	0.03
R2 overall	–	0.06	–	0.06	–	0.05	–	0.05
% Variance explained by area differences	–	40.7%	–	39.8%	–	40.9%	–	40.0%

Footnote: Household class refers to the social class of the family. The mean equivalised household annual income in each quintile is: €36974, €21959, €16886, €12650, €8180 (from Q5-Q1 respectively).

ness, food affordability and other factors including time constraints which may impact parent's ability to make healthy food choices (Patrick & Nicklas, 2005). This suggests that targeting household level inequalities including education may be useful to improve the diet of children. Further research is warranted to assess the potential mediating role of family level SES on the relationship between food availability and diet in children. From a population health perspective, targeting environmental level barriers to a healthy diet may be more effective than strategies targeting individual level or household level behaviours. Glanz et al., 2005 argued that of all the dimensions of the food environment, the community nutrition environment (e.g. accessibility of food outlets including availability) has one of the largest impacts on nutritional health (Glanz et al., 2005). Thus, it is essential we gain a deeper understanding of the interrelationship of individual, family, school, community, and environmental level factors associated with diet in children.

A recent systematic review by Engler-Stringer et al. (2014) highlights that there are studies which are in contrast to our findings (Engler-Stringer et al., 2014). Some studies reported that the availability of convenience stores was associated with lower consumption of healthy foods and that children living further from a convenience store had a higher diet quality, though effect sizes were small (Engler-Stringer et al., 2014). Furthermore, a recent study from the UK found an association between the sale of unhealthy food from supermarkets and the prevalence of childhood overweight and obesity (Wilsher, Harrison, Yamoah, Fearne, & Jones, 2016) highlighting that methodological considerations are important. Methodological and conceptual difficulties in assessing the food environment can reduce the comparability of studies (Lucan, 2014). As there are a number of dimensions to the food environment, methods used between studies vary. For example, measures of physical access to food outlets vary considerably between studies (Caspi et al., 2012; Cummins & Macintyre, 2006). For food availability, there is a lack of standardisation for methodology including the best method to group food stores and to define appropriate geographic boundaries, and findings may be sensitive to the availability measure used (Thornton, Pearce, Macdonald, Lamb, &

Table 3

Fixed effects (within sample cluster) ordinary least squares models of dietary quality by food outlet type (number of food outlets by type within a 1000 m radius of the household) in nine year old children in the Growing Up in Ireland Study, stratified by sex.

	Supermarkets				Convenience stores			
	Girls		Boys		Girls		Boys	
	Coefficient	95% CI	Coefficient	95% CI	Coefficient	95% CI	Coefficient	95% CI
Number (within 1000 m)	0.04	−0.10 to 0.19	−0.00	−0.17 to 0.16	0.09	0.02 to 0.17	0.03	−0.06 to 0.12
Mother's age < 30	ref	–	ref	–	ref	–	ref	–
30–39	0.53	−0.12 to 1.17	0.53	−0.26 to 1.31	0.53	−0.12 to 1.17	0.53	−0.25 to 1.31
40–49	0.78	0.13 to 1.44	0.55	−0.24 to 1.34	0.78	0.12 to 1.43	0.55	−0.24 to 1.35
50+	0.62	−0.49 to 1.73	0.66	−0.59 to 1.91	0.58	−0.53 to 1.69	0.66	−0.60 to 1.91
Household class Professional workers	ref	–	ref	–	ref	–	ref	–
Managerial and technical	0.22	−0.23 to 0.68	−0.19	−0.64 to 0.27	0.22	−0.23 to 0.68	−0.19	−0.64 to 0.27
Non-manual	−0.45	−0.99 to 0.09	−0.51	−1.05 to 0.03	−0.44	−0.98 to 0.10	−0.51	−1.05 to 0.03
Skilled manual	−0.10	−0.69 to 0.49	−0.68	−1.30 to −0.07	−0.09	−0.67 to 0.50	−0.68	−1.30 to −0.06
Semi- skilled and unskilled	0.08	−0.58 to 0.74	−0.98	−1.71 to −0.25	0.08	−0.58 to 0.74	−0.98	−1.71 to −0.26
Unclassified class	−0.32	−1.11 to 0.47	−1.24	−2.09 to −0.38	−0.30	−1.09 to 0.49	−1.24	−2.09 to −0.38
Log of equivalised household annual income	0.27	−0.01 to 0.56	0.13	−0.21 to 0.47	0.29	0.01 to 0.57	0.14	−0.20 to 0.48
Highest level of maternal education Third level	ref	–	ref	–	ref	–	ref	–
Post-secondary	−0.60	−1.01 to −0.18	−0.53	−0.96 to −0.11	−0.59	−1.00 to −0.18	−0.53	−0.96 to −0.11
Higher secondary	−1.01	−1.42 to −0.60	−1.22	−1.65 to −0.79	−1.01	−1.42 to −0.60	−1.22	−1.65 to −0.80
Lower secondary/less	−2.15	−2.65 to −1.65	−1.89	−2.43 to −1.34	−2.15	−2.65 to −1.65	−1.89	−2.43 to −1.34
Population density In open country	ref	–	ref	–	ref	–	ref	–
In a village (< 1500)	−0.53	−1.16 to 0.10	−0.43	−1.10 to 0.25	−0.62	−1.25 to 0.02	−0.46	−1.14 to 0.22
In a town (1500–9999)	−0.39	−1.00 to 0.23	−0.50	−1.18 to 0.19	−0.52	−1.14 to 0.10	−0.56	−1.27 to 0.14
In a town (10,000+)	−0.47	−1.16 to 0.22	−0.28	−1.05 to 0.48	−0.61	−1.31 to 0.09	−0.35	−1.13 to 0.43
In a city (not Dublin)	−1.02	−2.38 to 0.34	−0.31	−1.79 to 1.17	−1.22	−2.59 to 0.14	−0.37	−1.85 to 1.12
In Dublin City	−1.70	−2.89 to −0.52	−0.70	−1.91 to 0.50	−1.79	−2.98 to −0.61	−0.76	−1.97 to 0.45
Constant	8.17	5.15 to 11.19	9.54	5.92 to 13.16	7.93	4.91 to 10.95	9.48	5.85 to 13.10
Individuals (N)	–	4340	–	4099	–	4340	–	4099
Areas (N)	–	1347	–	1329	–	1347	–	1329
R2 within	–	0.05	–	0.05	–	0.05	–	0.05
R2 between	–	0.05	–	0.04	–	0.05	–	0.04
R2 overall	–	0.05	–	0.05	–	0.05	–	0.05
% Variance explained by area differences	–	40.9%	–	39.8%	–	41.0%	–	39.8%

Footnote: Household class refers to the social class of the family. The mean equivalised household annual income in each quintile is: €36974, €21959, €16886, €12650, €8180 (from Q5-Q1 respectively).

Ellaway, 2012). Some studies group food stores by size or type in a similar fashion to the current study whilst others consider the 'healthiness' of foods sold within individual stores, which is burdensome, particularly for larger studies (Lucan, 2014).

The Irish context

As the food environment varies between countries, it is plausible that geographic and cultural dimensions of the food environment in Ireland may explain the findings of the current study. Similar to other countries, the distribution of food outlets in Ireland has changed over time. There has been an increase in the number of supermarkets, particularly foreign outlets and a decline in the number of smaller food outlets (Friel, Walsh, & McCarthy, 2006). Furthermore, urban planning and development including out of town shopping centres may also have had an impact on food availability in Ireland.

The findings of this study are in contrast to recent findings from Irish adults which found an association between food availability in the local area and dietary quality (Layte et al., 2011). The study used similar methodologies to the current study though the measure of dietary quality in the adult study was more robust. Further, adults typically have greater autonomy over their food choice than children, which may help explain differences in the results between the two

studies.

Strengths and limitations

This study has a number of strengths. This data represents a large, nationally representative sample of nine year old children. As a single measure of food availability is unlikely to describe overall food availability (Charreire et al., 2010), we were able to use two measures (distance and number) to capture food availability in the local environment. Further, handheld devices were used when geocoding the individual households. Fixed effects modelling techniques were used to combat possible compositional and structural variation of households residing in different areas. For example, if standard regression approaches were adopted, it would have been difficult to adjust for the rurality of households when estimating the association between food availability and dietary quality.

This study also has a number of limitations including the measure of dietary quality used. Whole diet approaches including DQS have many advantages compared to assessing individual foods (Kant, 1996). However, our DQS is based on a short FFQ assessing the frequency of consumption of 20 foods/drinks items over the previous 24 h and data on the day of the week is not available. Though the list of food items is not complete and may not reflect habitual intake at an individual level,

the score is useful for identifying children with poorer dietary patterns. Previous research also argues that the DQS demonstrates construct validity (Perry et al., 2015). However, the DQS had limited variation in frequency coding and this reduced the measured variation in dietary quality. Further validation work on the FFQ used is needed.

Other limitations of the study include that we did not have data on the availability of takeaways and fast food outlets in the local area around households. Furthermore, categorising food outlets as either a supermarket or a convenience store is a broad categorisation especially when using the assumption that supermarkets are 'healthier' than convenience stores. Data on pedestrian pathways were not available and this study is based on the road network only, which is a limitation if children frequently use such pathways in accessing supermarkets and convenience stores. Data on potentially important factors including food purchasing behaviour, public transport options and access to private transport was not available suggesting that residual confounding may explain our findings. As this study is cross sectional, causality cannot be inferred.

Conclusion

Issues associated with conceptualising and measuring the food environment may explain our findings. In this nationally representative sample of nine year old children, the distance to and number of supermarkets and convenience stores around households did not contribute to dietary quality. However, there was some evidence that the economic resources of the family were associated with diet. Our data suggests that targeting household level inequalities including parental education may help improve the diet of children. Further research is needed to understand the contribution of local area food availability to diet and dietary behaviours in children.

Acknowledgements

Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ssmph.2016.10.002.

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