Published in final edited form as:
Health Place. 2010 March ; 16(2): 236–241. doi:10.1016/j.healthplace.2009.10.004.

Physical activity in children: does how we define neighbourhood matter?

Andy P Jones[1], **Esther MF van Sluijs**[2], **Andy R Ness**[3], **Robin Haynes**[1], and **Chris J Riddoch**[4]

[1]School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ.

[2]Medical Research Council Epidemiology Unit, Institute of Metabolic Science, Addenbrookes Hospital, Cambridge, CB2 0QQ.

[3]Department of Oral & Dental Science, University of Bristol, Lower Maudlin Street, Bristol, BS1 2LY.

[4]School for Health, University of Bath, Bath, BA2 7AY.

Abstract

Physical activity levels in children are low and factors in the neighbourhood are believed to be influential. However, uncertainty remains about how best to define the neighbourhood. We therefore sought to study the role of area definition on neighbourhood variations in child physical activity using data collected at age 11 from the Avon Longitudinal Study of Parents and Children, UK. We found the effect of neighbourhood of residence on variations in PA was small, explaining under 3% of variance at best, and was not strongly dependent on the manner by which the neighbourhood was defined. Our results suggest that whilst characteristics of local environments may be important determinants of activity, the delineation of neighbourhoods based on shared social or physical characteristics may not best capture local influences.

Keywords

Physical Activity; ALSPAC; environment; children; neighbourhood; multilevel

INTRODUCTION

In recent years there has been an increasing understanding of the health benefits that arise from a physically active lifestyle. People who are physically active reduce their risk of major diseases such as coronary heart disease, stroke, type 2 diabetes, and some cancers (Vogel et al. 2009). Increasing physical activity at the population level would thus contribute to reductions in the prevalence of these conditions and would also improve musculoskeletal

Corresponding author: Dr Andy Jones, School of Environmental Sciences, University of East Anglia, Norwich, Norfolk, NR4 7TJ, United Kingdom. Tel: 00 44 1603 593127. Fax: 00 44 1603 591327. a.p.jones@uea.ac.uk.
Authors' email addresses:
- Andy Jones: a.p.jones@uea.ac.uk
- Esther van Sluijs: esther.vansluijs@mrc-epid.cam.ac.uk
- Andy Ness: andy.ness@bristol.ac.uk
- Robin Haynes: r.haynes@uea.ac.uk
- Chris Riddoch: C.J.Riddoch@bath.ac.uk

The final published version of this article can be found at http://www.sciencedirect.com/science/article/pii/S1353829209001075
doi: 10.1016/j.healthplace.2009.10.004

health, reducing the risk of osteoporosis, back pain and osteoarthritis (Roetert et al., 2005) as well as having positive effects on wellbeing and mental health (Saxena et al., 2005).

Attaining adequate levels of physical activity in childhood may be particularly important given the evidence that it affects contemporary markers of disease risk (Ortega et al. 2008), and those at early middle age (Kvaavik et al. 2009). Furthermore, being physically active in childhood has been shown to be associated with a higher level of physical activity in later life (Telama et al. 1997). However, in the UK, levels of physical activity amongst children are low; recent surveys report that 3 out of 10 boys and 4 out of 10 girls fail to meet recommendations (Department for Health, 2003).

A recent review of the evidence of the effect of interventions to increase physical activity in children has shown that interventions targeted solely at individuals are less effective, with the strongest effect coming from those that included school, family, community or some form of environmental component (van Sluijs et al. 2007). A move of the research focus from individuals to the wider environment has been driven by the development of ecological models which suggest that physical activity behaviours arise as the result of the combined action of psychosocial, demographic, as well as physical environmental factors (e.g. Van Dyck et al. 2009). Panter et al. (2008), for example, have recently described a framework for the determinants of walking and cycling to school in youth that incorporates such components (Panter et al. 2008).

In line with ecological model development, there has been an increasing focus in the literature on the role of the neighbourhood environments within which people live as predictor of physical activity (Ball et al. 2006). Neighbourhood influences may include the effect of a shared physical environment, the availability of services to support residents, the influence of collective social functioning such as shared social and cultural norms, and the relative effects of material deprivation (Flowerdew, et al. 2008). However, whilst the term 'neighbourhood' is frequently used in the public health literature, it is a concept that is difficult to objectively define.

Researchers have commonly delineated neighbourhoods based on administrative units, or census tracts (Pickett and Pearl, 2001; Kawachi and Berkman, 2003). Whilst they have the benefit of convenience, whether or not these areas are appropriate for the study will depend very much on the actual behaviours being modelled (Diez-Rouz, 2001; Pickett and Pearl, 2001). A small number of studies so far have defined custom-made neighbourhoods to suit a particular investigation. Examples include the use of socially homogeneous areas (Reading et al, 1999; Law et al., 2005) and areas based on the local knowledge of key professionals (Ross, et al. 2004).

Automated zone design methodologies employ a computer algorithm to group geographical units into a smaller number of zones which can be used to delineate 'neighbourhoods' (Daras and Alvanides, 2006). The criteria used to define optimality in the grouping process might include combinations of the number of zones required, constraints on the population size of each, compactness of shape and a requirement to maximize the homogeneity of specified variables within each zone. Cockings and Martin, (2005) used the technique to demonstrate that these synthetic zones produced stronger relationships between morbidity and deprivation than census units, and it is thus possible that the clustering of health related behaviours such as physical activity are associated with the manner by which neighbourhoods are defined.

To our knowledge, no studies to date have examined how strongly neighbourhood associations with physical activity are influenced by the way that neighbourhoods are derived. Using data from the Avon Longitudinal Study of Parents and Children (ALSPAC)

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we examine if variance in objectively-measured physical activity levels amongst a sample of 11 year old children is associated with the neighbourhood in which each child resides and whether any such associations are modified by the manner by which the neighbourhood is delineated. As children have been shown to undertake a large amount of their physical activity, often in the form of unstructured play, in the environment around the home (Mackett & Paskins, 2008) we believe this group to be appropriate for the study.

METHODS

Study population

The Avon Longitudinal Study of Parents and Children (ALSPAC) is a prospective population based birth cohort study into predictors of childhood health. The study has been described in detail elsewhere (Golding et al. 2001). In brief, 14,541 pregnant women living in one of three Bristol-based health districts in the former County of Avon (UK) with an expected delivery date between April 1991 and December 1992 were enrolled. During pregnancy and throughout childhood, detailed information was collected using self-administered questionnaires, data extraction from medical notes, linkage to routine information systems and at research clinics.

At age 11 a total of 11,952 children were invited to attend the clinic in Bristol, where a range of clinical measures were taken; they completed questionnaires and were asked to wear an accelerometer afterwards. Of these, 7,159 (59.9%) attended, and of those attending 6,622 (92.5%) agreed to wear the accelerometer. Valid physical activity data and a valid address in the Avon area were available for 3935 children (59.4%), and these children constitute the analysis sample for this study. Ethical approval for the study was obtained from the ALSPAC Law and Ethics Committee and Local Research Ethics Committees.

Outcome measure – physical activity

The MTI Actigraph AM7164 accelerometer (Actigraph) is a small and light electronic motion sensor comprising a single plane (vertical) accelerometer. The Actigraph has been validated in both children and adolescents against indirect calorimetry (Melanson et al. 1995) observational techniques (Fairweather et al. 1999) and energy expenditure measured by doubly labelled water (Ekelund et al. 2001). They have been shown to be accurate, although they cannot pick-up water-based activities and underestimate activities not predominantly in the vertical plane, such as cycling (Corder et al. 2007).

The Actigraph monitors were set to average raw data (counts) over a 1-minute epoch. Children were asked to wear the monitor on an elastic band around their waist on the right hip during waking hours for seven consecutive days, only to be taken off for showering, bathing, or any contact or water sports. Monitors were returned by post and data were downloaded onto a PC and stored for further analyses. A valid day of physical activity data was defined as providing at least ten hours of information and children were only included in the analyses if they provided at least three valid days of recording (Mattocks et al. 2008). Sequences of 10 or more minutes with consecutive zero counts were deleted as representing periods when the monitor was not worn. Total physical activity was defined as the average accelerometer counts per min (counts/min) over the full period of valid recording. We derived variables for the total week, after school (weekdays between 16.00 and 21.00) and weekend days as neighbourhood influences were hypothesized to be most important during out-of-school hours.

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Defining neighbourhoods

In total 10 sets of neighbourhoods were generated for this study, using three different methodologies. The first methodology simply delineated neighbourhoods based on Enumeration District (ED) boundaries, and one set of neighbourhoods was generated in this manner. EDs were the smallest spatial units for which 1991 UK Census data was available, and hence produced the smallest neighbourhoods in this analysis. They were used as a comparator against which further sets of neighbourhoods generated using the other two methodologies were examined. One methodology was employed that subjectively identified areas with similar community characteristics within the study area, whilst another methodology delineated areas using a computer algorithm in such a way as to maximise the homogeneity of selected Census variables within each. The generation of the subjective communities and computer zones, originally undertaken for a study of accidental childhood injuries in Bristol, is described in more detail in Haynes et al. (2008), and is briefly recounted here.

The subjective communities were based around 101 small areas delineated by Bristol City Council Planning Department in 1994 which were deemed to best represent local “communities”. They were delineated manually, using local expertise and community consultation, and were based on shared community characteristics and identities, physical features and a minimum population threshold. Their boundaries were also determined by the requirement that each should nest within the 34 administrative wards in the city. The communities had an average population of 3711. They were not available for the ALSPAC study area outside Bristol. Hence, for this study the methodology of the former Avon County Council was used whereby communities outside Bristol were delineated as civil parishes in rural areas (typically a nucleated settlement surrounded by agricultural land) and administrative wards in urban areas. Slight adjustments to boundaries were made so as to create areas with a matching average population size to those in Bristol. Altogether 201 “communities” were therefore generated. To investigate the effects of scale, contiguous pairs of communities with similar Townsend material deprivation scores (Townsend et al. 1988) were manually amalgamated using 1991 Census enumeration district values to make a set of 101 “super communities” (average population 7497), and also split using the same criterion to make 307 “sub-communities” (average population 2499). Three sets of neighbourhoods were thus generated using subjective methods.

The computer generated synthetic areas were designed to optimise the homogeneity of social characteristics and environmental features. They were generated by grouping enumeration districts using an automated zone design program “A2Z” (Daras, 2006). The algorithm maximized the homogeneity of two census characteristics of the enumeration districts within zones, subject to a weak shape constraint that prevented long strings of enumeration districts being joined.

The algorithm used to generate the synthetic areas was firstly set to group EDs with similar Townsend material deprivation values (measuring unemployment, overcrowding, non-car ownership and non-home ownership) to produce “Deprivation zones”. An additional census measure was used to define a second set of zones; “housing type zones” where homogeneity of housing type (detached, semi-detached, terraced, purpose-built flat, converted flat and ‘other’) was maximised. This provided a set of units based on the characteristics of local built environments. For each of the two Census measures, 3 sets of neighbourhoods were created of 101, 201, and 307 units to match those of the subjective communities, and thus 6 sets of neighbourhoods were generated using automated methods.

In order to assign children to neighbourhoods, their residential postcodes were located within 1991 Census EDS. As the other neighbourhood definitions resulted from the

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amalgamation of EDs, this linkage enabled membership of the other neighbourhoods to be assigned based on those within which the residential ED of each child lived.

Covariates

A range of other covariates previously shown to be associated with children's physical activity levels (Sallis et al. 2000; Tucker and Gilliland, 2007; van Sluijs et al. 2009) were included. The date of clinic attendance was used to calculate age (in years and months) and determine season. At the clinic, height was measured using a Harpenden stadiometer and weight in light indoor clothing using a Tanita TBF 305 body fat analyzer. Body mass index (BMI) was then calculated as weight (in kilograms) divided by height squared (in metres).

In an antenatal questionnaire administered at 32 weeks, carers reported their occupation and that of their partner and this was used to allocate them to social-class groups (classes I to V with III split into non-manual and manual, with V being the lowest category) using the 1991 Office for Population Censuses and Surveys classification. The two highest and two lowest categories were grouped for analyses purposes and the lowest class of the carer and their partner, where present, was used in analysis. Carers were also asked to indicate the distance to school in one of four categories by answering the question 'How far away is school?', with the shortest distance being <0.5 miles and the longest >5 miles.

Statistical analyses

The data were summarized using means and standard deviations or percentages. In order to investigate the between-neighbourhood variations in physical activity, both before and after control for a range of covariates, a series of multilevel regression models were fitted using the MLwiN software package (Rasbash et al., 2009). Multilevel modelling was appropriate because the assembled data had a hierarchical structure of children (level 1) nested within the variously defined neighbourhoods (level 2). As only one child per household was usual in the ALSPAC cohort (except for 182 twin pairs), it was not possible to separate the child and household levels as there would not be enough power to model household effects independently from those associated with children.

The outcome variable, average counts per minute, was log-normalised. A series of multilevel models were then fitted for the different neighbourhood set definitions, using the specification outlined above, in order to determine the degree of between-neighbourhood variation in physical activity present after controlling for the covariates. The covariates were then removed from each model (to produce a 'null model') and the process repeated for each neighbourhood set to obtain unadjusted estimates of between-neighbourhood variance.

For all of these models, the amount of between child and between-neighbourhood variance present was summarised by the computation of the intra-class correlation (ICC). This gave the random variance at the neighbourhood level as a percentage of the sum of the random variance between children and neighbourhoods, and therefore provides a measure of the strength of any "neighbourhood effect". The modelling process was repeated for the three outcome variables examined; average daily counts per minute for the whole week, after school, and weekend days.

RESULTS

Within the sample that provided valid physical activity data, no differences on sex, ethnicity, physical activity or BMI were observed between those with and without a valid address that allowed their ED of residence to be determined. Table 1 shows the descriptive characteristics of the participants included in the analyses. Average age of the sample was

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11.8 (SD: 0.2) and 52.7% were girls. Boys were more active than girls, with boys averaging 668.2 (SD: 186.3) counts/min over the whole week and girls averaging 551.7 (SD: 150.9).

Table 2 shows the non-multilevel multivariate models from which the adjusted ICCs were computed. All showed some association with the outcomes studied, with the exception of social class and weekend activity. Associations were in the direction expected, with higher physical activity in males, younger children, and those with lower BMIs. Activity levels were highest in summer (most likely reflecting weather and school holidays), amongst those from lower class families (possibly reflecting lower car use) and amongst those living furthest from school (possibly reflecting a lower prevalence of walking and cycling to school amongst this group). Distance to school was not tested for weekend physical activity.

Table 3 shows the ICCs of the between-neighbourhood variations in the three physical activity measures. None of the neighbourhood sets exhibited high ICC values, either unadjusted or adjusted for the covariates in Table 2. Although the ICC values were generally greatest for those neighbourhoods defined using enumeration districts, the only ones that explained more than 1.5% of the variance in outcome were medium sized “Deprivation zones” (before and after adjustment) and enumeration districts (before adjustment) for after school PA. In addition just over 1.5% of the variation in weekend PA was explained by enumeration districts, although this was not statistically significant.

In order to test if neighbourhood effects were moderated by seasonality or by child sex, the models presented in Table 3 were re-fitted after being stratified by season and sex. However, no evidence of between-neighbourhood variance was present under any of these stratifications, and the results are not presented here for brevity.

DISCUSSION

Previous researchers have questioned the degree by which the area within which individuals live is likely to influence their levels of physical activity (Giles-Corti, 2006) and also whether the manner by which neighbourhood is defined is likely to influence the magnitude of any area effects present (Ball et al. 2006). Using a large cohort of children, and a wide variety of neighbourhood definitions, we found that very little variance in physical activity was associated with the neighbourhood in which the children lived. In this respect, our findings concur with the evidence from the wider literature, that the magnitude of area effects on health and related behaviours is generally relatively small, with area ICC effect sizes of 8% being reported for blood pressure (Lynch & Rastam, 2005), 5.6% for health complains amongst children (Torsheim & Wold, 2001), 1% for road traffic accidents (Jones & Jorgensen, 2003), and 0.8% for accidents amongst children (Reading et al., 2008) for example.

We found that the manner by which the neighbourhood was defined made little difference to strengths of association. Indeed, if anything, physical activity levels tended to show a higher degree of clustering within enumeration district census zones compared to areas that were defined on population or built environment characteristics. This does not mean that area characteristics have no influence on children’s physical activity behaviours. Indeed, there is a substantial body of research evidence to suggest that certain features of the physical environment are important (e.g. Tucker et al. 2009, Timperio et al. 2008). But what our analysis does show is that such behaviours do not seem to be influenced by collective membership of any particular set of geographical units, at least not those examined in our study.

A number of previous works (e.g. Kaczynski et al. 2009) have defined neighbourhoods as an area around the residential or school location of each study participant. Under this definition

a neighbourhood is conceptualised and modelled as a different form of spatial entity; rather than being a collective social unit, which multiple individuals share, it is rather seen as a zone of influence which is unique to each individual. The former conceptualisation emphasises features such as social cohesion, social capital and a shared environment, whilst the latter focuses on characteristics of the physical environment that may be encountered in daily living. Our results suggest that the former definition may not be the most appropriate for physical activity behaviours, at least in children where the evidence from behavioural mapping (e.g. Veitch et al., 2006) suggests that perceptions of the neighbourhood environment are particularly individual, and are thus more likely to be influenced by the surroundings of the home. To some extent, our findings also support the views of Saarloos et al. (2009), amongst others, who argue that the activity spaces of individuals (those zones that they actually use on a regular basis) extend far beyond their local neighbourhood, and hence a broader more system-based modelling approach is needed to better understand how the environment may influence health behaviours.

Our study has a number of strengths and weakness. It benefits from using a large well-characterised population-based sample, and an objective measure of physical activity. A further strength is our ability to examine the effect of a diverse series of neighbourhood boundaries, generated using both objective and subjective means, and we took particular care to ensure accurate postcode to census area matching was performed by using contemporaneous Enumeration District to postcode tables.

Limitations include the fact that our findings are restricted to children living in one part of the United Kingdom and may not be generalisable elsewhere. We only had valid physical activity and postcode date for 3,935 children out of an initial cohort of 14,541 (27%) and there is evidence of differential attrition in ALSPAC (ALSPAC, 2009) which may have led to the particular loss of children from more socio-economically deprived neighbourhoods. The sample size may also have reduced our power to detect differences between neighbourhoods, although the small size of the ICCs suggests that neighbourhood effects would not have been large even if more children had provided valid data. Whilst accelerometery provides an objective measure of physical activity it does have limitations such as the poor recording of activity associated with cycling behaviours; although the study only included a small sample of children of commuting to school, a quarter reported some cycling during the week. A further limitation was that we used data on overall physical activity levels in the children and it might be that moderate to vigorous activity patterns show stronger patterning by neighbourhoods, although the very small size of neighbourhood effects we observed means that the magnitude may still be expected to be small. So that our synthetic neighbourhoods were contemporaneous with those delineated by the planners, we used data from the 1991, rather than 2001, UK census and this was 11 years before physical activity measurements were made. Although it is unlikely that neighbourhood characteristics will have changed substantially during this time, it is likely that any changes would operate to dilute the neighbourhood effects observed here, and thus reduce their magnitude. A further limitation with our zone design methodology was that it delineated neighbourhoods based on a limited number of census characteristics. Whilst we chose one social (material deprivation) and one physical (housing type) characteristic, it may be that other measures would be more closely associated with physical activity behaviours. It is, however, noteworthy that the zones we created did have meaning to residents of the study areas (Haynes et al. 2008)

In conclusion, this study has provided new evidence on the effect of area delineation on between-neighbourhood variations in physical activity in children. We found little evidence of clustering in physical activity levels at the neighbourhood level and that neighbourhoods delineated based on social or physical characteristics were similar to those derived from

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population census units. Our results suggest that, whilst characteristics of local environments may be important determinants of activity, it seems that a more individual-based definition of neighbourhood, such as the area surrounding each home or school, may have a greater influence than neighbourhoods that are defined based on shared social functioning or physical characteristics.

Acknowledgments

We are extremely grateful to all the families who took part in this study, the midwives for their help in recruiting them, and the whole ALSPAC team, which includes interviewers, computer and laboratory technicians, clerical workers, research scientists, volunteers, managers, receptionists and nurses. The UK Medical Research Council, the Wellcome Trust and the University of Bristol provide core support for ALSPAC. This publication is the work of the authors and they will serve as guarantors for the contents of this paper. The work to design and generate the neighbourhoods used in this study was funded by the UK Department of Health. Ethical approval for the study was obtained from the ALSPAC Law and Ethics Committee and the Local Research Ethics Committees.

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Table 1

Descriptive characteristics of ALSPAC sample included in analyses

	Boys	**Girls**	**Total sample**
N (%)	1863 (47.3)	2072 (52.7)	3935
Age in years (mean, SD)	11.8 (0.2)	11.8 (0.2)	11.8 (0.2)
Ethnicity (%non-white)	4.0%	3.8%	3.9%
Social class (%) *			
I/II	29.5%	25.6%	27.5%
III non-manual	27.9%	27.9%	27.9%
III manual	26.9%	27.5%	27.2%
IV/V	15.6%	19.0%	17.4%
BMI (kg/m2) (mean, SD) **	18.7 (3.2)	19.4 (3.5)	19.1 (3.4)
Travel mode to school (%) **			
walk	45.5%	42.6%	44.0%
cycle	3.4%	0.9%	2.1%
public transport	20.7%	20.2%	20.4%
car	30.4%	36.4%	33.6%
Distance to school (%)			
<0.5 mile	28.3%	26.2%	27.2%
0.5-1 mile	27.4%	26.5%	26.9%
1-5 miles	36.0%	37.5%	36.8%
>5 miles	8.3%	9.8%	9.1%
Daily counts per minute			
whole week **	668.2 (186.3)	551.7 (150.9)	606.9 (178.3)
after school **	713.9 (275.0)	608.3 (219.6)	658.3 (252.9)
weekend days **	635.2 (259.2)	545.4 (215.0)	588.6 (241.5)

* Overall differences between boys and girls: $p<0.05$

** $p<0.001$

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Table 2

Associations between PA and covariates studied in the sample

	Physical activity over whole week			Physical activity after school			Physical activity at weekend		
Covariate	**Coefficient**	**S. E**	**P value**	**Coefficient**	**S. E**	**P value**	**Coefficient**	**S. E**	**P value**
Constant	1308.18	167.43	<0.001	838.02	193.80	<0.001	1451.45	254.28	<0.001
Male	117.70	5.92	<0.001	89.94	6.83	<0.001	93.87	8.918	<0.001
Age in years	−59.79	14.19	<0.001	−17.17	16.41	0.30	−74.78	21.60	<0.001
BMI (Kg/m2)	−7.12	0.90	<0.001	−6.46	1.03	<0.001	−6.41	1.37	<0.001
Season:									
Spring	86.48	8.37	<0.001	61.53	9.56	<0.001	107.77	12.56	<0.001
Summer	111.46	8.68	<0.001	79.19	10.12	<0.001	144.61	12.93	<0.001
Autumn	47.40	8.83	<0.001	60.57	10.01	<0.001	67.08	13.32	<0.001
Social class:									
3N	6.91	7.91	0.38	15.65	9.13	0.09	−11.99	11.89	0.27
3M	22.97	7.99	0.004	30.39	9.18	<0.001	11.84	11.91	0.32
4 & 5	26.79	9.05	0.003	29.99	10.46	<0.001	29.45	13.71	0.03
Distance to school:									
0.5 - 1 mile	9.84	8.01	0.22	32.77	9.31	<0.001	-	-	-
>1 - 5 miles	0.007	7.50	0.99	−6.14	8.65	0.49	-	-	-
>5 miles	−36.96	11.32	0.001	−63.90	13.09	<0.001	-	-	-

Table 3

Between-neighbourhood intra-class correlation values for physical activity

Neighbourhood set	Whole week		After school		Weekend	
	Unadjusted ICC%	Adjusted ICC%[1]	Unadjusted ICC%	Adjusted ICC%[1]	Unadjusted ICC%	Adjusted ICC%[1]
Largest areas (N=101)						
Super communities	0.13	0.01	0.51	0.27	0.67	0.96
Deprivation zones	0.00	0.01	0.26	0.31	0.61	1.15
Housing type zones	0.20	0.05	0.64	0.18	0.73	0.82
Medium areas (N=201)						
Communities	0.16	0.05	0.40	0.21	0.81	0.60
Deprivation zones	0.5	0.74	1.90*	2.15*	1.05	1.06
Housing type zones	0.17	0.00	0.75	0.00	0.89	1.22
Smaller areas (N=307)						
Sub communities	0.08	0.00	0.72	0.00	0.73	0.79
Deprivation zones	0.00	0.15	0.31	0.65	0.23	0.18
Housing type zones	0.04	0.09	0.60	1.00	1.15	1.20
Smallest areas (N=1653)						
Enumeration Districts	0.19	0.00	2.84*	1.7	1.52	0.64

* $p < 0.05$

** $p < 0.01$

[1] adjusted for sex, age, BMI, season, social class, and distance to school.