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Objective: It has been suggested that childhood obesity is inversely associated with deprivation, such that the prevalence is higher in more deprived groups. However, comparatively few studies actually use an area level measure of deprivation limiting the scope to assess trends in the association with obesity for this indicator. Furthermore, most assume a linear relationship. Therefore, the aim of this study was to investigate associations between area level deprivation and three measures of adiposity: body mass index (BMI), waist circumference (WC) and waist-to-height ratio (WHtR) in children.

Design: Cross sectional study, data collected on 3 occasions a year apart (2005 – 2007)

Subjects: Data was available for 13333 children, typically aged 11-12 years from 37 schools and 542 Lower Super Output Areas (LSOAs).

Measures: Stature, mass and WC. Obesity was defined as a BMI and WC exceeding the 95th centile according to British reference data. WHtR exceeding 0.5 defined obesity. The Index of Multiple Deprivation affecting children (IDACI) was used to determine area level deprivation.

Results: Considerable differences in the prevalence of obesity exist between the three different measures. However, for all measures of adiposity the highest probability of being classified obese is in the middle of the IDACI range. This relationship is more marked in girls, such that the probability of being obese for girls living in areas at the two extremes of deprivation is around half that at the peak, occurring in the middle.

Conclusion: These data confirm the high prevalence of obesity in children and suggest that the relationship between obesity and residential area level deprivation is not linear. This is contrary to the 'deprivation theory' and questions the current understanding and interpretation of the relationship between obesity and deprivation in children. These results could help make informed decisions at the local level.

Key words

Body mass index, waist circumference, waist-to-height ratio, obesity, deprivation

INTRODUCTION

Although obesity is not a new phenomenon, the increase in the prevalence occurring in virtually every country in the World is striking (1). Media, health experts and researchers talk about a paediatric 'obesity epidemic'. There has been a considerable increase in the prevalence of overweight and obesity in children in the UK over the last 30 years, with the most rapid rise occurring in the 1990s (2-5). Furthermore, studies that have predicted future trends in the prevalence of childhood obesity globally (6), in Europe (7) and in the UK (8) have reported an expectation of continuing increase in prevalence.

Monitoring the anthropometric status of children and adolescents is important in understanding the obesity epidemic. However, examination of the socio-demographic distribution of overweight and obesity may establish differences in prevalence between groups. This is particularly important from a public health perspective. For example, if overweight is found to be more prevalent among some children, (e.g. those living in more deprived areas), it may be appropriate to allocate health promotion resources differently to those groups. There is an established interest in the relationship between socio-economic status and obesity and there is a general assumption of a linear relationship in children, such that the prevalence of obesity is highest in the more deprived groups (9-15). Furthermore, data on time trends of socio economic disparities in childhood obesity prevalence suggest that inequalities in childhood obesity increase with age (12, 16-19).

The 2010 Marmot review (20) emphasised the importance of reducing health inequalities as a matter of fairness and social justice, calling for action to reduce the social gradient in all health measures, not just obesity, across all the social determinants of health. The review suggests that the physical and social characteristics of the area in which an individual lives makes a significant contribution to social inequalities. Stafford et al. (2010) agree that area

level deprivation is associated with obesity independently of individual deprivation (21). However, a considerable limitation of the evidence base to date is that it relies heavily on individual measures of deprivation and comparatively few studies use an area level measure of deprivation, especially applying to children, thereby limiting the scope to assess trends in the association with obesity for this indicator. Those that have investigated the relationship using an area level measure of deprivation (16, 22-24) report inconsistent findings. The limited evidence of the area level effect therefore warrants further investigation in light of the Marmot Review (20).

Furthermore, most research investigating the relationship between obesity and deprivation typically report excess adiposity in terms of body mass index (BMI). Few studies have considered alternative measures of obesity in children and those that have (22, 25, 26) report inconsistent findings. Although the choice of BMI as a measure of obesity in children is well established (27) there is emerging evidence to suggest that central adiposity in children is more relevant to health outcomes than overall adiposity estimated by BMI (28, 29). Also the prevalence of central adiposity (measured by waist circumference) is considerably higher than the prevalence of general obesity (measured by BMI) and is increasing at a faster rate (22, 30, 31). Therefore, the aim of this study is to investigate associations between area level deprivation and three measures of adiposity; BMI, waist circumference (WC) and waist-to-height ratio (WHtR) in children and explore if the relationship is linear.

METHODS

Data is from the Rugby League and Athletics Development Scheme (RADS) collected from 2005 – 2007. RADS is a collaboration between Leeds City Council (LCC), Leeds Metropolitan University and the Education Authority (Education Leeds - EL) and was set up

to identify talented children who were then offered a place on a talent development programme and to monitor obesity levels in the city. The programme involved a series of basic fitness assessments and anthropometric measurements of all year seven (age 11 years) children in Leeds secondary schools that agreed to participate. Response rates (at the pupil level) for the programme were consistently above 80% (Table 1). Ethical clearance was granted by the Ethics Committee of the Carnegie Faculty, Leeds Metropolitan University.

Measures

Anthropometric measures taken were stature, weight and WC, all measurements were carried out by the same person (CG). The technical error of measurement (TEM) and coefficient of variation (CV) (32) for WC in 250 pupils (selected from one school) measured twice (blind) on the same day was 0.74cm and 0.98% respectively. The TEM (CV) for height and weight (in the same 250 pupils) were 0.21cm (0.14%) and 0.05 kg (0.13%) respectively. These figures demonstrate appropriate reliability (33). All testing took place on school premises; more detailed protocols are reported elsewhere (31).

Outcome measures: Weight status classification : BMI and WC measurements were converted to standard deviation scores using the British 1990 growth reference charts for BMI (UK90), (34) and WC (35). Children were classified obese based on their standardised scores to allow comparison while accounting for normal growth. The 95th reference centile (standardised score = 1.64) was used to define obesity. Waist-to-height ratio (WHtR) is not subject to the same statistical drawbacks of standardisation like BMI and WC and so the raw values were used. A WHtR boundary value of 0.5 was used to define increased concern (36, 37). Standardised BMI and WC scores are reported here as sBMI and sWC respectively.

Table 1. Sample size for each measurement year (and in total) before and after deletion of incomplete cases (i.e. children with missing data).

		2005	2006	2007	Total
Complete sample		5447	5525	4869	15841
Response rate school level* (%)		85	82	71	79
Response rate pupil level** (%)		80	86	93	85
Sample: complete cases	BMI	4659	4568	4106	13333
	WC and WHtR	4477	4557	4099	13133

*39 schools were eligible to take part each year part each year

** the percentage of children that completed RADS from the participating schools, before data exclusion.

Measure of deprivation: The Index of Multiple Deprivation affecting children (IDACI) 2007 (38) was used to determine area level deprivation. IDACI scores were assigned to the lower super-output area (LSOA) of each individual, as determined by their postcode. LSOAs are geographical areas generated to have similar population sizes and are usually homogenous, based on tenure of household and dwelling types. They have a minimum population of 1000 and a mean of 1500. The IDACI score is the proportion of children (aged 0-16 years) in each LSOA that live in households that are income deprived (i.e. in receipt of income support, job seekers allowance, working families tax credit or disabled persons tax credit).

Individual measures: Age of the child, gender and ethnicity. Ethnicity data was obtained from Education Leeds and although data was obtained for 23 ethnic groups (including refusal to answer) the numbers in most ethnic groups, were very small in comparison to the White-British category, so the ethnicity groups used in all analyses were collapsed to ‘White-British’ and ‘other’. This weakens the analysis of data according to ethnic group, but is warranted based on representation in the study sample.

Over the three years 15 841 children took part in the RADS programme (Table 1). However, only children who had valid anthropometric data and both predictor variables (i.e. a valid postcode and ethnic group) were included in the analysis. The final analysis consisted of 13333 children for BMI and 13133 children for WC and WHtR from 37 schools and 542 LSOAs (Table 1). The final numbers are slightly lower than those reported in a previous report using the RADS data (31) due to the addition of the predictor variables with some missing data. Less than 5% of children's data was excluded in each measurement year because of missing anthropometric data (2005 n=105; 2006 n=231; 2007 n=74).

Statistical Analysis

Statistical analyses were performed using the multi-level modelling program MLwiN *(MLwiN. Bristol. UK*). A single level (fixed effects or standard regression) model gives no estimation of between school or area variability; a single level model 'averages' for the whole data set, and has just one variance, whereas a MLM determines the variance at its different levels. Initial analysis was carried out using 2 level hierarchical logistic binominal models (random intercept but fixed coefficients of the predictors) with obese or not (coded as one and zero) as the dependent variable, using maximum likelihood estimation. Two separate types of model were considered and fitted, the first with pupils (level 1) nested within LSOAs (level 2), and the second with pupils (level 1) nested within schools (level 2). Predictors, at the pupil level, were sequentially added to the models and possible interactions between explanatory variables were explored. Initially using maximum likelihood estimation. Quadratic terms (e.g. $IDACI^2$) were included in order to allow for curvature in a relationship. Only statistically significant interactions were included in the final model for reasons of parsimony ($p \leq 0.05$, i.e. absolute value of the coefficient if 1.96 times the SE) . IDACI was included in the MLM analysis as a continuous variable centred on its mean so that the intercept has a more

meaningful interpretation. Centring is the process whereby the sample mean is subtracted from each value. Finally the point estimate logits from the final models were converted into probability and plotted for graphical representation.

All results were checked using Markov Chain Monte Carlo (MCMC) estimation procedures and conclusions were very similar. Such that MCMC confirmed that single level models are sufficient in situations where the level 2 variance is effectively zero and that the additional complexity of the multilevel model was only required when the level 2 variance was statistically significant using the maximum likelihood estimation.

Results

Frequencies and mean scores for all variables can be seen in Table 2. Over 80% of the sample were white British and half were girls. Mean standardised scores for sBMI and sWC values were considerably greater than zero indicating a higher mean BMI and WC, after adjusting for age and sex than the reference sample for BMI (34) and WC (35). The mean WHtR in all three testing years is 0.45. There are considerable differences in the prevalence of obesity using the different measures, which has been reported previously (31) from the RADS data.

The final models can be seen in Table 3. Predictor variables were sequentially added to the model together with possible interactions. Interactions account for the effect of two variables in combination not simply the sum of the two separate (main) effects, so that the effect of one variable depends on the value of the other. Any subsequent elaboration did not improve

Table 2. Descriptive statistics and frequencies for all individual level factors.

	Individual Testing Years			
	2005	2006	2007	Combined
Age	11.58 (0.30)	11.58 (0.30)	11.59 (0.30)	11.58 (0.30)
BMI	19.36 (3.63)	19.28 (3.54)	19.23 (3.72)	19.29 (3.63)
sBMI	0.49 (1.22)	0.46 (1.21)	0.42 (1.26)	0.46 (1.23)
% obese BMI	19.4	18.1	18.0	18.6
WC	67.58 (9.78)	66.11 (8.89)	66.98 (8.89)	66.88 (9.22)
sWC	0.93 (1.26)	0.76 (1.19)	0.89 (1.14)	0.86 (1.20)
% obese WC	30.3	24.2	26.0	26.8
WHtR	0.46 (0.60)	0.45 (0.05)	0.45 (0.05)	0.45 (0.06)
% WHtR >0.5	22.0	16.1	17.4	18.5
Girls (%)	48.0	49.0	50.0	49.0
White (%)	82	83.5	82.1	82.2
Pupil IDACI	0.24 (1.19)	0.24 (1.19)	0.25 (1.19)	0.24 (1.19)

Values are means (standard deviations) unless otherwise stated

Prevalence data is slightly different to those recently reported from the RADS data (33) because additional predictors have changed the sample size (i.e. children without a valid postcode and ethnicity and have been excluded)

the model. Because the intercepts of the model has been allowed to vary between LSOAs and schools, the logit for being obese is given for each level 2 cluster by the model. In fact these are departures above or below the overall model intercept logit for being obese. These are the level 2 residuals (u_{0j}).

Children nested within LSOAs

When children are nested within LSOAs the level 2 variance is not statistically significant for any of the measures of obesity (BMI variance of u_{0j} =0.012 (SE 0.015); WC variance of u_{0j} = 0.012 (SE = 0.012); WHtR variance of u_{0j} = 0.025 (SE = 0.016)) i.e. there is not good evidence for a difference in the prevalence of obesity between LSOAs. However, there is considerable variation within LSOAs between types of children. For all measures of adiposity the linear variation with IDACI was not the same for boys and girls (interaction term IDACI.gender is statistically significant (BMI = 1.438 (SE = 0.282); WC = 0.834 (SE = 0.247); WHtR = 1.149 (SE = 0.284)) suggesting the linear component is greater for girls). However, the $IDACI^2$ term allows curvature in the relationship and is statistically significant in all models (BMI = -2.347 (SE = 0.825); WC = -1.841 (SE = 0.779); WHtR= -2.297 (SE = 0.852)) suggesting that the relationship between the log odds of obesity and IDACI is not linear. Furthermore, in all models non-white children were significantly more likely to be obese compared to white British children (coefficients for ethnicity in each logit model were, BMI = 0.191 (SE = 0.060); WC = 0.166 (SE = 0.055); WHtR = 0.127 (SE = 0.062)).

The results in Table 3 suggest that single level models are sufficient for analysing these data in all cases. The additional complexity of the MLM did not identify any further relationships in the dataset. For all measures of adiposity the logit of being obese did not differ between LSOAs (once the $IDACI^2$ term was included into the model i.e. level 2 variance og LSOAs was effectively zero). Presumably IDACI is sufficient to explain the effect of LSOA.

For graphical representation the logits from the LSOA models for all measures of obesity (Table 3) were converted into probabilities and plotted against the IDACI score (Figure 1) to illustrate the effects of interactions between both gender and IDACI. For all measures of obesity the highest probability of being classified as obese is around the middle of the IDACI range (Figure 1). The odds of being obese estimated by sWC, for girls is considerably higher than for boys across the whole IDACI range, (gender as a 'main effect' remains statistically significant in the logit model (0.493 (SE = 0.054)) but the gender.IDACI^2 term is not significant (WC = -1.663 (SE 1.031)) see Figure 1 panel B. At the peak girls' probability of being obese is increased by typically 0.10, compared to boys (Figure 1, Panel B). However when sBMI (Figure 1 – Panel A) and WHtR (Figure 1 – Panel C) are used to estimate obesity, the curves are flatter for boys compared to girls (gender.IDACI^2 interaction is statistically significant (BMI -2.867 (SE 1.199); WHtR -2.607 (SE 1.207)) and the probability of being obese at the extremes of the IDACI range is half that at the peak.

Figure 1 also shows that non-white children have a higher probability of being obese which is increased by typically 0.03, compared to their white British counterparts for all measures of obesity.

Children nested within schools

Table 3 shows that the log odds of being obese, estimated from sBMI does not appear to differ between the 37 schools, the level 2 variance is not statistically significant (0.009 (SE = 0.006)) and so MLM is not required. However, within schools there is considerable variation dependent upon the pupil level predictor variables. Girls (-0.156 (SE = 0.045)) are less likely to be obese compared to boys and non-white children are more likely to be obese (0.157

(SE = 0.061)) compared to white British children. Additional complexity including interaction terms did not improve the model and so a main effects model is reported for simplicity.

However, the between school variance in obesity prevalence estimated by sWC (0.069 (SE = 0.020)) and WHtR (0.102 (SE = 0.029)) remains statistically significant in the final model. with the inclusion of all predictor variables and their interactions, i.e. the log odds of being obese does appear to differ between the 37 schools. Within school variation is also observed dependent upon the predictor variables included in the model. Furthermore, the $IDACI^2$ term is statistically significant (sWC = -1.554 (SE = 0.777) WHtR = -1.723 (SE = 0.839)) suggesting that the relationship is not linear.

Discussion

These results confirm that there are inconsistencies between the different measures of obesity, with the greatest prevalence observed in central obesity, which is in agreement with previous research (30, 31). However, the most important message here is that, the relationship between obesity and deprivation seems not to be linear. Although the prevalence of obesity is higher than desirable across the whole IDACI range, it appears that children living in the most deprived and most affluent areas of the city are at the lowest risk, with boys and girls following different patterns. This novel finding is contrary to most previous research which has assumed a linear relationship between obesity and deprivation (10, 16, 22) and as far as the authors are aware, this is the first study to compare three different measures of adiposity.

This research took a local level approach which is novel in the context of obesity studies. Such detailed knowledge of the local area will enable the targeting of policy actions to local populations for effective results. This is especially important in light of the recently

Table 3. Coefficients (SE) from the 2 level logit models including possible interactions with children nested within LSOAs and children nested within schools for all measurements.

		Children nested within LSOAs				Children nested within schools		
		sBMI	sWC	WHtR		sBMI	sWC	WHtR
Fixed part								
B (intercept)		-1.296 (0.053)*	-1.009 (0.049)*	-1.160 (0.053)*		-1.369 (0.047)*	-1.023 (0.066)*	-1.182 (0.075)*
Gender (ref=boy)		-0.066 (0.061)	0.493 (0.054)*	-0.002 (0.061)		-0.156 (0.045)*	0.502 (0.055)*	0.006 (0.062)
IDACI		0.180 (0.194)	0.146 (0.185)	0.409 (0.201)*		0.296 (0.125)*	-0.086 (0.198)*	0.054 (0.214)*
Ethnicity (ref=white)		0.191 (0.060)*	0.166 (0.055)*	0.127 (0.062)*		0.157 (0.061)*	0.214 (0.058)*	0.171 (0.066)*
Testing year (ref=2005)	2006	-0.081 (0.054)	-0.317 (0.048)*	-0.389 (0.054)*		-0.088 (0.054)	-0.311 (0.049)*	-0.381 (0.056)*
	2007	-0.107 (0.055)	-0.239 (0.049)*	-0.315 (0.055)*		-0.109 (0.056)	-0.261 (0.052)*	-0.344 (0.059)*
gender.IDACI		1.438 (0.282)*	0.834 (0.247)*	1.149 (0.284)*		-	0.914 (0.248)*	1.236 (0.285)*
$IDACI^2$		-2.347 (0.825)*	-1.841 (0.779)*	-2.297 (0.852)*		-	-1.554 (0.777)	-1.723 (0.839)*
$gender.IDACI^2$		-2.867 (1.199)*	-1.663 (1.031)	-2.607 (1.207)*		-	-1.619 (1.026)	-2.582 (1.196)*
Random part								
Variance (u_{0j})		0.012 (0.015)	0.012 (0.012)	0.025 (0.016)	(u_{0j})	0.009 (0.006)	0.069 (0.020)*	0.102 (0.029)*
Level 2 units (SOA)		542	542	542	Schools	37	37	37
Level 1 units (children)		13333	13133	13133	Children	13333	13133	13133

B = the logit of the outcome variable associated with one unit change in predictor variable; SE = standard error; * significant at $p < 0.05$, sBMI = standardised BMI; sWC = standardised WC

announced enhanced role for local Governments and authorities with an increased focus on locally led action based on high quality local data in the UK to tackle childhood obesity (39, 40). Furthermore, the large sample size, reliability of anthropometric data and the sophistication of the analysis completed can also be viewed as strengths.

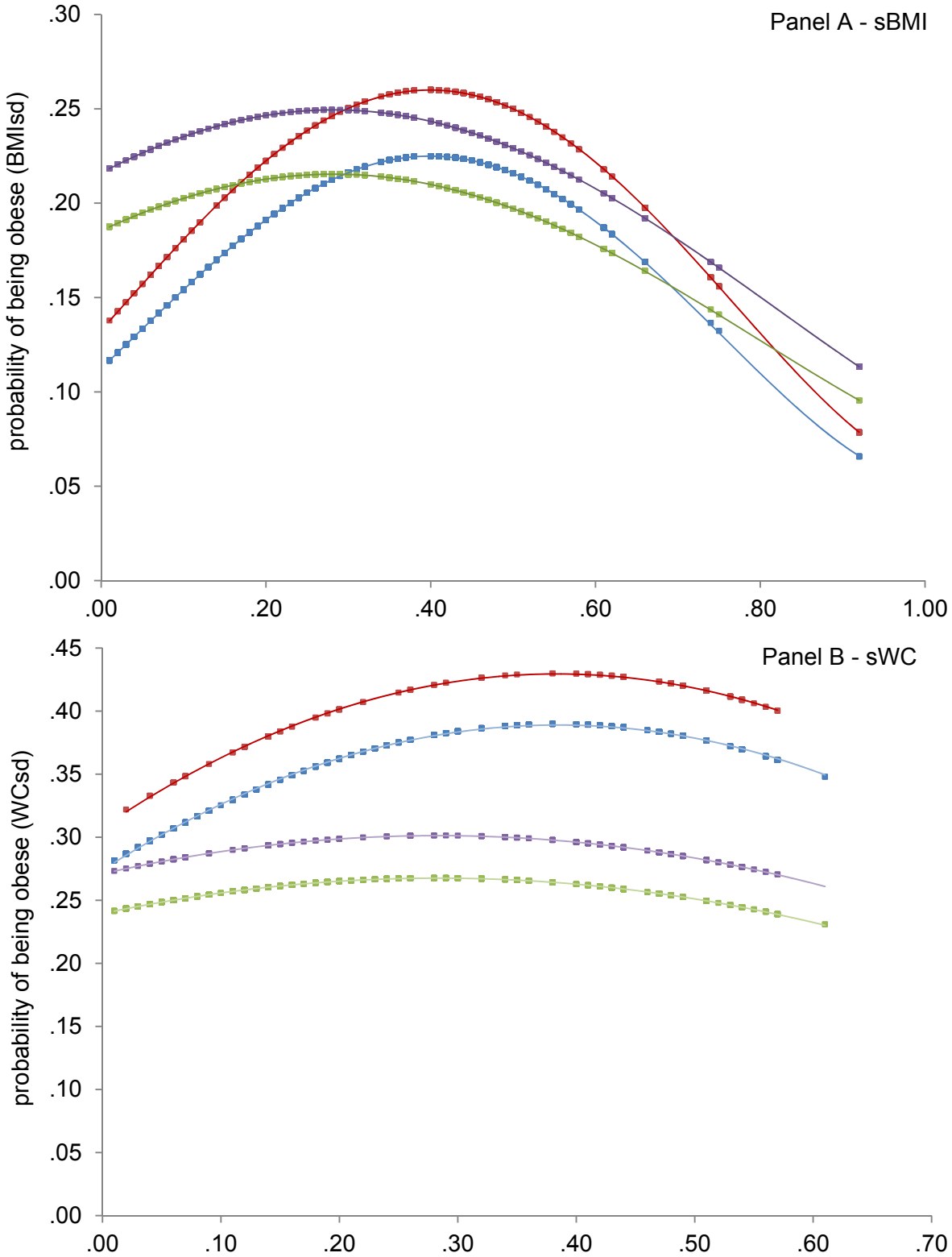
A limitation is that it was an observational study and so causality between deprivation and measures of adiposity cannot be directly inferred. A further limitation of the RADS data is that we studied area level deprivation with these areas defined by LSOAs. Although this method has been used by the National Child Measurement Programme (16) it is possible that these LSOA's do not reflect the areas important to the individuals living in them. Additionally, IDACI is an income-based area level indicator of deprivation and it is likely that alternative measures would result in different findings. Although there is increasing attention placed upon the influence of area level deprivation and its relationship with obesity (20, 21) there is no agreement regarding an appropriate measure. This is possibly because of the inherent complexities in developing a measure to truly investigate the influence of an area on obesity.

The Ecological Systems Theory (EST) (41) highlights the importance of considering the context(s), in which a person is located in order to understand the emergence of a particular characteristic. According to EST, development or change in individual characteristics cannot be effectively explained without consideration of the context in which the person is embedded. Multi-level modelling (MLM) used in this research modelled contextuality (differences between contexts) and heterogeneity (variation at each level) which is in agreement with EST. However, the IDACI score only provides a small piece of the area deprivation (context) puzzle, which is income based and therefore fails to account for other inequalities related to deprivation e.g. educational attainment.

Explanations for the non-liner association between obesity and area level deprivation are not currently understood. It is possible that the linear associations reported in the literature are a result of the statistical techniques applied. A positive linear trend was observed for all measures of adiposity in the logistic modelling of the RADS data (only significant in girls) when the relationship was assumed to be linear. However, the inclusion of $IDCAI^2$ outweighed this linear relationship. Without the inclusion of the quadratic term the RADS data would have been in agreement with the evidence base.

The environment has been described as 'obesogenic' – an environment that hinders sufficient physical activity and promotes excessive intake of food, thereby making obesity more likely to occur. It has been defined more precisely as 'the sum of influences that surroundings, opportunities or conditions of life have on promoting obesity in individuals or populations (42). It is reasonable therefore, to assume that the mechanisms linking obesity and area level deprivation reflect the underlying effects of deprivation on dietary habits and physical activity status. Evidence suggests that the deprivation of an area is associated with characteristics of the food (43-47) and physical activity environment (43, 45, 48-50), with more deprived areas thought to be more obesogenic (51). While this provides an explanation for the linear relationships it does not provide an explanation for the increased risk of obesity in the middle of the IDACI range observed here. Why this type of patterning exists is not clear. It may reflect changes in environmental aspects not captured by IDACI. Alternatively it may be because more recently born cohorts have spent greater periods of their life in the obesogenic environment, for some it is their entire life. It has been suggested, that each new birth cohort will have a progressively higher rate of overweight and obesity (22, 52) and this is likely to differ across SES groups and change with time. Finally, although we can investigate the link between obesity and area deprivation currently no evidence exists to explain what it is about area deprivation that causes this link. Causality cannot be inferred because of the complex nature of the obesity – deprivation relationship (53). The mechanisms for the relationship between obesity and deprivation need to be considered in

light of the possibilities that deprivation influences obesity but also that obesity influences deprivation.



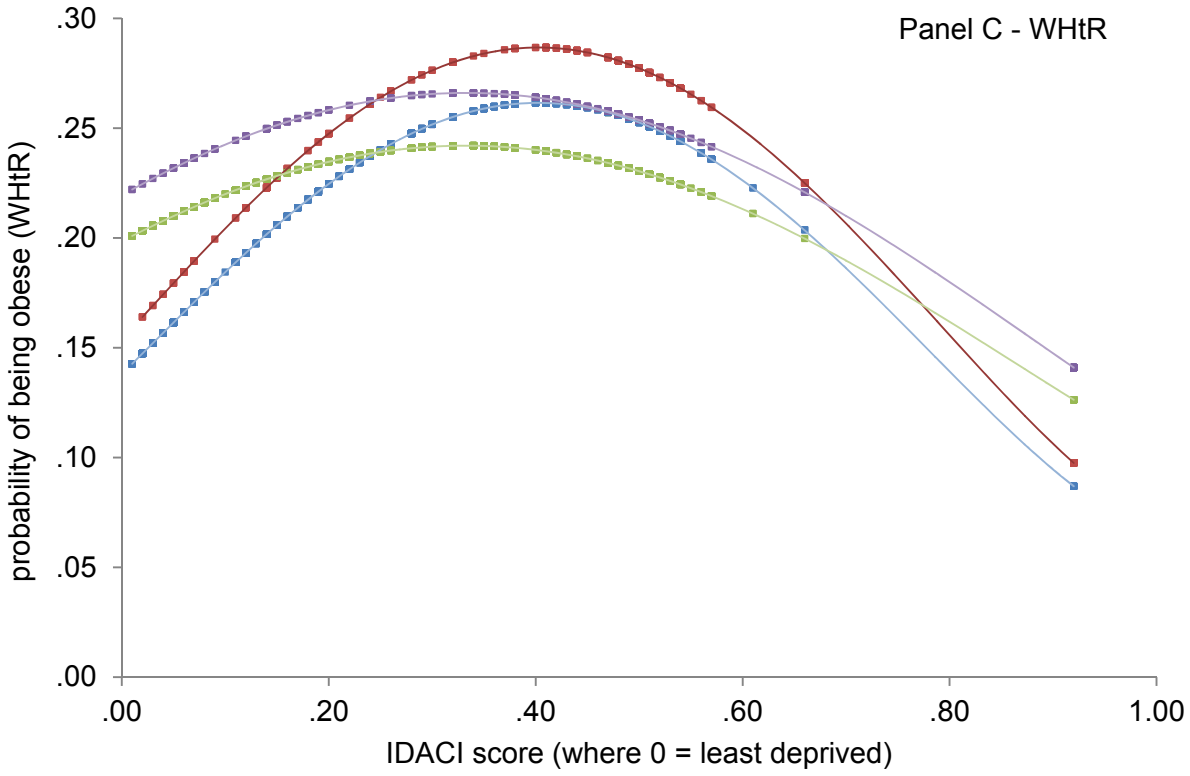


Figure 1 Probability (converted from logit) of being obese dependent upon IDACI score. Panel A = obesity estimated by sBMI; Panel B = obesity estimated by sWC; Panel C = obesity estimated by WHtR

Of further interest is that fact that the relationship between obesity and SES is stronger, and in many cases only shown to be statistically significant in girls. This was true for all measures of adiposity in the RADS data and has been shown in children of different ages (25, 26), suggesting that the relationship is robust. It is not clear why these gender differences exist but the different pattern between boys and girls and the environment they share warrants further investigation.

Very few studies have considered alternative measures of obesity when investigating the prevalence of obesity or its relationship in children and those that have report different findings. An Australian study of children aged 7-15 years (26) concluded that none of the anthropometric measures (mean BMI, WC, waist to hip ratio and skinfolds) were significantly

different between boys of different SES groups. Among, girls however there were significant inverse associations between SES and BMI, WC and WHR in all age groups. In contrast to these findings Wake et al. (2007) reported an inverse relationship between SES and obesity estimated by sBMI. Children in the bottom quintile (i.e. most deprived) had a 47% higher odds (95%CI 14-92) of being in a heavier weight category than those in the top quintile (25). However, the authors did not report any relationship between WC and SES. The only UK based study to compare different measures of adiposity reported that the relationship between obesity and deprivation is unclear (22). Children in the lowest deprivation quintile had higher rates of overweight and obesity, measured by BMIsd however, differences were not systematically graded across levels of deprivation and rates of overweight and obesity were also high in the least deprived girls (22). With regard to WC a statistically significant trend towards higher sWC scores with higher deprivation was reported (22). Although the findings are inconsistent many have assumed a linear relationship between deprivation and the different measures of obesity, the novel finding from this research is that this relationship does not appear to be linear regardless of the measure of adiposity.

To our knowledge this is the first study to investigate school effects comparing different measures of adiposity. Significant effects between the SES of a school and the prevalence of obesity estimated by sBMI have been reported previously (16, 24, 54) but with inconsistent results. Dummer et al. (2005) found no evidence of an association between school area deprivation and the prevalence of obesity estimated by sBMI, which is consistent with this study, and concluded that targeting interventions based on schools or on the basis of administrative boundaries may be wasteful. However, O'Dea and Dibley (2009) reported that obesity increased only among children from low SES schools and that suitable prevention strategies should target specific schools. Perhaps the most likely conclusion was reported by Townsend, Rutter and Foster, (2012), that school level deprivation does impact BMI status throughout childhood (aged 6-11), but, deprivation measures at the individual

area level (i.e. where the child actually lives) are more reliable. It must be acknowledged that all the children in the RADS data were in year 7 (first year of secondary school), and so had not been at the school for very long. It is unlikely therefore, that any differences are due to the impact of the school per se and more likely reflect the location of the school.

The key finding from this research is that the relationship between deprivation and adiposity in children is not linear which is contrary to the 'deprivation theory' and questions the current understanding and interpretation of the relationship between obesity and deprivation in children. The Marmot Review emphasised the importance of reducing health inequalities as a matter of fairness and social justice (20). However, to reduce the steepness of the social gradient in health, actions must be universal, but with a scale and intensity that is proportionate to the level of disadvantage – 'proportionate universalism' (20). The findings from this study support this proposal such that, focusing solely on the most disadvantaged may not reduce the health gradient, and will only tackle a small part of the problem.

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Competing Interest – none declared

All authors had full access to the all of the data and can take responsibility for the integrity of the data and the accuracy of the data analysis.

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