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Does the neighborhood food environment contribute to ethnic inequalities in fast-food intake? findings from the ORiEL study

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ABSTRACT

The neighborhood food environment may contribute to ethnic inequalities in diet. Using data from 1389 participants in the Olympic Regeneration in East London (UK) study we assessed whether ethnic inequalities in neighborhood availability of fast-food restaurants mediated and/or modified ethnic inequalities in fast-food intake in 13–15 year-old adolescents. We compared the proportion of high fast-food consumers across “White UK”, “Black”, and “South Asian” ethnic categories. We used Poisson regression with robust standard errors to assess direct and indirect effects (mediation analysis) and risk ratios of high fast-food intake by ethnic category and fast-food restaurant availability level (effect measure modification analysis). There were ethnic inequalities in high fast-food intake, with risk ratios in adolescents of Black and South Asian background of 1.53 (95% CI: 1.25, 1.87) and 1.71 (95% CI: 1.41, 2.07) respectively compared to White UK participants. We found no evidence of a mediating effect by fast-food restaurant availability, but found some evidence of effect measure modification: ethnic inequalities in fast-food intake were largest in neighborhoods lacking fast-food restaurants, and narrowed as availability increased. Future research should explore why ethnic minorities are more likely to be high fast-food consumers than the majority ethnic group, especially when fast-food restaurant availability is lowest.

1. Introduction

Fast-food, which is characterized by its relative affordability, large portion sizes, and high salt, fat and sugar contents, is a marker of poor dietary quality (Northstone et al., 2014). In a 36-country study 51.4% of adolescents reported consuming fast-food at least once per week (Braithwaite et al., 2014). Ethnic inequalities in diet-related health outcomes in young people have been found for overweight (Taylor et al., 2005; Harding et al., 2008; Zilanawala et al., 2015), obesity (Taylor et al., 2005; Harding et al., 2008; Zilanawala et al., 2015; Saxena et al., 2004), and Type 2 diabetes precursors such as insulin resistance (Whincup et al., 2010), but evidence for inequalities in underlying dietary behaviours is equivocal (Chowbey and Harrop, 2016). In three studies of UK youth, South Asian children were reported to have healthier diets than the average population (Leung and Stanner, 2011), another suggested that Bangladeshi children consumed fewer fruit and vegetables than their White counterparts (Zilanawala et al.,

2015), and another found no ethnic differences in fulfilling the five-a-day fruit and vegetables recommendation (Harding et al., 2008). Whether ethnic minority youth are at an advantage or disadvantage compared to the majority group may depend on the ethnic minority and dietary behaviour of interest.

Evidence regarding ethnic inequalities in diet among adolescents is scarce, even though adolescence is a critical period of change during which behaviours such as fast-food intake tend to increase, peaking between ages 19 and 29 (Adams et al., 2015). The retail food environment defined as ‘the number, type, location, and accessibility of food outlets such as grocery stores, convenience stores, fast food restaurants, and full-service restaurants’ (Glanz, 2009) has been related to dietary intake (Caspi et al., 2012; Engler-Stringer et al., 2014; Shareck et al., 2018), and may be one potential contributor to ethnic inequalities in diet (Public Health England, 2014; Public Health England, 2017). Two pathways have been suggested: (a) differential exposure and (b) differential vulnerability (Diderichsen et al., 2001). The former

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suggests that ethnic inequalities in diet result from the unequal distribution of resources across groups: ethnic minorities may live in areas with fewer healthy eating options compared to the majority group (Hilmers et al., 2012; Black et al., 2014). A “differential vulnerability” mechanism entails a differential effect of the neighborhood food environment on diet across ethnic groups: for similar levels of exposure to the food environment, minority groups would have higher unhealthy food intakes than the majority group. This vulnerability may chiefly stem from the social, economic or cultural characteristics associated with each ethnic group, and is unlikely to be related to biological or genetic factors (Diderichsen et al., 2018).

The objectives of this paper were to: (1) describe ethnic differences in high fast-food intake in a sample of adolescents from East London, UK; (2) assess if neighborhood availability of fast-food restaurants mediated the association between ethnicity and fast-food intake (differential exposure mechanism); and (3) assess if neighborhood availability of fast-food restaurants modified the association between ethnicity and fast-food intake (differential vulnerability mechanism).

2. Methods

2.1. Data sources

We analysed cross-sectional data from the third wave of the Olympic Regeneration in East London (ORIEL) study, a prospective cohort study aimed at assessing the impact of urban regeneration following the London 2012 Olympic and Paralympic Games on the health of young people and their families. Participants were recruited from 25 State secondary schools in four London boroughs: Tower Hamlets, Hackney, Barking and Dagenham, and Newham. These boroughs approximately cover a combined area of 111 km² and have a population of 1.1 million residents (Key Statistics 101 UK Usual Resident Population, Local Authorities in the United Kingdom, 2015). They are characterized by higher levels of social, economic and environmental disadvantage than the England and London averages, and are highly ethnically diverse with around two thirds of residents self-identifying with an ethnic minority group according to the 2011 Census (Smith et al., 2012).

3089 year 9 pupils provided socio-demographic and health information in a questionnaire self-completed during school hours under researcher supervision. 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. Data collection for wave 3 ran from January–July 2014. Full details on study procedures are described elsewhere (Smith et al., 2012).

2.2. Measures

2.2.1. Ethnicity

Ethnicity was assessed by asking participants: “Which one category best describes you? – This is your race or ethnic group?”, with 24 responses to choose from (Appendix A). We restricted the analysis to the three largest non-mixed ethnic groups – “White UK”, “Black” (Black: Caribbean, African, Somali, and British) and “South Asian” (Bangladeshi, Pakistani, and Indian) – as done elsewhere (Whincup et al., 2010).

2.2.2. Fast-food intake

Weekly frequency of fast-food intake was based on the combined answers to two questions adapted from the HABITS study (Wardle et al., 1998): “How often do you eat takeaways or fast-food at home? (e.g. Pizza Hut, Burger King, Subway, McDonald’s, Perfect Fried Chicken)” and “How often do you eat takeaways or fast-food away from home?”

(e.g. Pizza Hut, Burger King, Subway, McDonald’s, Perfect Fried Chicken)”, with five response options provided: “never or rarely”, “less than one day a week”, “2–3 days a week”, “4–6 days a week”, and “everyday”. Used elsewhere (Wardle et al., 1998; Timperio et al., 2009; Pereira et al., 2005), these questions had good internal reliability when compared with young adults’ diet history questionnaires (Pereira et al., 2005). Following results from a 15-year longitudinal study in which visiting fast-food restaurants more than twice a week was associated with weight gain and insulin resistance among young people (Pereira et al., 2005), we dichotomized fast-food intake as 2 days per week or more (high) vs. less than 1 day per week (low) (Shareck et al., 2018; Pereira et al., 2005; Cutumisu et al., 2017).

2.2.3. Fast-food availability

We extracted food businesses data (name, address and retailer type) from local authority registers for the same time period as the individual-level data were collected. The UK Food Standards Agency requires that all food businesses register with their local environmental health authority 28 days before opening and inform them of any changes in status (Lake et al., 2010). Food establishments were classified using mutually exclusive categories: chain supermarkets; independent supermarkets; discount retailers; ethnic-specific supermarkets; franchise stores (e.g. Spar, CostCutter); convenience stores A (mini-markets); convenience stores B (newsagent, tobacconist or confectioner); butchers and fishmongers; fruit and vegetable shops; other specialist food stores; bakeries; full-service restaurants; coffee shops; independent fast-food restaurants; and chain fast-food restaurants. Our measure of fast-food restaurants encompassed both independent and chain fast-food restaurants which we defined as offering food and drinks in a self-service manner to eat in, or by collection or delivery to take away. In a validation study, food services data (including fast-food restaurant locations) showed a high positive predictive value (PPV = 0.96, 95% CI: 0.94–0.98) when compared to contemporary street photography from Google and Bing search engines (unpublished data).

Food business and participants’ residential addresses were geocoded by matching reported addresses with authoritative address location data provided by the Ordnance Survey AddressLayer 2 database (Ordnance Survey Great Britain, 2011). We computed the relative availability of fast-food restaurants within 400-meter road-network buffers centered on participants’ residential address by dividing the number of fast-food restaurants within each buffer by the number of all types of food establishments combined (values ranging from 0 to 100%). A distance of 400 m represents an approximate 5-minute walk and has been used to study environmental correlates of dietary behaviours (Ghosh Roy et al., 2019) and guide policy (Foster, 2011; Lim, 2018). The relative availability of fast-food restaurants is an indicator of the degree to which an area is saturated with fast-food outlets and has been found to more strongly relate to dietary behaviors than the absolute number of fast-food restaurants (Shareck et al., 2018; Clary et al., 2015; Mason et al., 2013). Since a non-linear relationship might be expected, relative fast-food availability was categorised into tertiles based on the approximate analytical sample distribution: 0 (no availability), 3.7–29.6% (medium), and 30.0–100% (high availability).

2.2.4. Covariates

Covariates which reflect participants’ demographic and socio-economic characteristics, i.e., age (in years, continuous), sex (male/female), and living in a lone-parent family (yes/no), and the fact that acquiring knowledge of one’s neighborhood and the resources it provides may take time (Golledge et al., 1985), i.e., having lived in the neighborhood for five years or less (yes/no), were included in the models.

2.3. Statistical analyses

Out of 3089 participants, 1912 (61.9%) reported being from either White UK, Black or South Asian ethnic background and were considered

for inclusion in the analyses. Of these, 523 (27.4%) had missing data on at least one variable of interest (fast-food intake ($n = 344$, 18.0%), neighborhood fast-food restaurant availability ($n = 225$, 11.8%), living in a lone-parent family ($n = 25$, 1.3%), and time lived in the neighborhood ($n = 90$, 4.7%)). Missingness patterns assessment did not justify multiple imputation so a complete case analysis was performed on an analytical sample of 1389 respondents (White et al., 2011). Included and excluded participants were similar with regards to age, fast-food intake and neighborhood fast-food restaurant availability, but male participants, those of Black ethnic background, who lived in a lone-parent family or in the neighborhood for five years or less were under-represented in the analytical sample ($P < 0.05$) (data not shown).

Univariate and bivariate statistics were used to describe the data. Ethnic inequalities in fast-food intake and in neighborhood availability of fast-food restaurants were respectively assessed by modelling the association between ethnicity and fast-food intake using Poisson regression models, and between ethnicity and fast-food restaurant availability using ordinal logistic regression, before and after adjusting for covariates.

To assess the differential exposure pathway, we conducted a causal mediation analysis, decomposing the total effect (TE) of ethnicity on fast-food intake into a natural indirect effect (NIE) (through neighborhood fast-food availability) and a controlled direct effect (CDE) (through other, unexplained mechanisms). We let X be the exposure (ethnicity), M the potential mediator (neighborhood fast-food availability), and Y the outcome (fast-food intake). C represents the set of potential confounders of the ethnicity—fast-food intake association listed above. We used the causal mediation approach (2-way decomposition) using a counterfactual framework adapted for health inequalities research (Nandi et al., 2017). Here, TE represents the amplitude of ethnic inequalities in fast-food intake. The CDE represents the effect of ethnicity on fast-food intake, after hypothetically intervening to fix the level of neighborhood fast-food availability to a baseline value (here: no availability). The NIE represents the change in fast-food intake when ethnicity is held constant ($X = x$) and neighborhood fast-food availability changes (from no to medium or from medium to high availability) to what it would have been for a change in the other ethnic category ($X = x^*$). When interpreting TEs, NIEs and CDEs we are assuming that there is no unmeasured confounding or mediator-outcome confounder affected by the exposure.

We estimated risk ratios (RR) for the NIEs and CDEs using the generalized product method (VanderWeele, 2015) by fitting two consecutive models, respectively the outcome model and the mediator model. The outcome model is written as: $E(Y|X, M, C_{XY}) = \exp(\beta_0 + \beta_1 X + \beta_2 M + \beta_3 C)$ and the mediator model is written as: $E(M|X, C_{MY}) = \exp(\alpha_0 + \alpha_1 X + \alpha_3 C)$. In this method, $\exp(\beta_1)$ represents the RR_{CDE} of X on Y . The RR_{NIE} is the product of $\exp(\beta_1)$ and $\exp(\alpha_1)$. The RR_{TE} is the product of the RR_{CDE} and RR_{NIE} (as we are using multiplicative models). TEs, CDEs, and NIEs and their 95% confidence intervals (CI) were computed using bootstrapping procedures with 1000 replications. Models were built separately for Black and South Asian participants compared to White UK participants.

To explore the differential vulnerability pathway, we assessed effect measure modification of the ethnicity—fast-food intake association by the level of fast-food restaurant availability on the additive and multiplicative scales (Knol and VanderWeele, 2012). Risk ratios and 95% confidence intervals for high fast-food intake for each combination of ethnicity and fast-food restaurant availability level were computed compared to a single reference category: White UK participants living in neighborhoods characterized by the lowest availability level. The relative excess risk due to interaction (RERI) was calculated as an indicator of interaction on the additive scale using the formula: $RERI = RR_{11} - RR_{10} - RR_{01} + 1$, where RRs are risk ratios for Black or South Asian participants living in high (or medium) fast-food availability neighborhoods (RR_{11}), for those living in no availability neighborhoods (RR_{10}), and for White UK participants living in high (or medium) availability neighborhoods (RR_{01}) compared to the reference category. We computed RERI, 95% CIs and P -values using the Delta method (Hosmer and Lemeshow, 1992). RERI values above 0

indicate an additive effect modification and below 0, a sub-additive effect modification. A sub-additive effect measure modification would mean that if we were to intervene on the fast-food environment, those with ethnicity = 0 (White UK) would benefit more than participants of Black or South Asian background. To examine effect measure modification on the multiplicative scale, we included an interaction term between ethnicity and fast-food availability level in a fully adjusted model. We calculated stratum-specific risk ratios and obtained measures of effect modification and their 95% CIs based on the model. Since results of analyses on spatially-aggregated data may differ based on the spatial scale used to measure exposure (Openshaw, 1984), we performed sensitivity analyses using data aggregated within 600- and 800-meter road-network buffers following the same procedure as for the 400-meter buffers. All models were fitted using Poisson regression models with robust standard errors to account for the high prevalence of the outcome (McNutt et al., 2003).

3. Results

3.1. Sample description

Participants were on average 14.1 years-old ($SD = 0.32$) and 46.1% were female (Table 1). 33.0% of participants self-reported being of Black background and 39.0% of South Asian background. A little less than one third of participants lived in a lone-parent family (30.2%) and had lived in their neighborhood for fewer than five years (31.7%). While 37.3% consumed fast-food at least twice per week, this proportion varied by ethnicity, with the prevalence of high fast-food consumers increasing from 19.3% among White UK respondents to 34.8% among Black participants and 46.0% among South Asian participants. Differences between ethnic categories ($P < 0.05$) were also observed for sex, living in a lone-parent family, having lived in the neighborhood for five years or less, and neighborhood fast-food availability. A greater proportion of White participants had no fast-food restaurants in their neighborhood while Black and South Asian participants were over-represented in medium availability neighborhoods. A lower proportion of Black participants lived in high availability neighborhoods.

3.2. Ethnic inequalities in fast-food intake and in neighborhood fast-food restaurant availability

Table 2 shows the associations between fast-food intake and being of Black or South Asian background compared to White UK. Model 2 suggests that, had we set the distribution of covariates for Black or South Asian participants to that of White UK participants, the prevalence of high fast-food intake among Black and South Asian participants would be 1.50 (95% CI: 1.22, 1.85) and 1.74 (95% CI: 1.43, 2.12) times that among their White UK counterparts. Compared to White UK respondents, South Asian participants were more likely to live in medium or high availability neighborhoods (proportional odds ratio of 1.32 (95% CI: 1.02, 1.71), while the association for Black participants trended towards the null (proportional odds ratio of 1.05 (95% CI: 0.81, 1.36) (data not shown).

3.3. Assessing the differential exposure pathway

There was no evidence that inequalities in fast-food intake between Black or South Asian participants and White UK respondents were mediated by neighborhood fast-food availability, with natural indirect effects of 1.00 (95% CI: 0.99, 1.01) for Black vs. White UK and 1.01 (95% CI: 0.99, 1.02) for South Asian vs. White UK inequalities (Table 3). Results were robust across geographical scales (data not shown).

3.4. Assessing the differential vulnerability pathway

We tested whether neighborhood fast-food availability modified the association between ethnicity and fast-food intake on the additive scale

Table 1
Characteristics of 1389 Respondents From the ORIEL Study, London, UK, 2014

Individual-level characteristics	All participants n = 1389	White UK n = 389 (28.0%)	Black n = 458 (33.0%)	South Asian n = 542 (39.0%)
Mean age, years (SD)	14.1 (0.32)	14.1 (0.32)	14.1 (0.33)	14.1 (0.31)
Female, %	46.1	48.8	49.1	41.5
Living in a lone-parent family, %	30.2	35.7	41.5	16.6
Living in neighborhood ≤5 yrs, %	31.7	22.4	39.3	31.9
Fast-food intake ≥2–3 days/week, %	37.3	19.3	34.8	46.0
<i>Neighborhood-level characteristics</i>				
Relative availability of fast-food restaurants ^a				
No availability (0) ^b	32.8	38.8	33.0	28.4
Medium (3.7–29.6%)	33.6	26.5	38.0	35.1
High availability (30.0–100%)	33.6	34.7	29.0	36.5

n, sample size.

^a The relative availability of fast-food restaurants is the proportion of all food establishments within 400-m from participants' residential address that are fast-food restaurants.

^b Out of 456 participants, 239 had not fast-food restaurant and 217 had not food establishment of any type within 400 m of their home.

^c A 3.7% relative availability is exemplified by someone having 1 fast-food restaurant and 27 food stores of all types combined in their neighborhood.

Table 2
Risk Ratios (RR) and 95% Confidence Intervals (CI) for the Association Between Ethnicity and High Fast-Food Intake in 1389 Respondents From the ORIEL Study, London, UK, 2014.

Ethnic inequality ^a	Model 1	Model 2
	RR (95% CI)	RR (95% CI)
Black vs. White UK	1.53 (1.25, 1.87)	1.50 (1.22, 1.85)
South Asian vs. White UK	1.71 (1.41, 2.07)	1.74 (1.43, 2.12)

CI, confidence interval; RR, risk ratio.

Model 1 includes ethnic background and fast-food intake.

Model 2 further includes the covariates age (cont.), sex (male/female), lone-parent family (yes/no), and having lived in the neighborhood for ≤5 years (yes/no).

^a White UK ethnic background is the reference group.

(Table 4) and multiplicative scale (Appendix B). Table 4 shows risk ratios and 95% confidence intervals for high fast-food intake for combinations of ethnicity and neighborhood fast-food availability level compared to a single reference category: White UK participants with no fast-food restaurants in their neighborhood. High fast-food intake was more prevalent among Black and South Asian participants living in each of the fast-food availability levels compared to the reference category. Among each minority ethnic category, risk ratios for high fast-food intake followed an inverse gradient: they increased as neighborhood availability decreased. Measures of effect modification on the additive scale (RERI) suggested some indication of sub-additive interaction although confidence intervals were wide, especially for medium availability neighborhoods, with RERI (95% CI; *P*-value) of -0.40 (95% CI: $-1.25, 0.46$); *P*-value = 0.361) and -1.13 (95% CI: $-2.12, -0.13$; *P*-value = 0.026) for Black participants living in medium and high fast-food availability neighborhoods respectively, and -0.42 (95% CI: $-1.27, 0.42$; *P*-value = 0.326) and -1.05 (95% CI: $-2.02, -0.09$; *P*-value = 0.032) for South Asian participants living in medium and high availability neighborhoods respectively, compared to White UK participants. In sensitivity analyses, risk ratios for fast-food

Table 3
Risk Ratios (RR) and 95% Confidence Intervals (CI) for the Total and Controlled Direct Effects of Ethnicity on High Fast-Food Intake, and Natural Indirect Effect via Neighborhood Fast-Food Availability, ORIEL Study, London, UK, 2012.

	Total effect (TE) RR (95% CI)	Controlled direct effect (CDE) RR (95% CI)	Natural indirect effect (NIE) RR (95% CI)
Black vs. White UK	1.50 (1.22, 1.85)	1.50 (1.23, 1.84)	1.00 (0.99, 1.01)
South Asian vs. White UK	1.74 (1.43, 2.12)	1.73 (1.46, 2.12)	1.01 (0.99, 1.02)

CI, confidence interval; RR, risk ratio.

availability measured within 600- and 800-m buffers were slightly lower, while measures of effect modification were slightly stronger, than those presented here (data not shown).

4. Discussion

In this study, the extent of ethnic inequalities in fast-food intake was similar to that reported for other dietary behaviours such as fizzy drinks intake in UK children (Harding et al., 2008; Leung and Stanner, 2011) and adults (Leung and Stanner, 2011). When testing two pathways through which the neighborhood food environment may contribute to inequalities in fast-food intake, our findings did not support the differential exposure pathway (mediation analysis), but we found some evidence supporting a differential vulnerability pathway (effect modification analysis): ethnic inequalities in fast-food intake were most pronounced in neighborhoods where there were no fast-food restaurants, and narrowed as fast-food availability increased.

Though there is limited work on this specific topic, results from the mediation analysis are similar to those from a US study which found that ethnic inequalities in dietary quality was not due to inequalities in highly processed food purchasing (which could be a proxy for food environment exposure) (Poti et al., 2016). In contrast with two studies that found educational (Burgoine et al., 2014) and racial (Dunn et al., 2012) inequalities in diet among adults to be largest in high fast-food availability or proximity neighborhoods, we found ethnic inequalities in diet to be amplified in lower availability neighborhoods whereas in areas of higher fast-food availability, there seemed to be an equalisation of risk between the White UK majority and minority ethnic groups.

A number of plausible explanations may support this differential vulnerability pathway. The majority group might have a higher threshold tolerance for exposure to fast-food restaurants, which would explain why their risk of high consumption only reaches that of minority groups in high availability neighbourhoods. Processes related to price, convenience, or culturally-specific advertising may prompt greater consumption of fast-food by some ethnic sub-populations than others (Dunn et al., 2012), and make minority groups especially

Table 4
Effect Measure Modification on the Additive Scale of the Ethnicity-Fast-Food Intake Association by Relative Availability of Fast-Food Restaurants in the Neighborhood, ORiEL Study, London, UK, 2014.

Relative availability of fast-food restaurants	White UK		Black		South Asian		RERI (95% CI)	RR (95% CI)	RERI (95% CI)
	n with/without outcome	RR (95% CI)	n with/without outcome	RR (95% CI)	n with/without outcome	RR (95% CI)			
No availability	29/122	Reference	65/86	2.14 (1.47, 3.11)	72/82	2.42 (1.68, 3.50)			
Medium	25/78	1.23 (0.77, 1.98)	67/107	2.00 (1.37, 2.91)	83/107	2.24 (1.55, 3.23)	-0.40 (-1.25, 0.46)	2.24 (1.55, 3.23)	-0.42 (-1.27, 0.42)
High availability	46/89	1.81 (1.21, 2.71)	48/85	1.83 (1.23, 2.71)	83/115	2.18 (1.51, 3.15)	P = 0.361		P = 0.326
							P = 0.026		P = 0.032

CI, confidence interval; n, sample size; RERI, relative excess risk due to interaction; RR, risk ratio. RRs are adjusted for age (cont.), sex (male/female), lone parent family (yes/no), and living in the neighborhood for ≤5 years (yes/no).

vulnerable to high fast-food intake in lower availability settings (Janssen et al., 2018). For instance, ethnic inequalities in intake may reflect inequalities in different groups' socio-economic resources (Zilanawala et al., 2015; Corlett, 2017). Fast-food intake has been found to be higher among groups of lower income, education, or occupational class (Adams et al., 2015; Janssen et al., 2018), and ethnic differentials in socio-economic resources are widely documented (Corlett, 2017). Given the affordability of fast-food, these inequalities in socio-economic circumstances could explain why, even when fast-food restaurants are not available, ethnic minorities would consume more of it. Ethnic minorities may also rely more on the fast-food environment if it accommodates their social and cultural preferences (Rawlins et al., 2013). In a subsample of ORiEL, adolescents reported feeling a strong social attachment to "chicken shops", which are ubiquitous in East London, less expensive than other fast-food restaurants, often run by local residents, and seen as meeting places that contribute to the neighborhood identity and local economy (Thompson et al., 2018). Even in the relative absence of fast-food restaurants within 400 m of their home, ethnic minorities might therefore seek them out for they serve a social purpose in addition to a dietary one.

Factors other than the food environment *per se*, such as ethnic differences in family-level characteristics like nutritional knowledge and food literacy (Janssen et al., 2018; Patel et al., 2017), cooking skills (Patel et al., 2017) and time available for cooking at home (Lawrence et al., 2007), may also help interpret our findings, since they have been found to influence food choices (Lawrence et al., 2007) and to contribute to ethnic differentials in overweight and obesity (Zilanawala et al., 2015). Finally, a methodological explanation cannot be ruled out whereby residential neighborhoods spanning 400 m may not be the appropriate scale at which the fast-food environment impacts ethnic inequalities in diet. However, sensitivity analyses yielded similar findings, therefore this explanation in itself is insufficient.

Together our results suggest that reducing the proportion of fast-food restaurants in residential areas may benefit all ethnic groups to some extent, but that the White UK majority group, who is already advantaged, may benefit more than ethnic minorities. Such an intervention thus risks increasing ethnic inequalities in fast-food intake, so if the aim is to reduce *intake inequalities* rather than reduce *intake overall*, intervening in lower availability neighborhoods by targeting individuals' capabilities and social circumstances may be more promising (Diderichsen et al., 2018).

Strengths of our study include its large, ethnically diverse sample, comprehensive assessment of the fast-food environment using valid and complete data sources, and the geocoding precision of participants' residential addresses. While the socio-demographic characteristics of participants were broadly similar to those of a sample of similar ages based on the 2011 Census (Smith et al., 2015), exclusions due to missing data and the overall higher social disadvantage of our study locale may have reduced generalizability of our findings. Fast-food intake was self-reported, potentially leading to measurement error due to recall or social desirability biases. We only measured one dimension of the neighborhood fast-food environment although aspects such as restaurant proximity from home, the adequacy of offerings relative to patrons' preferences, cultural practices, or socio-economic capacity (Rawlins et al., 2013), and neighborhood-level social norms surrounding diet (Thompson et al., 2018) might also be important. By focusing on the residential environment, we neglected other settings where fast-food can be purchased (Burgoine et al., 2017) such as adolescents' school (Shareck et al., 2018) or parents' workplace neighborhoods (Burgoine et al., 2014). We also did not have data on who was responsible for food purchasing, but our decision to analyze wave 3 ORiEL data was driven by the assumption that participants would be more independent than at baseline and more likely, at least in part, to be responsible for their own fast-food purchases. Finally, for statistical power considerations we combined ethnic sub-groups into "Black" and "South Asian" categories (Whincup et al., 2010; Wardle et al., 2006),

overlooking the fact that ethnic background involves a complex set of characteristics including heritage, language, and religious beliefs (Patel et al., 2017), and that different sub-groups may have different levels of acculturation to the UK food culture (Leung and Stanner, 2011) and food practices (Harding et al., 2008; Leung and Stanner, 2011). Larger studies exploring sub-group differences in the ethnicity-fast-food intake relationships are warranted.

5. Conclusion

This study adds to the limited body of evidence on the contribution of the neighborhood food environment to ethnic inequalities in diet, as most studies have focused on describing inequalities in diet and related outcomes (Harding et al., 2008; Dunn et al., 2012) rather than assessing the mechanisms potentially explaining them (Zilanawala et al., 2015). Given that adolescence is a critical period for promoting healthy behaviors, addressing the high prevalence of, and ethnic inequalities in, fast-food intake in adolescents is required. Future research should focus on the wider social circumstances influencing fast-food intake among youth, along with explorations of complementary dimensions of the fast-food environment.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.pmedr.2019.100998>.

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