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Article

To what extent do unhealthy behaviour indicators explain the neighbourhood deprivation gradient in overweight among 11-year-old English children?

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A B S T R A C T

Aims: This study examined associations between neighbourhood deprivation, school commuting behaviour, a range of unhealthy behaviour indicators and overweight/obesity among 11-year-old English children.

Methods: Data are from wave five of the UK Millennium Cohort Study, collected in 2012. Subjects consisted of 7262 (3637 boys) 11-year-old English children. Children were classified as normal weight or overweight/obese. School commute mode (active/passive) and health behaviour indicators were parent-reported. Health behaviour indicator scores below the mean of the lower half of the distribution were classified as unhealthy on this indicator. Neighbourhood deprivation was defined using the 2004 English Indices of Multiple Deprivation. Odds ratios (ORs) for being overweight/obese according to neighbourhood deprivation were estimated. A range of unhealthy behaviour indicators were explored to assess the extent to which they attenuated associations between neighbourhood deprivation and overweight/obesity.

Results: Children living in the most deprived neighbourhoods in England were more likely to be overweight/obese, commute to and from school actively and participate in all unhealthy behaviour indicators compared to children living in the least deprived neighbourhoods. Adjusting for confounders and significant unhealthy behaviour indicators reduced the OR for overweight/obese from 1.81 (95% CI 1.54 to 2.13) to 1.56 (95% CI 1.30 to 1.88) in the highest neighbourhood deprivation group compared to the lowest.

Conclusion: Active school commuting alone is unlikely to be enough to prevent and reduce the prevalence of overweight/obesity in the most deprived English neighbourhoods. Childhood overweight/obesity-related interventions should focus on promoting participation in a range of health behaviours.

Background

Childhood overweight/obesity rates have increased 10-fold in the past 40 years (NCD Risk Factor Collaboration (NCD-RisC), 2017). There is now a steep social gradient to childhood overweight/obesity in England, such that the burden of overweight/obesity falls disproportionately on children living in the most deprived neighbourhoods (Noonan & Fairclough, 2018). Recent evidence shows that these social inequalities in overweight/obesity risk are widening (Noonan, 2018a).

The UK Government recently committed to setting a target to increase the number of children walking to school in the Childhood Obesity Strategy (HM Government, 2016). While broader societal and public health objectives (i.e., reduced road accidents, less congestion and carbon emissions) can be achieved if more children actively commute to school (Dosanjh, 2011; Liu & Grigg, 2018), evidence to support the positive contribution of active school commuting to children's weight status is currently weak (Larouche et al., 2014). For example, research conducted in Liverpool, England found that children living in deprived neighbourhoods were most likely to actively commute to and from school and were at greatest risk of overweight/obesity (Noonan et al., 2017).

Inequalities in childhood overweight/obesity are likely related to limited participation in behaviours that support energy balance and high participation in behaviours that compromise energy balance [referred to as "unhealthy behaviour" herein]. For the purpose of this study, unhealthy behaviours range from an unhealthy diet (e.g., high sweetened beverage consumption and/or low fruit consumption) to spending excess time engaged in sedentary behaviour(s) (e.g., high television; TV and/or computer use), to limited participation in modes of physical activity (e.g., low sport participation and/or outdoor play) beyond walking/cycling to school (Foresight, 2007). Children living in the most deprived neighbourhoods are considered to be most susceptible to weight gain because their living environment is most conducive to unhealthy behaviour. Firstly, children living in the most deprived neighbourhoods are least likely to have the financial resources to support a balanced healthy diet (Jones, Tong, & Monsivais, 2017) and participate in the physical activities (Hardy et al., 2010) which are widely encouraged to support a healthy weight. Moreover, they are exposed to

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the least supportive social and built environments for physical activity (Noonan et al., 2016). For example, research shows that the most deprived neighbourhoods are perceived by parents as unsafe and have the least access to parks, playgrounds and recreational facilities for physical activity (Noonan et al., 2016). However, to date, no research has examined the extent to which a range of unhealthy behaviour indicators relating to physical activity, sedentary behaviour and diet serve as mechanisms between neighbourhood deprivation and childhood overweight/obesity. Therefore, to fill this research gap the present study used nationally representative data from the UK Millennium Cohort Study to examine associations between neighbourhood deprivation, school commuting behaviour, a range of unhealthy behaviour indicators and overweight/obesity among 11-year-old English children.

Methods

Participants

This study is a secondary analysis of data derived from wave five of the UK Millennium Cohort Study (MCS). The MCS is a nationally representative UK sample of children born between September 2000 and January 2002. The sample design allowed for over-representation of ethnic minority families and families living in high deprivation neighbourhoods. MCS1 was conducted between 2001 and 2002, and contained information on 18 819 children in 18 533 families, collected from parents/carers when children were 9–11 months old (Hansen, 2014). Subsequent surveys were administered at the ages of 3 (MCS2; 2003/04), 5 (MCS3; 2006), 7 (MCS4; 2008) and 11 years (MCS5; 2012). MCS5 successfully collected data on 13 403 children (51% of those eligible to participate in MCS1). During MCS5, child anthropometric measurements were taken and information on sociodemographic characteristics and health behaviours were collected from parents/carers and children. All measures were collected in the family home. Only English children whose parent/carer provided complete data for the variables of interest were included in the present analysis. The resulting study population comprised 7262 children (3637 boys). Ethical approval for MCS5 was granted by the Northern and Yorkshire Research Ethics Committee (Ref: 11/YH/0203).

Measures

Outcome variable: child overweight/obesity

Stature was measured to the nearest millimetre using a portable stadiometer (Leicester Height Measure, Seca, Birmingham, UK), and body mass measured to the nearest 0.1 kg using Tanita HD-305 scales (Tanita UK Ltd, Middlesex, UK). BMI was calculated from stature and body mass (kg m^{-2}). The International Obesity Taskforce age-specific and gender-specific BMI cut-points were used to classify children as normal weight or overweight/obese (Cole et al., 2000).

Exposure variable: neighbourhood deprivation

Neighbourhood deprivation was calculated from home postcodes using the 2004 English Indices of Multiple Deprivation (IMD; (Department for Communities and Local Government, 2005)). The IMD is a UK Government produced measure comprising seven areas of deprivation (income, employment, health, education, housing, environment and crime). Lower decile scores represented higher deprivation. Decile scores were collapsed into five categories, and a categorical variable was created to represent children living in the most deprived (deciles 1–2) to least deprived neighbourhoods in England (deciles 9–10).

Potential mediating variables

School commute behaviour. School commute mode was parent/carer reported. Commute mode to and from school was assessed using the following responses: public transport, school or local authority bus, car or other vehicle, bicycle, walk, and other. A categorical variable was created to represent active commute (walk and cycle) and passive commute (motorised responses and other).

Health behaviour indicators and "unhealthy" behaviour threshold. All health behaviour indicators were parent/carer reported. Physical activity participation was assessed using two items. Sport/exercise and non-club/class physical activity participation were each assessed on a 7-point Likert scale, ranging from not at all to $\geq$ five days per week. Sedentary behaviour was assessed using two items. The number of hours per weekday children watch television (TV) or videos on a computer and play on a computer or console game were each assessed on a 7-point Likert scale, ranging from none to $\geq$ 7 h. Dietary behaviour was assessed using two items. Sweetened beverage consumption was assessed on a 7-point Likert scale ranging from never to more than once per day, and daily fruit consumption was assessed on a 4-point Likert scale ranging from none to $\geq$ three pieces.

For the purpose of this study unhealthy behaviour indicators reflected low sport/exercise participation, low non-club/class physical activity participation, high TV/video use, high computer/console game use, high sweetened beverage consumption and/or low daily fruit consumption. An unhealthy level of behaviour for each health behaviour indicator was established by identifying children who recorded a significantly worse behaviour score relative to their peers. This was achieved by first calculating the median value for each health behaviour indicator (to identify the lower half of the distribution), and then calculating the mean value for the lower half of the distribution. Children who fell below this threshold reported worse health behaviour than an average respondent among the least well performing half of the sample. This method has been applied in previous large-scale epidemiological cohort studies (Chzhen et al., 2018).

Confounders

Potential confounding factors were selected a priori based on previous evidence (Dixon, Peña, & Taveras, 2012; Govindan et al., 2013; Noonan et al., 2016). Participant gender and ethnicity were parent/carer-reported. Ethnicity categories were based on census categories (Kelly, 2008) and included White, Mixed, Indian, Pakistani and Bangladeshi, Black or Black British, and Other Ethnic group. A categorical variable was created to represent White and non-White participants. Family income was assessed using weekly household income equalized according to the Organisation for Economic Co-operation and Development household equivalence scale. Poverty was defined as having an equalized household income below 60% of the UK median (Hansen, 2014). Perceived neighbourhood environmental characteristics relating to physical activity were assessed using two items. Children reported whether there are parks in the neighbourhood where children can play (yes/no) and rated the extent to which the neighbourhood is safe to walk, play or hang out in during the daytime. Responses ranged from not at all safe (1) to very safe (4). Responses were collapsed, and a categorical variable created to represent safe and unsafe neighbourhoods.

Statistical analyses

Consistent with mediation analysis guidance from Baron and Kenny (Baron & Kenny, 1986), unadjusted associations between neighbourhood deprivation (primary exposure) and overweight/obesity at age 11 (outcome measures) were explored. Unadjusted odds ratios (ORs) were first calculated using multivariate logistic regression to explore associations between neighbourhood deprivation categories and all potential confounders and mediators (i.e., school commuting behaviour and unhealthy behaviour indicators). Secondly, associations between all potential confounders and mediators and child overweight/obesity were

examined using logistic regression. In the final analyses, sequential models were fitted; calculating adjusted ORs using multivariate logistic regression for overweight/obesity on the basis of neighbourhood deprivation (with children living in the least deprived neighbourhoods as the reference group), adjusting first for confounders that were significantly associated with overweight/obesity at the $p < 0.1$ level in the univariate analyses, and then for all significant mediators. Mediation was deemed to have existed if the statistically significant ORs in the final model was attenuated or removed. Two sensitivity analyses were conducted, first repeating the analyses with poverty income as an alternative exposure measure of social disadvantage and secondly, using BMI as an outcome measure. All analyses were conducted using SPSS v. 25 (SPSS Inc.; Chicago, IL, USA).

Results

The prevalence of overweight/obesity at age 11 was 32.40% among children living in the most deprived neighbourhoods compared to 20.90% in the least deprived neighbourhood group. All the other covariates of interest, except for child sex and park access, varied significantly by neighbourhood deprivation (Table 1).

Associations of confounders and mediators with overweight/obesity at age 11

In the univariate regression analyses, higher neighbourhood deprivation, living in an unsafe neighbourhood, female sex, non-White ethnicity, income poverty, low sport/exercise participation, low non-club/class participation, high TV viewing, high sweetened beverage consumption, and low fruit consumption were all associated with an increased OR for overweight/obesity at age 11 (Table 2). Fig. 1 shows the unadjusted and fully adjusted covariate estimates. In the fully adjusted model, higher neighbourhood deprivation, female sex, non-White ethnicity, low non-club/class participation and high TV viewing were all significantly associated with an increase in OR for overweight/obesity at age 11.

Main analyses

Fig. 2 presents the ORs for neighbourhood deprivation and overweight/obesity at age 11 before and after adjustment for confounders and unhealthy behaviour indicators added sequentially. The OR decreased by 9.94% from 1.81 (95% CI 1.54 to 2.13) to 1.63 (95% CI 1.36 to 1.96) after adjusting for confounders, and by a further 4.29% after adjusting for high TV viewing (OR = 1.59 (95% CI 1.33 to 1.91)),

Table 2
Prevalence of overweight/obesity at age 11 and univariate odds ratios (ORs).

	Total ($n = 7262$) %	Overweight ($n = 1951$) %	OR	Lower CI	Upper CI
Neighbourhood deprivation					
Most deprived	25.30	32.40	1.81	1.54	2.13
Q4	19.50	27.90	1.46	1.23	1.74
Q3	18.90	27.00	1.40	1.17	1.67
Q2	17.30	23.90	1.18	0.99	1.42
Least deprived	19.00	20.90	–	–	–
Child sex					
Female	49.90	29.00	1.24	1.12	1.38
Male	50.10	24.70	–	–	–
Child ethnicity					
Non-white	23.90	32.30	1.42	1.27	1.60
White	76.10	25.10			
Living in income poverty					
Yes	25.70	30.60	1.28	1.14	1.44
No	74.30	25.60	–	–	–
Neighbourhood safety					
Unsafe	11.30	31.90	1.32	1.13	1.54
Safe	88.70	26.20	–	–	–
Park access					
No	11.40	29.10	1.14	0.97	1.33
Yes	88.60	26.60	–	–	–
Active commute to school					
Yes	54.30	27.70	1.10	0.99	1.22
No	45.70	25.80	–	–	–
Active commute from school					
Yes	56.30	27.30	1.06	0.95	1.18
No	43.70	26.20	–	–	–
Unhealthy behaviour indicators					
Low sport/exercise participation					
Yes	25.40	29.50	1.20	1.06	1.34
No	74.60	26.00	–	–	–
Low non-club/class participation					
Yes	21.90	32.00	1.38	1.22	1.56
No	78.10	25.40	–	–	–
High television viewing					
Yes	16.50	34.10	1.51	1.33	1.73
No	83.50	25.40	–	–	–
High computer use					
Yes	15.20	28.50	1.10	0.96	1.27
No	84.80	26.60	–	–	–
High sweetened beverage consumption					
Yes	14.40	29.80	1.19	1.03	1.37
No	85.60	26.40	–	–	–
Low fruit consumption					
Yes	6.30	30.50	1.21	0.99	1.49
No	93.70	26.60	–	–	–

Table 1
Characteristics of study population by neighbourhood deprivation (%).

Variable	All ($n = 7262$) %	Least deprived ($n = 1380$) %	Q2 ($n = 1257$) %	Q3 ($n = 1376$) %	Q4 ($n = 1414$) %	Most deprived ($n = 1835$) %	P Value[a]
Overweight/obesity at age 11	26.90	20.90	23.90	27.00	27.90	32.40	<0.001
Sex (Boy)	50.10	50.20	49.90	50.10	51.00	49.40	0.94
Ethnicity (White)	76.10	91.90	88.10	82.60	73.50	53.00	<0.001
Living in income poverty	25.70	2.80	8.80	16.60	29.60	58.40	<0.001
Active commute to school	54.30	51.10	47.10	50.40	55.80	63.50	<0.001
Active commute from school	56.30	52.90	48.30	53.40	57.90	65.30	<0.001
Unhealthy behaviour indicators							
Low sport/exercise participation	25.40	14.00	20.80	24.30	30.30	34.30	<0.001
Low non-club/class participation	21.90	17.30	17.70	20.00	25.90	26.60	<0.001
High television viewing	16.50	12.00	13.40	17.10	18.40	20.00	<0.001
High computer use	15.20	11.30	11.20	14.20	17.80	19.60	<0.001
High sweetened beverage consumption	14.40	9.50	11.90	12.60	15.40	20.20	<0.001
Low fruit consumption	6.30	3.50	4.90	6.10	7.40	8.60	<0.001
Perceived neighbourhood factors							
Unsafe neighbourhood	11.40	5.20	6.50	10.30	13.20	18.50	<0.001
Access to park	88.60	90.40	88.70	88.30	87.80	87.80	0.17

[a] $\chi 2$.

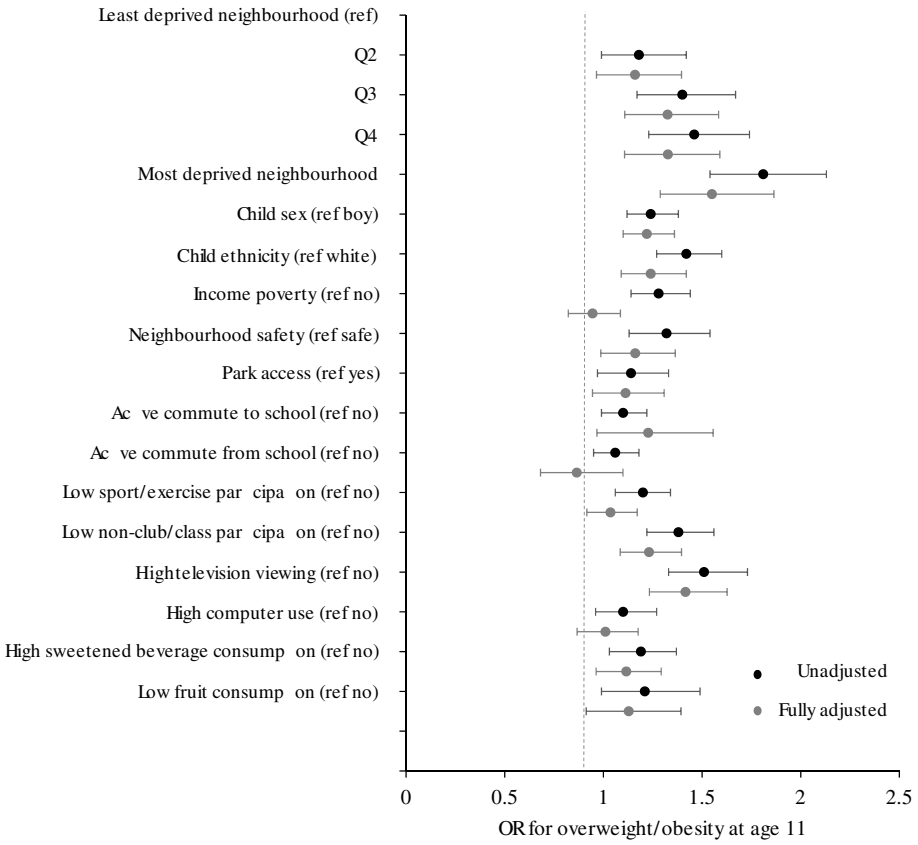

Fig. 1. Unadjusted and adjusted associations (odds ratio, OR) between covariates and overweight/obesity at age 11.

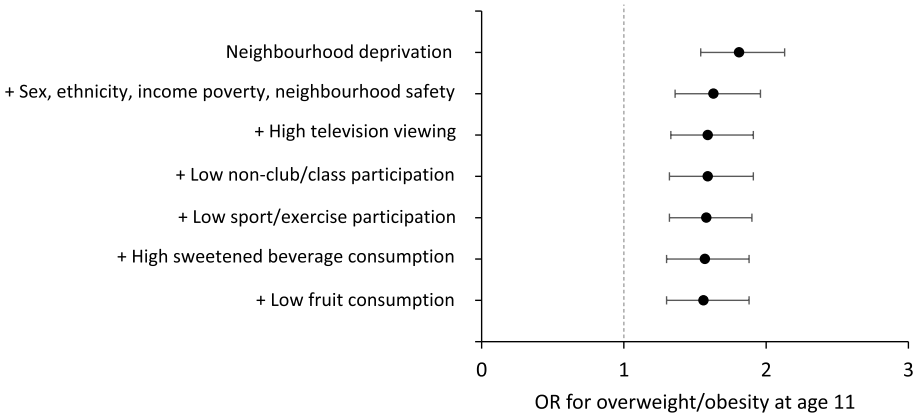

Fig. 2. Odds ratio (OR) for overweight/obesity comparing lowest neighbourhood deprivation group to highest in sequentially adjusted model.

low non-club/class participation (OR = 1.59 (95% CI 1.32 to 1.91)), low sport/exercise participation (OR = 1.58 (95% CI 1.32 to 1.90)), high sweetened beverage consumption (OR = 1.57 (95% CI 1.30 to 1.88)), and low fruit consumption (OR = 1.56 (95% CI 1.30 to 1.88)). The OR comparing the lowest to highest neighbourhood deprivation group remained significant in the final model (OR = 1.56 (95% CI 1.30 to 1.88)).

Discussion

The study revealed a steep neighbourhood deprivation gradient to overweight/obesity among 11-year-old children in England. Children living in the most deprived neighbourhoods in England were 1.81 times more likely to have overweight/obesity compared with children living in the least deprived neighbourhoods in England. This finding builds on prior research showing a steep neighbourhood deprivation gradient to overweight/obesity in England at age 7 (Noonan & Fairclough, 2018) and 14 years (Noonan, 2018b). Children living in the most deprived neighbourhoods in England were most likely to commute to and from school actively and were most likely to participate in all unhealthy behaviour indicators relating to sedentary behaviour, dietary behaviour and other modes of physical activity. Adjusting for significant unhealthy behaviour indicators reduced the OR for overweight/obesity in the most deprived group to 1.56, but relations remained significant. As such, the increased risk of overweight/obesity among age 11-year-old children living in deprived neighbourhoods in England is to some extent due to a combination of these unhealthy behaviour indicators but cannot be fully attributed to them.

A novel aspect of this study was the exploration of potential pathways linking neighbourhood deprivation and childhood overweight/obesity. Children living in the most deprived neighbourhoods in England were most likely to spend time engaged in screen-time behaviours (i.e., TV viewing and computer use) and least likely to participate in sport/exercise and non-club/class physical activity. There are a couple of potential explanations for these observed research findings. Firstly, consistent with local-level evidence from England (Noonan et al., 2016), children living in the most deprived neighbourhoods in England were most likely to report their neighbourhood as unsafe and having limited access to parks/green space. Children that perceive the neighbourhood environment as unsafe are potentially more likely to spend time indoors which may encourage them to spend an increased amount of time watching TV and playing computer games. These types of sedentary activities could have double negative effects on weight status, by first limiting energy expenditure, and secondly, through the increased exposure to unhealthy food marketing which is associated with higher unhealthy food intake and overweight/obesity (Boyland et al., 2011; Halford et al., 2008). Children living in the most deprived neighbourhoods in this study reported the greatest consumption of sweetened beverages and this could be one mechanism linking neighbourhood deprivation and childhood overweight/obesity.

Secondly, screen-based sedentary activities may be more appealing to children living in the most deprived neighbourhoods as they tend to have less opportunity to participate in more expensive leisure activities (i.e., sport/exercise) compared to their more affluent peers (Hardy et al., 2010). Indeed, relative to children living in the least deprived neighbourhoods, children living in the most deprived neighbourhoods were much more likely to experience income poverty (i.e., low-income household) and be categorised in the bottom-end of the sample for sport/exercise participation. Sport participation tends to be performed at the vigorous end of the intensity spectrum and is strongly associated with higher energy expenditure compared to unstructured low intensity activities such as walking to school (Butte et al., 2018). The present study findings suggest that broader intervention approaches are needed to address neighbourhood deprivation inequalities in the prevalence of sedentary behaviours, sport/exercise and non-club/class physical activity participation. Removing user charges from leisure facilities is an especially effective way to increase physical activity participation among disadvantaged socioeconomic groups (Higgerson et al., 2018). Local authority leisure centres across England once provided free and/or concessionary access to all children but this social support mechanism no longer exists in many parts of the country following recent budgetary cuts from central Government (Department for Communities Local Government, 2019). Local authorities across England should consider using their public health budgets to plug this funding gap, with a view to providing structured sustainable leisure opportunities for children living in deprived neighbourhoods.

The study revealed that most unhealthy behaviour indicators were positively associated to some extent with childhood overweight/obesity, but only high TV viewing and low non-club/class physical activity participation were positively associated with overweight/obesity independent of other unhealthy behaviour indicators. This finding further demonstrates the range of health behaviours that influence childhood overweight/obesity which extend beyond modes of physical activity including active school commuting. Some recent research has used computational data analysis approaches to examine the relative rather than the isolated effects of various movement behaviours (i.e., light and moderate-vigorous intensity physical activity (MVPA), sedentary behaviour, and sleep) on child weight status, and found that replacing MVPA with less vigorous movements results in higher risk of childhood overweight/obesity (Fairclough et al., 2017). Despite this growing body of evidence, there remains limited understanding as to whether some movement behaviours (i.e., physical activity) have a protective effect against unhealthy behaviours (i.e., unhealthy diet). Further research examining the concurrent effect of physical activity, sedentary behaviour, sleep and dietary behaviour on childhood weight status is warranted.

There are several strengths to this study. The sample size was large and the study covered the whole of England allowing for investigation of childhood health and health behaviour spanning the neighbourhood deprivation gradient. Perceived neighbourhood environmental factors relating to physical activity were measured alongside a range of health behaviour indicators, and analyses were adjusted for known confounding factors. There are a few study limitations to acknowledge. Parent/carer-reported health behaviour scores, and child-reported neighbourhood environmental scores could have been subject to measurement error and social desirability bias, and the physical activity indicators prohibited discussion of results in relation to public health physical activity guidelines. Furthermore, BMI was used as a measure of weight status which reflects fat and fat-free components of body mass (Sweeting, 2007) and may underestimate excess body fat mass (Javed et al., 2015). However, confidence can be taken from BMI being a relatively robust method at the population level and its widespread use by epidemiologists globally (NCD Risk Factor Collaboration (NCD-RisC), 2017). The study findings are based on data collected in 2012 and may underestimate present inequalities in childhood overweight/obesity in England given recent austerity programmes that have impacted on the poorest areas of the country most (UK Parliament, 2016). Moreover, the sedentary behaviour indicators in this study did not capture whether children engaged in concurrent sedentary behaviours (i.e., screen stacking) which may influence associations with child overweight/obesity. Moreover, it is possible that current youth may be watching more television programmes online using computers, tablet devices, and/or smartphones or tablets which the current study was unable to account for and thus high television use may have been underestimated here. Finally, the cross-sectional study design limits causality to be determined, and the study findings are generalisable only to children living in England. Despite these limitations, the study findings add to the growing body of evidence regarding behavioural mechanisms linking neighbourhood deprivation and childhood overweight/obesity.

Conclusion

Children living in the most deprived neighbourhoods in England were most likely to commute to and from school actively but were at greatest risk of overweight/obesity and all unhealthy behaviour indicators. Active school commuting alone is unlikely to be enough to prevent and reduce inequalities and prevalence of childhood overweight/obesity in deprived neighbourhoods. Intervention programmes to reduce inequalities in childhood obesity should promote and support participation in a range of health behaviours not just active school commuting. The clear demonstration of childhood health and health behaviour inequalities across England is very significant in the context of ongoing austerity and public health funding cuts which will undoubtedly challenge the health behaviour choices of the most socially disadvantaged children in society.

Funding

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Ethical approval

This study was a secondary analysis of publicly available data. Ethical approval for the original study was granted by the Northern and Yorkshire Research Ethics Committee (Ref: 11/YH/0203).

Declaration of competing interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2020.100541.

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