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

3

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21 **Running head:** Food environment and adolescent food intake

Accepted

22 **Abstract**

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

26 **Design:** Cross-sectional observational study.

27 **Setting:** East London, UK.

28 **Subjects:** 3089 adolescents (13-15 years-old) from the Olympic Regeneration in East  
29 London study self-reported their weekly frequency of fast-food and SSB consumption. We  
30 used food business addresses collected from local authority registers to derive absolute  
31 (counts) and relative (proportions) exposure measures to fast-food restaurants and  
32 convenience stores within 800 meters from home, school, and home and school combined.

33 Associations between absolute and relative measures of the food environment and fast-food  
34 and SSB intake were assessed using Poisson regression models with robust standard errors.

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

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

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

47

## 48 **Introduction**

49 Poor diet is a key risk factor for a range of health problems including excess weight and  
50 related disorders such as Type 2 diabetes and cardio-vascular diseases.<sup>(1)</sup> High intakes of fast-  
51 food and sugar-sweetened beverages (SSBs) are major contributors to poor dietary quality  
52 among young people <sup>(2; 3)</sup> with a recent study using data from 36 countries reporting that  
53 51.3% of adolescents consume fast-food at least once per week.<sup>(4)</sup> Fast-food is characterized  
54 by large portion sizes and high calorie, salt, sugar, and saturated fat contents, and is often  
55 consumed with SSBs.<sup>(5)</sup> SSBs are responsible for the largest proportion of refined sugar  
56 intake in 11-18 year-olds <sup>(6)</sup> and, similar to fast-food, contribute to weight gain.<sup>(7)</sup> As a critical  
57 transition period during which unhealthy diets may become established and track into  
58 adulthood <sup>(8; 9)</sup> adolescence provides a window of opportunity for intervention.

59  
60 In addition to personal and social characteristics,<sup>(10)</sup> the food environment, which is  
61 commonly characterized as the “number, type, location, and accessibility of food outlets such  
62 as grocery stores, convenience stores, fast food restaurants, and full-service restaurants”,<sup>(11</sup>  
63 <sup>p.S96)</sup> has emerged as a key contributor to dietary behaviour <sup>(12; 13; 14)</sup> and excess weight.<sup>(15; 16)</sup>  
64 The food environment may influence dietary behaviours through structural differences in  
65 availability and access to components of healthy and less healthy diets. In one study,  
66 adolescents were more likely to self-purchase from fast-food restaurants or convenience  
67 stores when they lived or attended school in neighbourhoods characterized by a high density  
68 of such stores.<sup>(17)</sup> Food retailers may also provide visual and olfactory cues provoking the  
69 desire to purchase and eat certain foods,<sup>(18; 19; 20; 21)</sup> a mechanism which may be even stronger  
70 when energy-dense foods are promoted since young people tend to have a general preference  
71 for such foods.<sup>(22)</sup> A high concentration of similar food retailers may also be indicative of a  
72 more price competitive market, thereby decreasing the cost of certain foods compared to

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

78

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

91

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

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

108  
109 In this paper we explore the associations between the home and school neighbourhood food  
110 environment considered separately and together and high consumption of fast-food and SSBs  
111 using both absolute and relative exposure measures. We hypothesized (1) that a high  
112 availability of fast-food restaurants and convenience stores in the home and school  
113 neighbourhoods considered separately would be associated with a higher consumption of  
114 fast-food and SSBs; (2) that the availability of fast-food restaurants and convenience stores in  
115 the home and school neighbourhoods considered together would be more strongly associated  
116 with fast-food and SSB consumption than availability in each setting taken separately; and  
117 (3) that associations with relative measures would be stronger than with absolute measures.

## 118 119 **Methods**

### 120 Data collection

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

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

129

130 Measures

131 *Fast-food and sugar-sweetened beverage intake*

132 Weekly frequency of fast-food intake was based on two questions adapted from earlier  
133 studies<sup>(26; 44; 45)</sup>: (i) “How often do you eat takeaways or fast-food at home?” and (ii) “How  
134 often do you eat takeaways or fast-food away from home?”. Examples of typical sources of  
135 fast-food were given (Pizza Hut, Burger King, Subway, McDonald’s, Perfect Fried Chicken).  
136 These questions were found to have good internal reliability in a sample of young adults.<sup>(45)</sup>  
137 Five response options were available: “never or rarely”, “less than one day a week”, “2 to 3  
138 days a week”, “4 to 6 days a week” and “everyday”. Responses to each question were  
139 dichotomized as fast-food consumed  $\geq 2$ -3 days per week and  $< 2$ -3 days per week.<sup>(21; 38; 45)</sup>

140 We also analyzed fast-food intake regardless of where it was consumed by comparing  
141 participants who ate fast-food at least two days per week at home or away to less frequent  
142 consumers. SSB intake was assessed with the question “How often do you drink fizzy drinks”  
143 with five possible responses: “never”, “rarely”, “at least once a week”, “once a day”, and  
144 “more than once per day”. SSB intake was dichotomized as  $\geq$  once per day and  $<$  once per  
145 day.<sup>(32)</sup> Fast-food and SSB outcomes were analyzed separately.

146

147 *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.<sup>(46)</sup> 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.<sup>(47)</sup> Home and school locations were used as  
172 anchors to create 800-meter pedestrian road network buffers. A distance of 800 meters



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

184

#### 185 *Covariates*

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

194

#### 195 *Analyses*

196 Out of 3089 participants, between 17.5% and 18.5% had missing data on one or more of the  
197 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.<sup>(50)</sup> 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.<sup>(51)</sup>

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%).<sup>(52)</sup> 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 <sup>(53)</sup> on  
216 the complete imputed dataset (without deleting imputed outcomes) as recommended when  
217 estimating relative risks.<sup>(54)</sup>

## 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

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

227

228 Insert Table 1 approximately here

229

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

236

237 Insert Table 2 approximately here

238

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

244

245 Insert Table 3 approximately here

246

247 **Table 4** shows results for the association between relative measures of the food environment  
248 in each setting, and high intakes of fast-food or SSBs. Associations between exposure to fast-  
249 food restaurants in the home and combined home and school neighbourhoods and high fast-  
250 food intake were in the expected, positive direction, but none of the fully adjusted models  
251 reached statistical significance. The proportion of fast-food restaurants around school was  
252 inversely associated with fast-food intake, albeit non-significantly so. An increased  
253 proportion of convenience stores in all three settings was associated with higher SSB intake,  
254 with results reaching statistical significance for the home neighbourhood (RR=1.45, 95% CI:  
255 1.08, 1.96) and the combined home and school neighbourhoods (RR=1.69, 95% CI: 1.11,  
256 2.57).

257  
258 Insert Table 4 approximately here

#### 259 Sensitivity analyses

260 We ran several sensitivity analyses to test model robustness. Results of analyses of food  
261 environment measures computed for 400 and 600 meter buffers did not qualitatively differ  
262 from those presented here, save for the relative availability of convenience stores around  
263 home which was not significantly associated with SSB intake, while the school  
264 neighbourhood availability was (RRs and 95% CIs of 1.30 (1.13, 1.50) and 1.36 (1.13, 1.64)  
265 for the 400 and 600 meter buffers respectively). In analyzing the unhealthiest definitions of  
266 dietary behaviours, i.e., eating fast-food at least 4 times per week and drinking SSBs more  
267 than once per day, we found results to be robust across model specification for absolute  
268 availability measures and both outcomes, and for relative exposure to fast-food restaurants  
269 and fast-food intake. Contrary to results for consuming SSB once a day or more (Table 4), the  
270 relative availability of convenience stores was not associated with consuming SSBs more  
271

272 than once per day (data not shown). When assessing exposure to convenience stores in  
273 addition to fast-food restaurants, where young people may also consume SSBs, we found  
274 similar results to those presented here, with RRs and 95% CIs of 1.41 (1.10, 1.79) and 1.44  
275 (1.05, 1.99) for the home and the combined home and school neighbourhoods respectively  
276 (data not shown).

277

## 278 **Discussion**

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

287

288 We found no evidence of an association between the absolute availability of fast-food  
289 restaurants or convenience stores and fast-food or SSB intake, findings which add to the  
290 weight of evidence suggesting no effect for the home<sup>(18; 32; 36)</sup> and school<sup>(26; 30; 32; 34; 35; 36; 37)</sup>  
291 neighbourhoods on these dietary outcomes. The null associations found for absolute  
292 availability measures in our sample could possibly be explained by the relatively low  
293 heterogeneity in the food environment exposures. Indeed few participants had no fast-food  
294 restaurant or convenience store in any given setting (Appendix 2), hampering the  
295 differentiation between those not exposed at all to these types of food establishments from  
296 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.<sup>(12)</sup> 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.<sup>(40; 41; 42)</sup> 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.<sup>(24)</sup>  
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.<sup>(48)</sup> 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.<sup>(24)</sup> 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 <sup>(32)</sup> and positive <sup>(56)</sup> associations between the residential  
319 or school neighbourhood food environments and fast-food and SSB intake in young people.

320

321 In accordance with our hypothesis, the relative availability of fast-food restaurants or  
322 convenience stores in the combined home and school neighbourhoods was more strongly  
323 associated with fast-food consumed away from home and at home and/or away, as well as  
324 with SSB, than the home and school food environments considered separately. Although  
325 confidence intervals overlapped, these findings provide some support to Burgoine *et al.*  
326 (2014) who found that in British adults the cumulative exposure to fast-food restaurants in  
327 residential and work neighbourhoods was more strongly associated with daily fast-food  
328 intake than each distinct setting.<sup>(57)</sup> Repeat encounters with a similar type of food  
329 establishment across the day and over time may cumulatively impact individuals' knowledge  
330 of the options available to them and render some of these more enticing or seemingly more  
331 accessible than others.<sup>(24)</sup>

332

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

344

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.<sup>(37)</sup> 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 <sup>(40)</sup> and elsewhere.<sup>(27)</sup> 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.<sup>(61)</sup> 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.<sup>(62)</sup> Since  
367 measures of association are prone to vary depending on the shape and size of the  
368 geographical unit studied,<sup>(63)</sup> we tested model robustness when food environment measures  
369 were aggregated within 400 and 600 meter road network buffers, and found results to be



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

395

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

Accepted

407 **References**

- 408 1. Organization WH (2012) *Population-based approaches to childhood obesity prevention*.  
409 Geneva, Switzerland.
- 410 2. Northstone K, Smith AD, Cribb VL *et al.* (2014) Dietary patterns in UK adolescents obtained  
411 from a dual-source FFQ and their associations with socio-economic position, nutrient  
412 intake and modes of eating. *Public Health Nutr* **17**, 1476-1485.
- 413 3. Lachat C, Nago E, Verstraeten R *et al.* (2012) Eating out of home and its association with  
414 dietary intake: a systematic review of the evidence. *Obes Rev* **13**, 329-346.
- 415 4. Braithwaite I, Stewart AW, Hancox RJ *et al.* (2014) Fast-food consumption and body mass  
416 index in children and adolescents: an international cross-sectional study. *BMJ Open* **4**,  
417 e005813.
- 418 5. Bowman SA, Gortmaker SL, Ebbeling CB *et al.* (2003) Effects of Fast-Food Consumption  
419 on Energy Intake and Diet Quality Among Children in a National Household Survey.  
420 *Pediatrics* **113**, 112.
- 421 6. Agency PHEatFS (2014) *National Diet and Nutrition Survey Results from Years 1, 2, 3 and*  
422 *4 (combined) of the Rolling Programme (2008/2009 – 2011/2012)*. London: Public  
423 Health England.
- 424 7. Tedstone A, Targett V, Allen R *et al.* (2015) *Sugar Reduction: The evidence for action*.  
425 London: Public Health England.
- 426 8. Craigie AM, Lake AA, Kelly SA *et al.* (2011) Tracking of obesity-related behaviours from  
427 childhood to adulthood: A systematic review. *Maturitas* **70**, 266-284.
- 428 9. Mikkila V, Rasanen L, Raitakari OT *et al.* (2005) Consistent dietary patterns identified from  
429 childhood to adulthood: the cardiovascular risk in Young Finns Study. *Br J Nutr* **93**, 923-  
430 931.

- 431 10. Mazarello Paes V, Hesketh K, O'Malley C *et al.* (2015) Determinants of sugar-sweetened  
432 beverage consumption in young children: a systematic review. *Obes Rev* **16**, 903-913.
- 433 11. Glanz K (2009) Measuring food environments: a historical perspective. *Am J Prev Med* **36**,  
434 S93-98.
- 435 12. Engler-Stringer R, Le H, Gerrard A *et al.* (2014) The community and consumer food  
436 environment and children's diet: a systematic review. *BMC Public Health* **14**, 522.
- 437 13. Caspi CE, Sorensen G, Subramanian SV *et al.* (2012) The local food environment and diet:  
438 A systematic review. *Health Place* **18**, 1172-1187.
- 439 14. Black C, Moon G, Baird J (2014) Dietary inequalities: What is the evidence for the effect  
440 of the neighbourhood food environment? *Health Place* **27**, 229-242.
- 441 15. Fitzpatrick C, Datta GD, Henderson M *et al.* (2017) School food environments associated  
442 with adiposity in Canadian children. *Int J Obes* **41**, 1005-1010.
- 443 16. Williams J, Scarborough P, Matthews A *et al.* (2014) A systematic review of the influence  
444 of the retail food environment around schools on obesity-related outcomes. *Obes Rev* **15**,  
445 359-374.
- 446 17. He M, Tucker P, Gilliland J *et al.* (2012) The influence of local food environments on  
447 adolescents' food purchasing behaviors. *Int J Environ Res Public Health* **9**, 1458-1471.
- 448 18. Shier V, Nicosia N, Datar A (2016) Neighborhood and home food environment and  
449 children's diet and obesity: Evidence from military personnel's installation assignment.  
450 *Soc Sci Med* **158**, 122-131.
- 451 19. Sadler RC, Clark AF, Wilk P *et al.* (2016) Using GPS and activity tracking to reveal the  
452 influence of adolescents' food environment exposure on junk food purchasing. *Can J*  
453 *Public Health* **107**, 5346.

- 454 20. Pearce A, Kirk C, Cummins S *et al.* (2009) Gaining children's perspectives: a multiple  
455 method approach to explore environmental influences on healthy eating and physical  
456 activity. *Health Place* **15**, 614-621.
- 457 21. Wansink B (2004) Environmental factors that increase the food intake and consumption  
458 volume of unknowing consumers. *Annu Rev Nutr* **24**, 455-479.
- 459 22. Drewnowski A (1989) Sensory preferences for fat and sugar in adolescence and adult life.  
460 *Ann N Y Acad Sci* **561**, 243-250.
- 461 23. Khan T, Powell LM, Wada R (2012) Fast food consumption and food prices: evidence from  
462 panel data on 5th and 8th grade children. *J Obes.*
- 463 24. Clary C, Matthews SA, Kestens Y (2017) Between exposure, access and use: Reconsidering  
464 foodscape influences on dietary behaviours. *Health Place* **44**, 1-7.
- 465 25. Sallis JF, Glanz K (2009) Physical activity and food environments: solutions to the obesity  
466 epidemic. *Milbank Q* **87**, 123-154.
- 467 26. Timperio AF, Ball K, Roberts R *et al.* (2009) Children's takeaway and fast-food intakes:  
468 associations with the neighbourhood food environment. *Public Health Nutr* **12**, 1960-  
469 1964.
- 470 27. Fraser LK, Clarke GP, Cade JE *et al.* (2012) Fast food and obesity: a spatial analysis in a  
471 large United Kingdom population of children aged 13-15. *Am J Prev Med* **42**, e77-85.
- 472 28. Longacre MR, Drake KM, MacKenzie TA *et al.* (2012) Fast-food environments and family  
473 fast-food intake in nonmetropolitan areas. *Am J Prev Med* **42**, 579-587.
- 474 29. Jennings A, Welch A, Jones AP *et al.* (2011) Local food outlets, weight status, and dietary  
475 intake: associations in children aged 9-10 years. *Am J Prev Med* **40**, 405-410.
- 476 30. Laska MN, Hearst MO, Forsyth A *et al.* (2010) Neighbourhood food environments: are  
477 they associated with adolescent dietary intake, food purchases and weight status? *Public*  
478 *Health Nutr* **13**.

- 479 31. Davis B, Carpenter C (2009) Proximity of fast-food restaurants to schools and adolescent  
480 obesity. *Am J Public Health* **99**, 505-510.
- 481 32. Van Hulst A, Barnett TA, Gauvin L *et al.* (2012) Associations between children's diets and  
482 features of their residential and school neighbourhood food environments. *Can J Public*  
483 *Health* **103**, eS48-54.
- 484 33. Skidmore P, Welch A, van Sluijs E *et al.* (2010) Impact of neighbourhood food  
485 environment on food consumption in children aged 9-10 years in the UK SPEEDY  
486 (Sport, Physical Activity and Eating behaviour: Environmental Determinants in Young  
487 people) study. *Public Health Nutr* **13**, 1022-1030.
- 488 34. Svastisalee C, Pagh Pedersen T, Schipperijn J *et al.* (2016) Fast-food intake and perceived  
489 and objective measures of the local fast-food environment in adolescents. *Public Health*  
490 *Nutr* **19**, 446-455.
- 491 35. Buck C, Bornhorst C, Pohlabein H *et al.* (2013) Clustering of unhealthy food around  
492 German schools and its influence on dietary behavior in school children: A pilot study.  
493 *Int J Behav Nutr Phys Act* **10**.
- 494 36. An RP, Sturm R (2012) School and residential neighborhood food environment and diet  
495 among California youth. *Am J Prev Med* **42**.
- 496 37. van der Horst K, Timperio A, Crawford D *et al.* (2008) The school food environment  
497 associations with adolescent soft drink and snack consumption. *Am J Prev Med* **35**, 217-  
498 223.
- 499 38. Cutumisu N, Traore I, Paquette MC *et al.* (2017) Association between junk food  
500 consumption and fast-food outlet access near school among Quebec secondary-school  
501 children: findings from the Quebec Health Survey of High School Students (QSHSS)  
502 2010-11. *Public Health Nutr* **20**, 927-937.

- 503 39. Barrett M, Crozier S, Lewis D *et al.* (2017) Greater access to healthy food outlets in the  
504 home and school environment is associated with better dietary quality in young children.  
505 *Public Health Nutr*, 1-10.
- 506 40. Clary C, Lewis DJ, Flint E *et al.* (2016) The Local Food Environment and Fruit and  
507 Vegetable Intake: A Geographically Weighted Regression Approach in the ORiEL  
508 Study. *Am J Epidemiol* **184**, 837-846.
- 509 41. Clary CM, Ramos Y, Shareck M *et al.* (2015) Should we use absolute or relative measures  
510 when assessing foodscape exposure in relation to fruit and vegetable intake? Evidence  
511 from a wide-scale Canadian study. *Prev Med* **71**, 83-87.
- 512 42. Mason KE, Bentley RJ, Kavanagh AM (2013) Fruit and vegetable purchasing and the  
513 relative density of healthy and unhealthy food stores: evidence from an Australian  
514 multilevel study. *J Epidemiol Commun Health* **67**.
- 515 43. Smith NR, Clark C, Fahy AE *et al.* (2012) The Olympic Regeneration in East London  
516 (ORiEL) study: protocol for a prospective controlled quasi-experiment to evaluate the  
517 impact of urban regeneration on young people and their families. *BMJ Open* **2**.
- 518 44. Wardle J, Sutton S, Jarvis M (1998) HABITS – The Health and Behaviours in Teenagers  
519 Study. London Health Behaviour Unit, Department of Epidemiology and Public Health,  
520 University College London.
- 521 45. Pereira MA, Kartashov AI, Ebbeling CB *et al.* (2005) Fast-food habits, weight gain, and  
522 insulin resistance (the CARDIA study): 15-year prospective analysis. *Lancet* **365**, 36-42.
- 523 46. Lake AA, Burgoine T, Greenhalgh F *et al.* (2010) The foodscape: classification and field  
524 validation of secondary data sources. *Health Place* **16**, 666-673.
- 525 47. Britain OSG (2011) OS MasterMap Address Layer 2.
- 526 48. Bridle-Fitzpatrick S (2015) Food deserts or food swamps?: A mixed-methods study of local  
527 food environments in a Mexican city. *Soc Sci Med* **142**, 202-213.

- 528 49. Lamb KE, White SR (2015) Categorisation of built environment characteristics: the trouble  
529 with tertiles. *Int J Behav Nutr Phys Act* **12**, 19.
- 530 50. Carpenter JR, Kenward MG (2013) *Multiple imputation and its application*. 1st ed.  
531 Chichester, West Sussex: John Wiley & Sons.
- 532 51. StataCorp (2017) *Stata Multiple Imputation Reference Manual - Release 15*. College  
533 Station, TX: Stata Press.
- 534 52. McNutt LA, Wu C, Xue X *et al.* (2003) Estimating the relative risk in cohort studies and  
535 clinical trials of common outcomes. *Am J Epidemiol* **157**, 940-943.
- 536 53. StataCorp (2017) *Stata Statistical Software: Release 15*. College Station, TX: StataCorp  
537 LLC
- 538 54. Sullivan TR, Lee KJ, Ryan P *et al.* (2017) Multiple imputation for handling missing  
539 outcome data when estimating the relative risk. *BMC Med Res Methodol* **17**, 134.
- 540 55. Huang JG, Lu XX, Sellers JM (2007) A global comparative analysis of urban form:  
541 Applying spatial metrics and remote sensing. *Landscape and Urban Planning* **82**, 184-  
542 197.
- 543 56. Babey S, Wolstein, J. and Diamant, AL (2011) *Food Environments Near Home and School  
544 Related to Consumption of Soda and Fast Food*. Los Angeles, CA: UCLA Center for  
545 Health Policy Research.
- 546 57. Burgoine T, Forouhi NG, Griffin SJ *et al.* (2014) Associations between exposure to  
547 takeaway food outlets, takeaway food consumption, and body weight in Cambridgeshire,  
548 UK: population based, cross sectional study. *BMJ* **348**, g1464.
- 549 58. Penchansky R, Thomas JW (1981) The concept of access: definition and relationship to  
550 consumer satisfaction. *Med Care* **19**, 127-140.



- 551 59. Cowburn G, Matthews A, Doherty A *et al.* (2016) Exploring the opportunities for food and  
552 drink purchasing and consumption by teenagers during their journeys between home and  
553 school: a feasibility study using a novel method. *Public Health Nutr* **19**, 93-103.
- 554 60. Paquet C, Dubé L, Gauvin L *et al.* (2010) Sense of mastery and metabolic risk: moderating  
555 role of the local fast-food environment. *Psychosom Med* **72**, 324-331.
- 556 61. Chaix B, Merlo J, Evans D *et al.* (2009) Neighbourhoods in eco-epidemiologic research:  
557 delimiting personal exposure areas. A response to Riva, Gauvin, Apparicio and Brodeur.  
558 *Soc Sci Med* **69**, 1306-1310.
- 559 62. Cummins S, Macintyre S (2009) Are secondary data sources on the neighbourhood food  
560 environment accurate? Case-study in Glasgow, UK. *Prev Med* **49**, 527-528.
- 561 63. Fotheringham AS, Wong DWS (1991) The Modifiable Areal Unit Problem in Multivariate  
562 Statistical-Analysis. *Environment and Planning A* **23**, 1025-1044.
- 563 64. Stewart T, Schipperijn J, Snizek B *et al.* (2017) Adolescent school travel: Is online mapping  
564 a practical alternative to GPS-assessed travel routes? *Journal of Transport & Health* **5**,  
565 113-122.
- 566 65. Harrison F, Burgoine T, Corder K *et al.* (2014) How well do modelled routes to school  
567 record the environments children are exposed to? A cross-sectional comparison of GIS-  
568 modelled and GPS-measured routes to school. *Int J Health Geogr* **13**, 5.

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Table 1. Individual-level characteristics for 3089 adolescents from the ORiEL study <sup>1</sup>

<b>Individual-level characteristics</b>	<b>Mean (95% CI)</b>	<b>% missing</b>
<b>Mean age, years</b>	14.1 (14.1, 14.1)	0
<b>Female, %</b>	43.3 (41.6, 45.1)	0
<b>Ethnicity, %</b>		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)	
<b>Have free school meals, %</b>	33.3 (31.6, 34.9)	2.3
<b>Fast-food intake, %</b>		
≥ 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
<b>Sugar-sweetened beverage intake <sup>2</sup>, %</b>		
Once/day or more	47.0 (45.1, 49.0)	17.5

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CI, confidence interval.

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<sup>1</sup> Descriptive statistics are for the imputed datasets.

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<sup>2</sup> Sugar-sweetened beverage intake approximated with intake of fizzy drinks.

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Table 2. Food environment characteristics for 3089 adolescents from the ORiEL study <sup>1</sup>

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

578 CI, confidence interval.

579 <sup>1</sup> Descriptive statistics are for the imputed datasets.

580 <sup>2</sup> Absolute availability is the number of fast-food restaurants or of convenience stores in  
581 a given buffer.

582 <sup>3</sup> Relative availability is the proportion of all food establishments that are fast-food  
583 restaurants or convenience stores in a given buffer.

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

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

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	Home		School		Home and school combined	
	Unadjusted RR (95% CI)	Adjusted <sup>1</sup> RR (95% CI)	Unadjusted RR (95% CI)	Adjusted <sup>1</sup> RR (95% CI)	Unadjusted RR (95% CI)	Adjusted <sup>1</sup> RR (95% CI)
<b>Exposure: number of fast-food restaurants</b>						
Eating fast-food $\geq$ 2-3 days/week <sup>2</sup>						
At home	1.00 (1.00, 1.01)	1.00 (1.00, 1.01)	<b>0.98 (0.97, 0.99)</b>	<b>0.98 (0.97, 0.99)</b>	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)
<b>Exposure: number of convenience stores</b>						
Drinking SSBs $\geq$ once/day <sup>3</sup>	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)

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CI, confidence interval; RR, risk ratio

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

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<sup>2</sup> Reference category is “one day/week or less”.

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<sup>3</sup> Reference category is “less than once/day”.

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

593 Table 4. Risk ratios and 95% confidence intervals for the association between relative measures of the food environment  
 594 and high fast-food or sugar-sweetened beverage intake in the ORiEL study (n=3089)  
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	Home		School		Home and school combined	
	Unadjusted RR (95% CI)	Adjusted <sup>1</sup> RR (95% CI)	Unadjusted RR (95% CI)	Adjusted <sup>1</sup> RR (95% CI)	Unadjusted RR (95% CI)	Adjusted <sup>1</sup> RR (95% CI)
<b>Exposure : proportion of fast-food restaurants</b>						
Eating fast-food $\geq$ 2-3 days/week <sup>2</sup>						
At home	<b>1.88 (1.03, 3.43)</b>	1.76 (0.96, 3.23)	<b>0.41 (0.22, 0.78)</b>	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)	<b>0.48 (0.29, 0.80)</b>	0.65 (0.38, 1.10)	1.20 (0.58, 2.48)	1.41 (0.66, 3.01)
<b>Exposure: proportion of convenience stores</b>						
Drinking SSBs $\geq$ once/day <sup>3</sup>	<b>1.49 (1.10, 2.01)</b>	<b>1.45 (1.08, 1.96)</b>	1.19 (0.98, 1.45)	1.18 (0.98, 1.44)	<b>1.62 (1.07, 2.47)</b>	<b>1.69 (1.11, 2.57)</b>

596 CI, confidence interval; RR, risk ratio

597 <sup>1</sup> Models are adjusted for age (continuous), sex (female/male), ethnicity (White/ Black/South Asian/Other), and free school meals  
 598 (yes/no).

599 <sup>2</sup> Reference category is “one day/week or less”.

600 <sup>3</sup> Reference category is “less than once/day”.

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

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Appendix 1: Descriptive statistics for the ORiEL sample <sup>1</sup>

<b>Characteristic</b>		<b>% missing</b>
<b>Age in years, mean (SD)</b>	14.1 (0.32)	0
<b>Female, %</b>	43.3	0
<b>Ethnicity, %</b>		0.9
White UK	16.9	
South Asian	22.9	
Black	22.7	
Other	37.6	
<b>Have free school meals, %</b>	33.2	2.3
<b>Fast-food intake, %</b>		
≥ 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
<b>Sugar-sweetened beverage intake <sup>2</sup>, %</b>		
Once/day or more	46.9	17.0
<b>School borough, %</b>		0
Tower Hamlets	25.6	
Hackney	24.0	
Barking and Dagenham	19.9	
Newham	30.5	
<b>Relative income deprivation in residential neighbourhood, %</b>		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	

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SD, standard deviation

<sup>1</sup> Descriptive statistics are based on complete cases for each variable.

<sup>2</sup> Sugar-sweetened beverage intake approximated with intake of fizzy drinks.

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Appendix 2: Food environment characteristics and % missing for the ORiEL sample <sup>1</sup>

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

611 IQR, Interquartile range

612 <sup>1</sup> Descriptive statistics are based on complete cases for each variable.

613 <sup>2</sup> Absolute availability is the number of fast-food restaurants or convenience stores in a  
 614 given buffer.

615 <sup>3</sup> 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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622

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630 **Conflict of Interest**

631 None.

632

633 **Authorship**

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

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640 **Ethical Standards Disclosure**

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

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