Title: Associations between home and school neighbourhood food environments and adolescents' fast-food and sugar-sweetened beverage intake: Findings from the ORiEL Study

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Running head: Food environment and adolescent food intake

Abstract

Objective: To examine associations between availability of fast-food restaurants and convenience stores in the home and school neighbourhoods considered separately and together, and adolescents' fast-food and sugar-sweetened beverage (SSB) intake.

Design: Cross-sectional observational study.

Setting: East London, UK.

Subjects: 3089 adolescents (13-15 years-old) from the Olympic Regeneration in East London study self-reported their weekly frequency of fast-food and SSB consumption. We used food business addresses collected from local authority registers to derive absolute (counts) and relative (proportions) exposure measures to fast-food restaurants and convenience stores within 800 meters from home, school, and home and school combined. Associations between absolute and relative measures of the food environment and fast-food and SSB intake were assessed using Poisson regression models with robust standard errors.

Results: Absolute exposure to fast-food restaurants or convenience stores in the home, school, or combined home and school neighbourhoods was not associated with any of the outcomes. High SSB intake was associated with relative exposure to convenience stores in the residential neighbourhood (RR=1.45, 95% CI: 1.08, 1.96) and in the home and school neighbourhoods combined (RR=1.69, 95% CI: 1.11, 2.57).

Conclusions: We found no evidence of an association between absolute exposure to fast-food restaurants and convenience stores around home and school and adolescents' fast-food and SSB intake. Relative exposure, which measures the local diversity of the neighbourhood food environment, was positively associated with SSB intake. Relative measures of the food environment may better capture the environmental risks for poor diet than absolute measures.

Keywords: adolescent; diet; dietary behaviours; fast-food; sugar-sweetened beverages; food environment; foodscape; neighborhood; youth

Introduction

Poor diet is a key risk factor for a range of health problems including excess weight and related disorders such as Type 2 diabetes and cardio-vascular diseases.[1] High intakes of fast-food and sugar-sweetened beverages (SSBs) are major contributors to poor dietary quality among young people [2; 3] with a recent study using data from 36 countries reporting that 51.3% of adolescents consume fast-food at least once per week.[4] Fast-food is characterized by large portion sizes and high calorie, salt, sugar, and saturated fat contents, and is often consumed with SSBs.[5] SSBs are responsible for the largest proportion of refined sugar intake in 11-18 year-olds [6] and, similar to fast-food, contribute to weight gain.[7] As a critical transition period during which unhealthy diets may become established and track into adulthood [8; 9] adolescence provides a window of opportunity for intervention.

In addition to personal and social characteristics,[10] the food environment, which is commonly characterized as the "number, type, location, and accessibility of food outlets such as grocery stores, convenience stores, fast food restaurants, and full-service restaurants",[11 p.S96] has emerged as a key contributor to dietary behaviour [12; 13; 14] and excess weight.[15; 16] The food environment may influence dietary behaviours through structural differences in availability and access to components of healthy and less healthy diets. In one study, adolescents were more likely to self-purchase from fast-food restaurants or convenience stores when they lived or attended school in neighbourhoods characterized by a high density of such stores.[17] Food retailers may also provide visual and olfactory cues provoking the desire to purchase and eat certain foods,[18; 19; 20; 21] a mechanism which may be even stronger when energy-dense foods are promoted since young people tend to have a general preference for such foods.[22] A high concentration of similar food retailers may also be indicative of a more price competitive market, thereby decreasing the cost of certain foods compared to

others. This may be important for adolescents who tend to be price-sensitive given their restricted financial means, and who are less likely than adults to weigh the nutritional implications of their poor dietary choices against price considerations.[23] The dominant category of food establishments in a given environment may also reflect local market demand for particular types of food and relate to the normalization of certain dietary behaviours.[24]

In light of these hypothesized mechanisms, policymakers see the potential in intervening in the food environment to improve diet and reduce obesity.[25] This is despite equivocal evidence for an association between the food environment and young people's dietary behaviours.[12; 13] While some studies have found that the density of fast-food restaurants or convenience stores around the home was positively associated with young people's purchase [17] and intake of fast-food [26; 27; 28] or SSBs,[29; 30; 31] others have not.[17; 18; 32] In one study that investigated proximity rather than density, Skidmore *et al*. (2012) found that living further away from a fast-food restaurant or convenience store was associated with less frequent consumption of sugary drinks.[33] Studies of fast-food retailer availability in the school neighbourhood have tended to report null associations with fast-food [26; 32; 34; 35] and SSB intake,[30; 32; 36; 37] although school density and proximity to fast-food restaurants have been found to positively relate to fast-food intake and SSB consumption.[31; 38]

Previous research on adolescents has focused primarily on the effect of the food environment in the home neighbourhood, and to a lesser extent the school neighbourhood.[12] Young people spend most of their time either at home or in school, making these two settings central to their daily lives and activity spaces. Despite this, studies have rarely quantified the effect of exposure to both settings considered together,[26; 32; 36; 39] hampering exploration of the cumulative impact of multiple environmental exposures occuring across the day that may

affect diet. A second limitation is an almost exclusive focus on environmental exposures based upon the presence of specific types of food retailers in a given area (i.e., absolute availability), and less consideration of measures of relative availability where exposure is defined as the number of specific types of food retailers expressed as a proportion of all food establishments in an area, or as the ratio of healthy to unhealthy food outlets.[12; 16] Unlike absolute measures, relative measures characterize an individual's simultaneous exposure to a wide array of food retailers from which to purchase food.[24] Relative measures thus account for the co-location of healthy and unhealthy food outlets, providing an indication of local food retail diversity, and in adults have been found to more consistently predict dietary behaviours.[40; 41; 42]

In this paper we explore the associations between the home and school neighbourhood food environment considered separately and together and high consumption of fast-food and SSBs using both absolute and relative exposure measures. We hypothesized (1) that a high availability of fast-food restaurants and convenience stores in the home and school neighbourhoods considered seperately would be associated with a higher consumption of fast-food and SSBs; (2) that the availability of fast-food restaurants and convenience stores in the home and school neighbourhoods considered together would be more strongly associated with fast-food and SSB consumption than availability in each setting taken separately; and (3) that associations with relative measures would be stronger than with absolute measures.

Methods

Data collection

Data came from wave 3 (n=3089) of The Olympic Regeneration in East London (ORiEL) Study, a prospective cohort study of adolescents and their parents which evaluated the health

impacts of urban regeneration following the London 2012 Olympic Games.[43] Adolescent participants were recruited from 25 randomly selected secondary schools in four boroughs of East London, UK: Tower Hamlets, Hackney, Barking and Dagenham, and Newham. Year 9 students (aged 13-15 years) completed a self-administered paper-based questionnaire in class-time under researcher supervision. Data collection ran from January-July 2014. Full details on study recruitment and data collection are described elsewhere.[43]

Measures

Fast-food and sugar-sweetened beverage intake

Weekly frequency of fast-food intake was based on two questions adapted from earlier studies [26; 44; 45]: (i) "How often do you eat takeaways or fast-food at home?" and (ii) "How often do you eat takeaways or fast-food away from home?". Examples of typical sources of fast-food were given (Pizza Hut, Burger King, Subway, McDonald's, Perfect Fried Chicken). These questions were found to have good internal reliability in a sample of young adults.[45] Five response options were available: "never or rarely", "less than one day a week", "2 to 3 days a week", "4 to 6 days a week" and "everyday". Responses to each question were dichotomized as fast-food consumed ≥2-3 days per week and <2-3 days per week.[21; 38; 45] We also analyzed fast-food intake regardless of where it was consumed by comparing participants who ate fast-food at least two days per week at home or away to less frequent consumers. SSB intake was assessed with the question "How often do you drink fizzy drinks" with five possible responses: "never", "rarely", "at least once a week", "once a day", and "more than once per day". SSB intake was dichotomized as ≥ once per day and < once per day.[32] Fast-food and SSB outcomes were analyzed separately.

Availability of fast-food restaurants and convenience stores

148 Food businesses data (full name, address and category of food retailer) were extracted from
149 local authority registers of the four study and adjacent boroughs for the same time period as
150 the individual-level data were collected. In the UK, all food businesses are obliged by the
151 Food Standards Agency to register with their local environmental health authority 28 days
152 prior to opening and to inform them of any status changes or closures.[46] Food establishments
153 were classified using the following 15 mutually exclusive categories: chain supermarkets,
154 independent supermarkets, discount retailers, ethnic-specific supermarkets, affiliated
155 franchise stores (eg. Spar, CostCutter), convenience stores Type A (mini-markets selling
156 fresh fruit and vegetables), convenience stores Type B (newsagent, tobacconist or
157 confectioner), meat and fish shops, fruit and vegetables shops, other specialist food stores,
158 bakeries, full service restaurants, chain fast-food restaurants, independent fast-food
159 restaurants, and coffee shops and sandwich bars. Food retailers that were not assigned a
160 retailer type in the register were incorporated in the existing classification using store name
161 and visual appearance in Google streetview. Fast-food restaurants encompassed independent
162 or multi-premises restaurant businesses offering food and drink in a self-service manner to
163 eat in, or by collection or delivery to take away, while convenience stores were defined as
164 small stores selling a limited range of foods. In a validation study, food services data which
165 included fast-food restaurants showed high positive predictive value (PPV=0.96, 95% CI:
166 0.94-0.98) when compared to contemporary street photography from Google and Bing search
167 engines (unpublished data).
168
169 Residential, school, and food business addresses were geocoded using a Python script which
170 matched reported addresses with authoritative address location data provided by the
171 Ordnance Survey AddressLayer 2 database.[47] Home and school locations were used as
172 anchors to create 800-meter pedestrian road network buffers. A distance of 800 meters

corresponds approximately to a 10-minute walk and has previously been used to study environmental correlates of young people's dietary behaviours.[26; 30] For each buffer we computed the number of (a) chain and independent fast-food restaurants, (b) convenience stores (both types as described above), and (c) all 15 types of food establishments combined. For the combined buffer, the numbers for the home and school buffers were summed but avoided double counting within any spatial overlap. Using these metrics, absolute availability measures were computed as the number of (a) fast-food restaurants or (b) convenience stores in each buffer. Relative availability measures were defined as the proportion of all food establishments that were fast-food restaurants (a/c) or convenience stores (b/c).[42; 48] Availability measures were treated as continuous variables to allow comparison with other studies.[49]

Covariates

Individual-level covariates considered for inclusion in the models were based on previously published work in the field and included age (continuous), sex (male/female), ethnicity (White UK/Black/South Asian/Other) and having free school meals (yes/no). Residential neighbourhood disadvantage was considered a potential confounder and operationalized as the 2015 relative income deprivation index categorized into quintiles based on the London distribution for the lower super output area (LSOA) in which the home address was located. Residential neighbourhood disadvantage was not found to be associated with exposures and outcomes in bivariate analyses was excluded from subsequent analyses.

Analyses

Out of 3089 participants, between 17.5% and 18.5% had missing data on one or more of the dietary outcomes, 14.0% did not have residential exposure measures, 2.3% were missing free

198 school meals information, and 0.9% had missing data for ethnicity. Missingness patterns
199 were assessed and missing data were imputed under a ‘‘missing at random’’ assumption
200 using the multivariate imputation using chained equations (MICE) method.[50] The imputation
201 model included all variables from the final models along with the auxiliary variables body
202 mass index z-score (continuous) and time lived in the neighbourhood (more vs. less than one
203 year). A burn-in period of 20 iterations was specified and a total of 30 imputed datasets were
204 produced after 600 iterations. Diagnostic checks were performed by comparing the
205 distributions of observed and imputed values and examining trace plots for chain
206 convergence.[51]
207
208 We used generalized linear models with Poisson distribution and log link function to regress
209 fast-food intake on fast-food restaurant availability measures, and SSB intake on convenience
210 store availability measures. Poisson regression with robust standard errors was preferred over
211 logistic regression since it provides unbiased estimates of the adjusted relative risk when
212 outcomes are highly prevalent (>10%).[52] Individual-level models were fitted since school-
213 level clustering was found to be minimal (intra-class coefficients ranging from 0.01 to 0.05).
214 Crude and adjusted relative risks and 95% confidence intervals were estimated comparing
215 high to low consumers of fast-food or SSBs. Analyses were performed in Stata v.15 [53] on
216 the complete imputed dataset (without deleting imputed outcomes) as recommended when
217 estimating relative risks.[54]
218
219 **Results**
220 **Table 1** provides means and 95% confidence intervals for participants’ individual-level
221 characteristics based on the imputed datasets. Girls comprised 43.3% of the imputed samples
222 which were 16.8% White UK, 22.9% South Asian, and 22.3% Black. A third (33.3%) of

participants received free school meals. About one quarter of the sample consumed fast-food at least 2-3 days per week at home (27.3%) or away (25.7%), while 36.7% frequently consumed fast-food at and/or away from home. Nearly half (47.0%) of participants reported drinking SSBs at least once per day (Table 1).

Insert Table 1 approximately here

Food environment characteristics for the imputed datasets are presented in **Table 2**. There were on average 11.5, 10.0, and 19.6 fast-food restaurants in home, school, and combined neighbourhoods respectively. Expressed as a proportion, fast-food restaurants represented between 21% and 25% of all food establishments. There were on average 11.1, 11.6, and 20.6 convenience stores in participants' home, school, and combined neighbourhoods, which accounted for 28% to 31% of all food establishments in these settings (Table 2).

Insert Table 2 approximately here

Results from regression models for the association between the absolute availability of fast-food restaurants and convenience stores in the home, school, and combined home and school neighbourhoods and fast-food or SSB intake are presented in **Table 3**. For all outcomes, estimates from both unadjusted and fully-adjusted models controlling for age, sex, ethnicity, and free school meals approximated the null value.

Insert Table 3 approximately here

Table 4 shows results for the association between relative measures of the food environment in each setting, and high intakes of fast-food or SSBs. Associations between exposure to fast-food restaurants in the home and combined home and school neighbourhoods and high fast-food intake were in the expected, positive direction, but none of the fully adjusted models reached statistical significance. The proportion of fast-food restaurants around school was inversely associated with fast-food intake, albeit non-significantly so. An increased proportion of convenience stores in all three settings was associated with higher SSB intake, with results reaching statistical significance for the home neighbourhood (RR=1.45, 95% CI: 1.08, 1.96) and the combined home and school neighbourhoods (RR=1.69, 95% CI: 1.11, 2.57).

Insert Table 4 approximately here

Sensitivity analyses

We ran several sensitivity analyses to test model robustness. Results of analyses of food environment measures computed for 400 and 600 meter buffers did not qualitatively differ from those presented here, save for the relative availability of convenience stores around home which was not significantly associated with SSB intake, while the school neighbourhood availability was (RRs and 95% CIs of 1.30 (1.13, 1.50) and 1.36 (1.13, 1.64) for the 400 and 600 meter buffers respectively). In analyzing the unhealthiest definitions of dietary behaviours, i.e., eating fast-food at least 4 times per week and drinking SSBs more than once per day, we found results to be robust across model specification for absolute availability measures and both outcomes, and for relative exposure to fast-food restaurants and fast-food intake. Contrary to results for consuming SSB once a day or more (Table 4), the relative availability of convenience stores was not associated with consuming SSBs more

than once per day (data not shown). When assessing exposure to convenience stores in addition to fast-food restaurants, where young people may also consume SSBs, we found similar results to those presented here, with RRs and 95% CIs of 1.41 (1.10, 1.79) and 1.44 (1.05, 1.99) for the home and the combined home and school neighbourhoods respectively (data not shown).

Discussion

In this study we assessed associations between the home and school neighbourhood food environment and fast-food and SSB consumption in adolescents. Our study fills a gap in the literature on young people's dietary behaviours, especially as they relate to the cumulative exposure to fast-food restaurants and convenience stores in the home and school neighbourhoods combined.[12] It also provides evidence specific to a high density urban context (London, UK) which is of importance since findings from different cities may not be directly comparable because of differences in urban density, form, planning and legislation.[55]

We found no evidence of an association between the absolute availability of fast-food restaurants or convenience stores and fast-food or SSB intake, findings which add to the weight of evidence suggesting no effect for the home [18; 32; 36] and school [26; 30; 32; 34; 35; 36; 37] neighbourhoods on these dietary outcomes. The null associations found for absolute availability measures in our sample could possibly be explained by the relatively low heterogeneity in the food environment exposures. Indeed few participants had no fast-food restaurant or convenience store in any given setting (Appendix 2), hampering the differentiation between those not exposed at all to these types of food establishments from those with some exposure, which might have been informative.

297

298 Our study is one of a handful to have employed relative measures of exposure to assess food
299 environment diversity in relation to young people's dietary behaviours.[12] Researchers have
300 recommended the exploration of both absolute and relative availability measures, with the
301 latter seemingly providing more consistent positive associations between the local food
302 environment and diet.[40; 41; 42] One suggested argument in favour of relative rather than
303 absolute availability measures is that they better reflect the overall environment within which
304 food-related choices are made. As suggested by Clary *et al*. (2017), individuals consciously
305 and unconsciously weigh the various options available to them (and that they are aware of)
306 and as such final decisions are not solely based on the knowledge of one single category of
307 food outlet being present, but rather also involve consideration of potential alternatives.[24]
308 Exposure to a disproportionate share of stores selling certain types of food (recently coined
309 "food swamps"), may relate to intake through mechanisms involving a cumulative increase in
310 exposure to point-of-sale marketing and environmental cues stimulating the desire to
311 consume the advertised foods.[48] A high relative availability of food stores may also be
312 indicative of higher competition between establishments and thus more enticing promotions
313 and lower prices, as well as social normalisation of intake.[24] As expected, we found that the
314 more saturated the home or the combined home and school neighbourhoods were with fast-
315 food restaurants or convenience stores, the higher the risk of consuming fast-food and SSBs
316 frequently, although results only reached statistical significance for SSB intake. These results
317 add to the small body of work concerning relative measures of the food environment, with
318 previous studies reporting both null [32] and positive [56] associations between the residential
319 or school neighbourhood food environments and fast-food and SSB intake in young people.
320

In accordance with our hypothesis, the relative availability of fast-food restaurants or convenience stores in the combined home and school neighbourhoods was more strongly associated with fast-food consumed away from home and at home and/or away, as well as with SSB, than the home and school food environments considered separately. Although confidence intervals overlapped, these findings provide some support to Burgoine *et al*. (2014) who found that in British adults the cumulative exposure to fast-food restaurants in residential and work neighbourhoods was more strongly associated with daily fast-food intake than each distinct setting.[57] Repeat encounters with a similar type of food establishment across the day and over time may cumulatively impact individuals' knowledge of the options available to them and render some of these more enticing or seemingly more accessible than others.[24]

The lack of statistically significant associations between most availability measures and food behaviours may also be explained by the fact that the food environment as measured in our study is only one dimension of food outlet access and use - aspects of proximity, affordability, accommodation (eg. store opening hours), and socio-cultural acceptability may also be important.[58] Cowburn *et al*. (2015) for instance reported that despite having the opportunity to purchase food on the journey between home and school, children did not necessarily do so because they did not have enough money or time.[59] It should thus be kept in mind that there is inter-individual variability in how people interact with the food environment [24; 60] and that the purchase of food from a given outlet ultimately arises from a complex interaction between adolescents' circumstances at a specific time and the environment.[24]

345 Unmeasured individual, peer, family, school, and community-level factors such as personal
346 taste, preferences, and sense of mastery, foods available within schools, as well as parenting
347 style and parents' own food intake could also mediate or moderate the relationship between
348 the food environment and food behaviours.[37] In our study uncontrolled confounding by
349 these factors may have masked true associations, while untested effect modification may
350 potentially conceal significant subgroup effects. For example, restrictions on leaving school
351 grounds at lunch time and the use of non-active commuting modes such as the car or bus
352 might have limited the extent to which adolescents could actually access the food outlets
353 surrounding their school. While we could not verify the former hypothesis for lack of data on
354 school policies, we did not find that mode of transportation to school moderated the
355 associations reported here. We also observed inequalities in some food behaviours and some
356 exposure measures by ethnicity and free school meal status, two potential moderators of the
357 food environment-food behaviour relationships, but interactions were not significant in this
358 sample (data not shown). Alternatively, the null associations we found may be masking
359 heterogeneity in relationships across space, as found in the adult sample of the ORiEL study
360 [40] and elsewhere.[27] Further exploring spatial heterogeneity in how the food environment
361 relates to younger people's eating behaviours is a sound avenue for future research.
362
363 Strengths of our study include that home, school, and food retail locations were geocoded
364 with high precision (to the address level), thereby reducing spatial error.[61] Food environment
365 data were drawn from official council registers collected for regulatory purposes, thus
366 providing high levels of validity in comparison to data from commercial sources.[62] Since
367 measures of association are prone to vary depending on the shape and size of the
368 geographical unit studied,[63] we tested model robustness when food environment measures
369 were aggregated within 400 and 600 meter road network buffers, and found results to be

relatively consistent with those presented here. Given policymakers' interest in intervening in the food environment, especially around schools, it seems important to assess associations for different threshold distances. Limitations include that the study area mainly comprised disadvantaged neighbourhoods (see Appendix 1) and that fast-food outlets and convenience stores were ubiquitous in places (see Appendix 2), which may have reduced the amount of heterogeneity in individual and food environment measures, reducing the likelihood of uncovering significant associations. We also were unable to account for children's exposure to food outlets on their commute between home and school, an exposure which has been found to relate to unhealthy food purchases in one study,[19] but not in two others.[26; 30] Investigating the food environment along pupils' commuting routes nevertheless remains a relevant avenue for research, although this should be done with caution since children have been found to often vary the routes they travel between home and school.[64; 65] Limitations related to food behaviour measures should also be mentioned. We utilised adolescent self-reported dietary intake which, although common in food behaviour studies of young people, can lead to measurement error compared to gold-standard approaches of dietary assessment. Furthermore the specific question used to assess fast-food intake, although borrowed from the HABITS and other studies [26; 44; 45] and validated in young people,[45] was not validated in the ORiEL sample. It is thus possible that participants misreported their fast-food intake, for instance by under-reporting fast-food purchased from independent restaurants since the question only provided examples of chain fast-food outlets. In that case, true fast-food intake would be underestimated. However, we do not expect such response bias to have been differential between high and low consumers, thus our results would be conservative estimates of true associations. Finally, our measure of SSB intake only included fizzy drinks, which might have underestimated true intake since adolescents also consume other types of sugar-sweetened beverages such as fruit juices, cordials, and energy drinks.

In this study of adolescents from East London, UK, we found limited evidence for an association between the food environment around home and school and fast-food or SSB intake. Where positive associations were observed these were for relative rather than absolute measures of exposure, as seen with the proportion of convenience stores around home and in the combined home and school neighbourhoods being associated with increased SSB consumption. Modifying the local food retail system through increasing diversity in food retailing and reducing the proportion of unhealthy food outlets within the local food environment may be more promising than a simple focus on individual food establishments. Better conceptualization and operationalization of adolescents' dietary behaviours in terms of when, how, and what they purchase and consume, and where they do so, is also a worthwhile avenue for future research.

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568 modelled and GPS-measured routes to school. *Int J Health Geogr* **13**, 5.

569

570

571 Table 1. Individual-level characteristics for 3089 adolescents from the ORiEL study [1]

Individual-level characteristics	Mean (95% CI)	% missing
Mean age, years	14.1 (14.1, 14.1)	0
Female, %	43.3 (41.6, 45.1)	0
Ethnicity, %		0.9
White UK	16.8 (15.5, 18.2)	
South Asian	22.9 (21.4, 24.4)	
Black	22.3 (21.2, 24.2)	
Other	37.6 (35.9, 39.3)	
Have free school meals, %	33.3 (31.6, 34.9)	2.3
Fast-food intake, %		
≥ 2-3 days/week at home	27.3 (25.5, 29.1)	17.5
≥ 2-3 days/week away from home	25.7 (24.0, 27.4)	18.0
≥ 2-3 days/week at and/or away from home	36.7 (34.8, 38.6)	18.5
Sugar-sweetened beverage intake [2], %		
Once/day or more	47.0 (45.1, 49.0)	17.5

572 CI, confidence interval.

573 [1] Descriptive statistics are for the imputed datasets.

574 [2] Sugar-sweetened beverage intake approximated with intake of fizzy drinks.

575

576 Table 2. Food environment characteristics for 3089 adolescents from the ORiEL study [1]
577

Food environment characteristics	Mean (95% CI)	% missing
Availability of fast-food restaurants around home		14.0
Absolute [2]	11.5 (11.1, 11.8))	
Relative [3]	0.25 (0.25, 0.26)	
Availability of fast-food restaurants around school		0
Absolute [2]	10.0 (9.8, 10.2)	
Relative [3]	0.21 (0.21, 0.22)	
Availability of fast-food restaurants around home and school		14.0
Absolute [2]	19.6 (19.2, 20.0)	
Relative [3]	0.25 (0.25, 0.25)	
Availability of convenience stores around home		14.0
Absolute [2]	11.1 (10.8, 11.4)	
Relative [3]	0.28 (0.27, 0.28)	
Availability of convenience stores around school		0
Absolute [2]	11.6 (11.3, 11.8)	
Relative [3]	0.31 (0.30, 0.32)	
Availability of convenience stores around home and school		14.0
Absolute [2]	20.6 (20.2, 21.0)	
Relative [3]	0.28 (0.27, 0.28)	

578 CI, confidence interval.
579 [1] Descriptive statistics are for the imputed datasets.
580 [2] Absolute availability is the number of fast-food restaurants or of convenience stores in
581 a given buffer.
582 [3] Relative availability is the proportion of all food establishments that are fast-food
583 restaurants or convenience stores in a given buffer.

584 Table 3. Risk ratios and 95% confidence intervals for the association between

585 absolute measures of the food environment and high fast-food or sugar-sweetened beverage intake in the ORiEL study (n=3089)

586

	Home		School		Home and school combined	
	Unadjusted RR (95% CI)	Adjusted [1] RR (95% CI)	Unadjusted RR (95% CI)	Adjusted [1] RR (95% CI)	Unadjusted RR (95% CI)	Adjusted [1] RR (95% CI)
Exposure: number of fast-food restaurants						
Eating fast-food ≥ 2-3 days/week [2]						
At home	1.00 (1.00, 1.01)	1.00 (1.00, 1.01)	**0.98 (0.97, 0.99)**	**0.98 (0.97, 0.99)**	1.00 (0.99, 1.00)	1.00 (0.99, 1.00)
Away from home	1.00 (0.99, 1.01)	1.00 (0.99, 1.01)	0.98 (0.98, 1.00)	0.99 (0.98, 1.00)	1.00 (0.99, 1.00)	1.00 (0.99, 1.00)
At home and/or away	1.00 (0.99, 1.01)	1.00 (0.99, 1.00)	0.99 (0.98, 1.00)	0.99 (0.98, 1.00)	1.00 (0.99, 1.00)	1.00 (0.99, 1.00)
Exposure: number of convenience stores						
Drinking SSBs ≥ once/day [3]	1.00 (0.99, 1.00)	1.00 (0.99, 1.00)	1.00 (0.99, 1.00)	1.00 (0.99, 1.00)	1.00 (0.99, 1.00)	1.00 (0.99, 1.00)

587 CI, confidence interval; RR, risk ratio

588 [1] Models are adjusted for age (continuous), sex (female/male), ethnicity (White/Black/South Asian/Other), and free school meals
589 (yes/no).

590 [2] Reference category is "one day/week or less".

591 [3] Reference category is "less than once/day".

592 Statistically significant estimates (P<0.05) are in bold.

Table 4. Risk ratios and 95% confidence intervals for the association between relative measures of the food environment and high fast-food or sugar-sweetened beverage intake in the ORiEL study (n=3089)

	Home		School		Home and school combined	
	Unadjusted RR (95% CI)	Adjusted [1] RR (95% CI)	Unadjusted RR (95% CI)	Adjusted [1] RR (95% CI)	Unadjusted RR (95% CI)	Adjusted [1] RR (95% CI)
Exposure : proportion of fast-food restaurants						
Eating fast-food ≥ 2-3 days/week [2]						
At home	**1.88 (1.03, 3.43)**	1.76 (0.96, 3.23)	**0.41 (0.22, 0.78)**	0.54 (0.28, 1.04)	1.32 (0.56, 3.11)	1.49 (0.61, 3.61)
Away from home	1.29 (0.71, 2.35)	1.25 (0.68, 2.30)	0.54 (0.27, 1.07)	0.82 (0.39, 1.69)	1.19 (0.48, 2.94)	1.52 (0.60, 3.88)
At home and/or away	1.35 (0.83, 2.20)	1.30 (0.80, 2.12)	**0.48 (0.29, 0.80)**	0.65 (0.38, 1.10)	1.20 (0.58, 2.48)	1.41 (0.66, 3.01)
Exposure: proportion of convenience stores						
Drinking SSBs ≥ once/day [3]	**1.49 (1.10, 2.01)**	**1.45 (1.08, 1.96)**	1.19 (0.98, 1.45)	1.18 (0.98, 1.44)	**1.62 (1.07, 2.47)**	**1.69 (1.11, 2.57)**

CI, confidence interval; RR, risk ratio

[1] Models are adjusted for age (continuous), sex (female/male), ethnicity (White/ Black/South Asian/Other), and free school meals (yes/no).

[2] Reference category is "one day/week or less".

[3] Reference category is "less than once/day".

Statistically significant estimates (P<0.05) are in bold.

602
603 Appendix 1: Descriptive statistics for the ORiEL sample [1]
604

Characteristic		% missing
Age in years, mean (SD)	14.1 (0.32)	0
Female, %	43.3	0
Ethnicity, %		0.9
White UK	16.9	
South Asian	22.9	
Black	22.7	
Other	37.6	
Have free school meals, %	33.2	2.3
Fast-food intake, %		
≥ 2-3 days/week at home	27.3	17.5
≥ 2-3 days/week away from home	25.5	18.0
≥ 2-3 days/week at and/or away from home	36.5	18.5
Sugar-sweetened beverage intake [2], %		
Once/day or more	46.9	17.0
School borough, %		0
Tower Hamlets	25.6	
Hackney	24.0	
Barking and Dagenham	19.9	
Newham	30.5	
Relative income deprivation in residential neighbourhood, %		14.1
Quintile 1 (high deprivation)	50.4	
Quintile 2	31.6	
Quintile 3	14.6	
Quintile 4	2.8	
Quintile 5 (low deprivation)	0.7	

605 SD, standard deviation
606 [1] Descriptive statistics are based on complete cases for each variable.
607 [2] Sugar-sweetened beverage intake approximated with intake of fizzy drinks.

608

609 Appendix 2: Food environment characteristics and % missing for the ORiEL sample [1]

610

Food environment measure	Median (IQR)	Range	n (%) with 0 food outlet	% missing
Availability of fast-food restaurants around home				
Absolute [2]	10.0 (13.0)	0 – 46	178 (6.7)	14.0
Relative [3]	0.27 (0.13)	0 – 1		14.0
Availability of fast-food restaurants around school				
Absolute [2]	10.0 (12)	0 – 24	311 (10.1)	0
Relative [3]	0.22 (0.10)	0 – 0.41		0
Availability of fast-food restaurants around home and school				
Absolute [2]	18.0 (16)	0 – 62	55 (2.1)	14.0
Relative [3]	0.25 (0.10)	0 – 0.43		14.0
Availability of convenience stores around home				
Absolute [2]	10.0 (11.0)	0 – 39	108 (4.1)	14.0
Relative [3]	0.26 (0.15)	0 – 1		14.0
Availability of convenience stores around school				
Absolute [2]	11.0 (8.0)	0 – 35	97 (4.5)	0
Relative [3]	0.26 (0.18)	0 – 1		0
Availability of convenience stores around home and school				
Absolute [2]	19.0 (16.0)	0 – 64	35 (1.3)	14.0
Relative [3]	0.26 (0.12)	0 – 1		14.0

611 IQR, Interquartile range

612 [1] Descriptive statistics are based on complete cases for each variable.

613 [2] Absolute availability is the number of fast-food restaurants or convenience stores in a
614 given buffer.

615 [3] Relative availability is the proportion of all food establishments that are fast-food
616 restaurants or convenience stores in a given buffer.

617

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Conflict of Interest

None.

Authorship

M.S. formulated the research question, conducted the analyses, and wrote the manuscript. D.L. computed the environmental measures and provided feedback on the analyses and all drafts of the manuscript. N.S., C. C., and S.C. provided feedback on the analyses and all drafts of the manuscript. All authors agreed to the final version of the manuscript.

Ethical Standards Disclosure

This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects were approved by the Queen Mary University of London Research Ethics Committee (QMREC2011/40), the Association of Directors of Children's Services (RGE110927), and the London Boroughs Research Governance Framework (CERGF113). Headteachers gave written consent for the study to take place within their school, parents gave passive informed consent for their child to participate, and adolescent participants gave written informed assent.