Small area variations in health related behaviours; do these depend on the behaviour itself, its measurement, or on personal characteristics?

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Abstract

In this paper we examine the area patterning of four health related behaviours (smoking, alcohol consumption, diet, and exercise) in the West of Scotland, after controlling for a range of individual/household characteristics, using multilevel models. Smoking and drinking were measured both as binary and as continuous variables, and diet and exercise were each measured in two ways: ‘good’ (health promoting) and ‘bad’ (health damaging). ‘Area effects’ (unattributed random variation by post code sector) were found for ‘bad’ diet and for smoking consumption and both ‘good’ and ‘bad’ diet, ‘bad’ exercise patterns and current smoking were associated with postcode sector deprivation, though for ‘bad’ diet the effect was found only for individuals in low deprivation households. We conclude that the influence of area on health related behaviours varies according to the behaviour and the way it is measured, but, apart from age, not according to a range of individual/household characteristics.

Keywords: health related behaviours, area effects, Scotland, deprivation, area deprivation, multilevel models
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Introduction

A considerable body of research in the UK, Europe, and USA has documented
geographical differences in health related behaviours, using a range of sizes of areas,
from regions to smaller localities [1], [2], [3], [4], [5], [6], [7], [8, 9] [10]. Indeed,
national, regional or local variations in health promoting or health damaging
behaviours are often assumed to underpin observed differences in particular disease
outcomes, hence the establishment of many studies designed to examine these
national or regional differences in health (e.g. Monica studies [11] Scottish Heart
Health Study [12], Regional Heart Study [13])

In order both to understand better these geographical variations and to design
policies to reduce health damaging behaviour, it is important to distinguish between
compositional and contextual explanations for area patterning [14], [15]. A purely
compositional explanation for observed area variations in smoking would be that the
sort of people whose personal and household characteristics are associated with high
smoking rates tend to live in certain sorts of regions or localities, and this is why
rates there are high; the people would smoke wherever they lived, and the place itself
has no effect on their likelihood of smoking. A compositional effect has been
invoked to explain differences in mortality between subjects in the Paisley/Renfrew
Study (in the West of Scotland) and in the Whitehall Study (in London and the South
East of England); it was argued that observed differences between the study
populations were due to differences in the distribution of types of people in the two
study populations, not to other differences between the West of Scotland and South East of England [16].

A contextual explanation would be that there are some features of the social, economic, cultural or physical environment that influence smoking rates. Contextual effects may either impact on all residents equally, or more on some types of residents than others (for instance males rather than females). Such environmental influences might include climate, soil or water conditions, the built environment, publicly or privately provided amenities or facilities, socio-cultural factors such as predominant religion or history, and the reputation of the area [14].

Contextual explanations are perhaps most intuitively plausible when we compare countries; cultural differences in attitudes to smoking may be in large part the reason why middle class professional men are far more likely to smoke in Paris than in San Francisco, and people in the Mediterranean may be more likely to eat fresh fruit and salads all the year round than are those in Russia or Scotland because of differential availability. The question is whether such cultural, or ease of access, explanations also apply to variations in health related behaviours within countries, whether by regions, districts or neighbourhoods.

Studies of area effects on health can be divided into those which examine differences between areas without necessarily relating these to particular characteristics of areas, and those which examine an area characteristic considered on an a-priori basis to be important for health (such as deprivation). In briefly summarising the literature we deal with the former type of study first – within this study type, studies vary as to
whether they consider a complete (or representative sample) coverage of areas within a population or whether they select particular areas with contrasting socio-economic and cultural profiles. We deal with the former type first. We confine our survey to the health behaviours examined by us (smoking, alcohol consumption, diet, and exercise) – a number of other behaviours have been examined, including the use of benzodiazepines [17], blood donation, [18]

*Studies relating areas without necessarily relating to particular area characteristics*

In general the evidence for contextual effects on health related behaviours in these studies is suggestive but equivocal. Balaragan and Yuen [1] observed regional differences in smoking and drinking in Britain for both men and women, standardised for age and socio-economic group. However, the regional differences varied by sex and according to which measures of these behaviours were used; for example, the proportion who had never smoked did not differ by region for males, though it did for females, but both sexes showed significant variation by region in the proportions who had given up smoking. Standardised smoking ratios for heavy smoking showed a gradient from the North West to South East for both sexes; standardised drinking ratios were low in Scotland but showed a North West/ South East gradient within England.

Blaxter’s analysis of data from the British 1984 Health and Lifestyle Survey, [2] concluded that social class was related to smoking and drinking in different ways in different types of areas, and that social context was an important determinant of rates of these behaviours. However, Duncan et al [8] criticised her analysis for not taking
the multilevel nature of the data sufficiently into account. Using the same dataset as Blaxter, they examined smoking (smoker v non smoker) and drinking (units per week) at three levels; individual, ward (local electoral districts, average population size around 5000) and region (22 in UK, average population around 2.5 million). Controlling for a number of individual characteristics reduced regional differences in smoking prevalence to 3% either side of the national average, and in average alcohol consumption to 10% either side of the national average. They suggested on the basis of this that: ‘place, expressed as regional differences, may be less important than previously implied’ (p725).

The same team subsequently used the same dataset to examine ward level variations (within region) in smoking behaviour measured in two ways: whether or not a current smoker, and the number smoked per day. Using multilevel models, they found that, controlling for individual/household characteristics, there was significant inter-ward variation in the odds of being a smoker, but not in the number of cigarettes smoked. However, there was a high correlation (0.77) between these two measures, average consumption rates being higher in areas with a higher proportion of smokers. The authors concluded that ‘smoking cultures develop in local neighbourhoods whereby the co-presence of similarly behaving people influences the number of times people practice that behaviour’ ([9], p 827).

Hart et al [19] studied variation in risk factors for coronary heart disease between 22 local government districts in Scotland. Alcohol consumption was measured both in number of units per week and whether or not a current drinker, and smoking was defined as whether or not a current smoker. For both sexes, they found statistically
significant variations between districts after controlling for individual socio-demographic variables in whether a current drinker; and, for men but not for women, in current alcohol consumption. However, the district variation in being a current smoker did not reach statistical significance for either sex.

A study in the western US showed significant variation between 15 communities (most of them the size of entire counties), after controlling for a range of individual characteristics, in the proportion of current smokers, fat and alcohol consumption, and use of seat belts. There were similar effect sizes for smoking and drinking (R² values of 0.56 and 0.55 respectively). While the community’s overall effect on any individual’s behaviour may be seen as small (R² less than 1%), the adjusted differences in prevalence among communities was reasonably large (for example a 7.7% difference in smoking prevalence between the 10th and 90th percentiles of the distribution of estimated prevalences by area after controlling for individual socio-economic characteristics) [7].

Rice et al [20] examined the influence of characteristics of households and areas of residence on drinking behaviour (units consumed in last week), applying a multilevel modelling approach to data from the Health Survey for England. After controlling for individual and household characteristics, they found 58% of unexplained variation attributable to differences between individuals, 40% to households and 2% to areas (the measure of area used here being census enumeration districts typically containing between 150 and 250 households).

Finally, we mention studies in areas with contrasting socio-economic composition.
Uitenbroek et al [21] examined differences in a number of health related behaviours (diet, cigarette and alcohol consumption, exercise) through telephone interviews of adults in three cities with contrasting socio-economic composition, two (Glasgow, Edinburgh) in Scotland and one (Varna) in Bulgaria. As well as differences in overall rates (particularly for smoking, fruit and vegetable consumption and exercise, but also in alcohol consumption) between the cities in the direction of more healthy behaviour patterns in the Scottish cities, differentials according to education and employment status varied between the cities, the effects of both education and employment being similar in both Glasgow and Edinburgh being stronger than in Varna where little effect of these factors was found for any of the health related behaviours examined. Differences in the relationships to age were also found between the cities.

In a study of adults in four socially contrasting neighbourhoods in Glasgow, Scotland, we found neighbourhood variations in diet, whether a smoker or not, and exercise, but not in alcohol consumption [22],[23].

Studies of relation of health related behaviours to specific characteristics of area.

These studies examines all relate health related behaviours to various measures of area deprivation or disadvantage.
Lockyer et al [24] used Canadian data to examine the predictive value of median household income at the enumeration district (ED) level for ten health related behaviours. After controlling for age and sex, ED median household income was significantly associated with six of the behaviours; four of these associations (with two oral health behaviours, use of seat belts and alcohol consumption) remained significant after further adjustment for household income. Smoking was not associated either with self reported household income or with ED median household income.

A study of Finnish adolescents found that drinking alcohol and use of high fat milk products were related to municipality of residence as well as to the socio-economic background of the adolescents ([6], page 1473). Gender modified this relationship; ‘even within the same socio-regional context boys may be subjected to different kinds of environmental pressures than girls’ ([6], page 1473). Further work by these authors (Karvonen and Rimpela, 1997) examining variation between areas of smaller size, 33 subareas in Helsinki, found that prolonged unemployment in an area was influential on different health related behaviours in boys (increased monthly drunkenness) and girls (less abstaining from dietary fat). Jones et al, using the 1984/5 Health and Lifestyle Survey in Britain, found that ward level deprivation predicted smoking status after controls for a large range of personal characteristics, but that there were significant differences in smoking behaviour between wards which could not be explained either by population composition or ward level deprivation [25]. With the exception of those in public sector rented dwellings, and those who left school at 16, among whom there was a suggestion that the effect of
area deprivation on smoking behaviour was less, the effect of area deprivation on smoking behaviour appeared to be uniform across different categories of people.

There are suggestions in some of this literature that effects of area or of aspects of area, for example deprivation on health behaviours may vary according to characteristics of the individual such as gender [19],[25] and housing tenure [25]. This is consistent with recent findings on socioeconomic and area variations in health (as opposed to health related behaviours). Some studies have shown particularly marked health differences, between rich and poor people, in more affluent places [15], [26]; and socio-economic gradients in health are usually stronger for men than for women, with the exception of coronary heart disease ([27],[28]).

Thus the existing literature on the relationship between area of residence and health related behaviours suggests that there may be some variation between areas not accounted for by compositional factors, and that the level of disadvantage or deprivation of the local area may have predictive power over and above individual factors. However, whether or not area effects are detected (as statistically significant) seems to vary between studies. This may be because: different behaviours are studied; they are operationalised in different ways; different sizes of areas are used; variations in sample size.

In this paper we aim to contribute to the investigation of area effects on health related behaviours by examining variation in four health related behaviours (smoking, alcohol consumption, diet and exercise) by area, and their relationship to
area (postcode sector) deprivation, among three age cohorts in the West of Scotland, using multilevel models. We investigate the effect of alternative forms of measurement of these behaviours, and the variation in the effects of area according to personal characteristics. In doing so we address the following questions:

- is there variation between areas in these behaviours, having controlled for personal characteristics?
- is there a relationship between area deprivation and these behaviours, having controlled for personal characteristics?
- is there variation between areas in these behaviours having controlled both for personal characteristics and area deprivation?
- does variation between areas either on its own or in relation to area deprivation differ according to the operationalisation of the behaviours? In particular, for ordinal measures, is this variation affected by the position of the break point to create binary variables for analysis, and, for potentially continuously distributed measures does it depend on whether what is analysed is whether the behaviour occurs at all (e.g. smoker versus non-smoker) or the intensity of the behaviour (e.g. number of cigarettes smoked per week)?
- are there differences according to personal characteristics in any observed variation in these health behaviours, either by area or by deprivation of area?

**Design, measures and methods**

**Design**

The data were obtained from the first, baseline, wave of the West of Scotland Twenty-07 Study, a prospective study of three age cohorts, aged 15, 35 and 55 in...
1987/8, in the Central Clydeside Conurbation (CCC), a predominantly urban area in and around Glasgow City with a population size of 1.7 million, and a standardised mortality ratio (relative to Scotland as a whole) of 109, around the 1981 census [29]. The design involved a two stage stratified sample based on 52 postcode sectors (out of 203 postcode sectors in CCC), having average population size 8320, as primary sampling units, the same postcode sectors being used for each age group, and sampled with probability proportional to the total population in the age groups in the postcode sector. The sampling frame was Strathclyde Regional Council’s Voluntary Population Survey, an enhanced electoral register with information on the age and sex composition of households [30]. For further details of the sampling procedure see [31]. ‘Area of residence’ was here defined and analysed as postcode sector of residence at interview.

Interviews were conducted by trained interviewers in respondents’ homes. Achieved sample sizes for the three age groups were, in the 15, 35 and 55 year age groups, 1009, 985 and 1042 respectively. Patterning of a range of health measures by postcode sector and social class has previously been reported ([32], [33]).

Analysis is by multilevel models. These have origins in economics and other subject areas some way back in time [50]. They allow for the ‘residual correlation between individuals within contexts’ [51] thus avoiding the overestimation of precision encountered when these residual correlations (of unexplained variation in the model within higher order units – areas – schools etc.) are ignored in the analysis. By relaxing common modelling constraints – for example, by allowing the relationship of health to individual or household deprivation to vary randomly between areas;
and they allow greater generality of inference to the population from which the sample is drawn.

**Measures**

Smoking was defined in two ways; firstly whether the respondent currently smokes or not, and secondly in terms of the number of cigarettes or equivalent (cigars, pipes) smoked in a week. For analysis of the latter, due to the positive skewness of the distribution, a transformation is made to log (number of cigarettes, or equivalent, per day), those with no cigarettes, or equivalent, per day in last week having been excluded.

Drinking was defined both as whether or not currently drinking at or above the safe limits (set at the time by the Royal College of Psychiatrists, namely 14 units and above for females and 21 units and above for males) and in terms of the number of units drunk in the last week (for 15 years olds the measure used was number of units drunk on the last occasion). Two measures were constructed for exercise and diet, one representing the ‘good’ (health promoting) pole and one representing the ‘bad’ (health damaging) pole. Exercise was defined as the total amount of exercise undertaken in free time in the previous week "which made you sweat or made you out of breath for more than 20 minutes...". The ‘good’ pole corresponds to exercise of this nature on at least two occasions per week, the ‘bad’ pole corresponding to less than one occasion per week (for 15 year olds, exercise both in school and outside school was counted). A measure of diet was based on five self reported measures: whether usually eats ‘fresh fruit once a day or more’, and ‘fresh vegetables once a
day or more’, and whether usually consumes ‘wholemeal bread as opposed to white bread’, ‘soft margarine or spread as opposed to hard margarine or butter’ and ‘skimmed/semi-skimmed, as opposed to full cream, milk’. A ‘good’ diet is here defined as comprising four or more of these items, and a ‘bad’ diet as comprising none of these items. This diet scale used is similar to the scale used by Blaxter, [2], though it excludes information, used in her scale, on consumption of fried foods (including chips) and sweets/chocolates/biscuits.

Personal or household socio-demographic characteristics used in the analysis include occupational social class, education, household material deprivation, marital status and whether moved in last five years. These are defined as follows; social class is based on own occupation for the 35 and 55 year groups, and on occupation of head of household for the 15 year group, and is classified according to the Registrar General’s classification of occupations[34] and then grouped into three categories: non-manual, skilled manual, and semi or unskilled manual. Education was defined as whether left school at or beyond the statutory minimum school leaving age then in operation for that cohort. For the fifteen year cohort, who had not yet left school, a comparable measure was obtained by taking the pupil’s assessment at interview at age 15 of whether they were likely to stay on at school beyond the minimum school age.

Income (after deduction for tax, benefits, pensions etc.) was asked in grouped form (11 groups of roughly equal size) for the 15 and 35 year groups and, for 55 year group, the option of answering a question on income group was given to those not giving actual income. Further details are given in [35]. Household
equivalent income is then obtained using the McClements [36] scale (see [37] [35]). Housing tenure was divided into owner occupied versus renting or other, and car access was defined as living in a household with or without access to a car or van. Household (material) deprivation, a continuously distributed constructed variable, is the principal component underlying the following variables; household equivalent income, car ownership, and housing tenure. It is derived similarly to the measure used previously in this study [32].

Marital status for the older two groups was defined as never, currently or ex-married. Recent movers were defined as those who had moved house in the last five years and includes people who moved within the same postcode sector. Deprivation of postcode sector was measured using the categorical Carstairs-Morris Deprivation Index (DEPCAT) [38], having a range from 1 (non-deprived) to 7 (most deprived), derived from the sum of standardised proportions at the 1981 census of persons in households with no car access, overcrowded housing, male unemployment and persons in households headed by someone in social classes 4 or 5.

Because of a relatively high proportion of missing values in particular groups for particular variables (social class, education and recently moving house), additional variables, indexing missing values on these variables, were included as dummy variables in order to maximise the size and representativeness of the analysed sample.
The maximum percentage missing in any such group was 25%. Due to the few remaining missing values (on further variables) not represented as dummy variables the analysed sample – for cigarette smoking and alcohol consumption - reduced to 985, 967 and 1022 respectively for the 15, 35 and 55 year cohorts (comprising 97.6, 98.2 and 98.0% of the original achieved in sample of each age group). Missing values on the dependent variables diet and exercise reduced overall sample sizes on these variables to 2652 and 2845 (89.2 and 95.7 percent respectively of that for current cigarette smoking and alcohol consumption). The mean number of subjects per postcode sector is 45, range 31 to 81.

Methods

Multilevel models ([39], [32], [40]) were used to relate each of the four health related behaviours to demographic and socio-economic characteristics. We do not propose to describe these methods in any detail in this paper, as they have been described and applied in much of the literature referred to. Essentially, for each behaviour they provide an estimate of the size, and standard error, of the variance component at the area level after adjusting for a range of demographic and socio-economic variables at the individual/household level. The variance component at the area level is used as an estimate of the ‘effect’ of area (or area effect). This is a summary measure, estimated by the variance of the differences between the average behaviour for that area and that predicted from the model which includes relevant individual, household, and in some cases area characteristics. All models in this paper which use continuously varying outcomes (number of cigarettes smoked, units of alcohol drunk) allow the (error) variation at the individual level was allowed to vary by sex and by age group. For binary outcomes, extra-binomial individual level
variation was allowed in all models (though the possible variation in this by age group or sex was not assessed).

The analyses proceeded as follows; firstly we regressed each behaviour on all personal characteristics simultaneously, together with all two way interactions with age and sex. Area level variance was assumed constant over all age/sex categories. Non-significant interactions were then eliminated by backward elimination in the following order (based on the relative sizes of the overall effects of these variables, from the lowest to the highest); recent mover, marital status, education, social class, household material deprivation. Non-significant main effects, when they did not interact with other variables, were then eliminated in the same order. The area level variation was then allowed to vary according to age and sex, both separately and in combination. Variation in the area level variation was then further assessed, separately, by the remaining explanatory variables, namely occupational social class, education, marital status, whether recently moved, and household material deprivation. When significant variation was found between groups, multiple comparison tests were carried out to test which of the contrasts was responsible for the difference, and categories which were non-significantly different amalgamated. In addition, some post-hoc examination was carried out of differences which did not achieve significance overall, and possible divisions into two groups were examined for significant differences. We advise caution in the interpretation of these results due to the multiple testing involved. Finally, the categorical Carstairs-Morris deprivation index (DEPCAT) was included in the model, this being allowed to interact separately with all explanatory variables in the model namely age, sex, occupational social class, education, marital status, whether recently moved, and
household material deprivation. These interactions parallel the allowing for differences in the size of the area level variance according to these factors.

Two measures, raw and normed, of the size of the area effect are calculated. Both measures use the estimated probabilities (or prevalences) corresponding to the 10th and 90th percentiles of the distribution of random effects at area level (area) for a chosen reference group (male, aged 35, married, social class 1 or 2, non-recent mover, with average household material deprivation), the first being a raw measure, the second norming by the mean in the reference group. The raw measure (col. 6, Table 2) is calculated by firstly obtaining an estimate of the standard deviation of the random effect at the area level (0.41 for ‘bad’ diet). 1.28 times this value is then subtracted from, and added to, the estimated logit corresponding to the chosen reference group to form logits corresponding to the 10th and 90th percentiles of the distribution, assumed normally distributed. These logits are then transformed back into probabilities (giving 0.13 and 0.30 for ‘bad’ diet). The difference between these probabilities constitutes the measure. The normed measure (col. 7, Table 2) expresses the raw measure as a percentage of the mean prevalence for a reference group. This allows studies to be compared in which the mean prevalence varies. It also allows, as in this case, comparisons between measures on different scales, for example of prevalence (whether a current smoker, measured on a binary scale) or intensity (number of cigarettes per week, measured on an interval scale). These measures allow unbiased comparisons between studies with samples of differing size, being unaffected by differential additional sampling variability - the posterior means, on which these measures are based, are shrunk to the overall sample mean.
(Goldstein, 1995) by factors inversely proportional to the sample size. Alternative measures for health inequality are compared by Manor et al [41].

All models were fitted using MLn [39]. For binary outcomes, second order PQL (predictive quasi-likelihood) estimation was used throughout for testing the variations in the specification of the random part of the models [42]. Variation at area level, both overall and its variability according to further explanatory variables, was assessed using the Wald Test [43]. As the size of the variance component at the area level was generally small we had some confidence that the PQL (second order) estimation methods would give reasonably unbiased estimates and that the use of more time consuming MCMC methods (Goldstein et al 1998) would not be necessary.

**Results**

Table 1 shows the prevalence of each of the health related behaviours according to age and sex. Men had healthier exercise patterns than women, this being more marked when measured by the ‘good’ than ‘bad’ exercise categories, and younger persons had healthier exercise patterns than older ones. Men in the two adult groups smoked more tobacco than women, though differences in whether or not a current smoker were inconsistent between sexes in these adult age groups. Tobacco consumption rates, but not generally the probability of being a current smoker, were lower in the 55 than 35 year age groups. In general, females had a healthier diet than males, and differences in diet between the sexes was more marked, in all age groups (though differences were smaller at 15 years), for ‘good’ than for ‘bad’ diet. ‘Good’ diet was most prevalent among the middle cohort, though amongst males at this age
A 'bad' diet is also more common than among either of the other age groups. Alcohol consumption (both measured in mean units and according to the percentage over safe limits) was greater amongst males than females in both adult age groups, and was lower in the oldest group.

Table 2 shows variation by area of residence for each health related behaviour separately over all age groups combined, after controlling for personal characteristics in the manner described in the previous section. Statistically significant variation according to area was found for 'bad' diet and smoking consumption. For the continuously distributed measures (alcohol and smoking consumption) the remaining random variability at the individual level was found to vary according to sex and age in combination, with larger variation throughout all age groups for males than for females, and largest variation in the 35 year cohort. There was no evidence of any significant extra-binomial variation for any of the binary measures.

No statistically significant variation in the size of the area effect was found for any of the health related behaviours by age or by sex. Variation was next examined therefore by the remaining explanatory variables, namely occupational social class, education, marital status, whether recently moved and household deprivation.

For one behaviour only, smoking consumption, variation in the size of the area effect between areas was found for marital status with variance for ‘never married’ of 1.74 (standard error, 0.04), and for ‘currently married’ of 2.28 (standard error 0.03) and for ‘ex-married’ of 0.00 (standard error, 0.00). The difference between categories
was highly significant, $\chi^2 = 14.29$, $p<0.001$). Only for the ‘ex-married’ is the effect of area significantly different from zero.

The raw 90%-10% measure shows some variation between the binary outcomes, having largest value (0.12) for ‘bad’ diet and the smallest (0.01) for ‘good’ diet. The corresponding normed measure ranges 60.1% for ‘bad’ diet to 10.4% for ‘good’ diet. The order of the raw and normed measures for the binary measures varies, the minimum normed measure (7.4%) occurring for drinking over limits, due to the relatively high mean probability of occurrence. Norming produces measures of a similar size and spread of sizes for the continuous measures (8.4, 21.2) and for the binary measures (7.4 to 60.1, mean 20.1).

Table 3 examines the relationship of the (Carstairs-Morris) area deprivation index to each of the outcomes separately after controlling for the relationship to all individual/household level variables in the model. Diet (both ‘good’ and ‘bad’), exercise (‘bad’) and ‘whether current smoker’ were each significantly related to area deprivation, greater deprivation being associated in each case with less healthy behaviour.

Table 4 shows interactions between the area deprivation index, household deprivation, sex and age. Interactions with household deprivation were found only for ‘bad’ diet (shown in Figure 1). The two lines show the relationship to area deprivation for high household deprivation (one standard deviation above the mean) and for low household deprivation (one standard deviation below the mean). A positive relationship is found between area deprivation and ‘bad’ diet for low
household deprivation but not for high individual deprivation. No interactions were found with sex. Area effects are examined for variation by age between the 15 year age group and the 35 and 55 year age groups combined in columns 4,5 of Table 4. For most of the health related behaviours effects of area deprivation were found for the 35 and 55 year age groups only; these include 'good' and 'bad' diet, 'bad' exercise, number of units drunk and current cigarette smoking. For 'good' exercise the effect was significantly different and of opposite sign in the 15 and 35/55 year age groups but was not significant in either case. A further analysis of 'good' exercise found stronger and significant(negative) relationship to area deprivation in the 35 year age group (-0.205 st. error 0.085). For 'drinking over limits' and 'number of cigarettes smoked' effects were not significant in either age group nor were there differences between age groups.

For 'bad' diet the variance between areas remained statistically significant after controlling for area deprivation, in interaction with household deprivation, (0.124, standard error of 0.058, $\chi^2_{1.1}=4.53$, p=0.031) reducing to 70% of the value before such controls.

Examination of interactions of area deprivation index with further explanatory variables showed only one relationships, the effect of area deprivation being lower in social classes 3 (manual and non-manual) then in social class 1 or 2 (0.165, standard error 0.078). In interpreting this relationship we would caution against multiple testing generating spurious significance
We mapped the residuals from the model for ‘bad’ diet and found two postcode sectors with greater than predicted rates of ‘bad’ diet; one with low levels of area deprivation and one with middling levels. It would be interesting, but beyond the scope of this paper, to examine possible reasons, either in compositional or contextual factors, for their dietary habits.

**Summary**

We return now to the questions posed at the end of the introduction.

- **Is there variation between areas in these behaviours, having controlled for personal characteristics?** Yes, but only for ‘bad’ diet and amount smoked.
- **Is there a relationship between area deprivation and these behaviours, having controlled for personal characteristics?** Yes, but only for some behaviours and ways of measuring them (‘good’ and ‘bad’ diet, current smoking, and ‘bad’ exercise patterns), behaviour conducive to better health being found in less deprived areas. Relationships are in all cases linear; no evidence of quadratic relationships to area deprivation was found for any of the outcomes examined.
- **Is there variation between areas in these behaviours having controlled both for personal characteristics and area deprivation?** Only for ‘bad’ diet. 70% of the variation in ‘bad’ diet between areas after controlling for individual variables (10th and 90th percentiles for probability of bad diet in reference group are 0.15, 0.27 respectively) is retained after further controlling for area deprivation.
- **Does variation between areas either on its own or in relation to area deprivation differ according to the operationalisation of the behaviours?** Yes, it seems that how the behaviours are operationalised determines whether there is any area variation. For example ‘bad’ diet varies by area and by area deprivation, but
‘good’ diet varies only with area deprivation. Also, ‘bad’ exercise patterns, but not ‘good’ exercise patterns, and current smoking (in adults only) but not amount smoked were associated with area deprivation.

- Are there differences according to personal characteristics (age, gender, material deprivation, social class, marital status, whether recent mover) in any variation in these health behaviours by area or by deprivation of area? Apart from an interaction between household and area deprivation for ‘bad’ diet, and differences in the variation in number of cigarettes smoked between areas according to marital status, there were no interactions with personal characteristics. Effects of area deprivation varied with age for ‘good’ exercise and current smoking.

Generally effects of area deprivation were stronger in the adult groups.

Discussion

We address four main questions in this discussion. Firstly, why has previous literature shown inconsistent results? Second, how do our results relate to this literature? Thirdly, how do we reconcile the apparent differences between the apparent lack of the effects of area per se with the apparent presence of effects of area deprivation? Fourthly, we try to clarify differences between multilevel data and multilevel models. Finally we make some concluding comments.

Why has previous literature shown inconsistent results?

Previous work on area effects on health related behaviours have produced somewhat inconsistent results, some studies showing few contextual effects once individual characteristics are taken into account, and most finding that area characteristics
explain less of the variance in behaviours than individual characteristics. Whilst we recognise that results may legitimately differ according to the setting of the study (population, period, ages of subjects etc), we would suggest that the lack of consistency in these results stems in part from lack of consistency in a) the conceptualisation and measurement of health related behaviours, b) the particular individual or household characteristics used as controls, c) the conceptualisation and definition of areas of residence and their characteristics. Health behaviours are analysed either as binary good/bad categories, or as ordinal or continuous scales. Individual characteristics vary, from a core of age, sex, and measures of socio-economic position, to include variables such as family composition, marital status and, in one instance, prior health. Moreover the size and nature of the areal units shows considerable variation, from large regions to relatively small enumeration districts.

Given that there is no a priori reason why area effects should be similar in size across areal scales, behaviours, and types of people, this inconsistency in findings is not surprising. As Curtis and Jones have recently commented:

‘Empirical research using a variety of methods to explore the existence or the relative importance of contextual effects has produced results which are not always consistent. This inconsistency may arise partly from the different data and methods which have been used. It also seems likely that we have not yet fully and adequately theorised how contextual or environmental effects may occur; this may have implications for the design and the interpretation of empirical studies.’ [15](p649)
In this paper we, like others, have used administratively defined areal units (postcode sectors, which are built up of a number of mail delivery rounds) rather than residential areas based on theory in respect of either the scale of operation of area effects, or the defining characteristics of areas which might influence health related behaviours. The detection of area effects might be more likely if one defined areas in relation to features hypothesised to influence the behaviours in question; for example, the price and availability of healthy food, the number and location of drinking places, alcohol outlets or facilities for exercise, the location of industries with traditionally high smoking habits etc.

How do our results relate to this literature?

Our approach to the question of whether area effects might differ according to the behaviour, the way it is measured, and the characteristics of the people was a reasonably fine grained one. Considering firstly the area effects, we detected an area effect only for one type of health related behaviour, reporting a diet considered ‘bad’ according to current health promotion advice; we found no area effect on ‘good’ diet or on any of the other health related behaviours examined. However area deprivation, as well as being related to ‘bad’ diet was also related to ‘bad’ exercise and to current smoking. For ‘bad’ diet, in addition, an interaction between individual and area level deprivation was found, being related to area deprivation only at low levels of individual deprivation.
Moreover for all behaviours the relationship to area deprivation was as strong or stronger in the adult cohorts (35 and 55 years of age) as in the 15 year cohort (only exception being number of cigarettes smoked).

No differences were generally found in either the size of the area effect by any of the further individual or household level explanatory variables examined (namely gender, household social class, household deprivation, whether recently moved house, current marital status). The only exception to this was the area effect on smoking consumption, which was present for both the groups ‘never married’ and ‘ex married’ but not for ‘currently married’.

The findings on diet are broadly consistent with earlier findings from four neighbourhoods in Glasgow City which found significant variations between neighbourhoods after controlling for individual characteristics in the consumption of some foodstuffs (e.g. fruit, vegetables, meat, bread, spreading fats and sugar) but no such area variation for other foods (e.g. semi-skimmed milk, white fish, confectionery, cakes and pastries, savoury snacks). That paper concluded that ‘intra-urban variations in food consumption cannot be explained simply by socio-demographic or socio-economic factors in individuals and that cultural and supply factors also need to be taken into account’ [22]. Similar findings have been reported from a study of neighbourhoods in four US communities; neighbourhood patterning of energy adjusted intake of fruit, vegetable, meat and fish intake persisted in particular gender/ethnic groups after controlling for individual level income, although mean differences between neighbourhoods were small compared to individual differences and not always statistically significant, associations with
neighbourhood income being more consistent for foods than for nutrients, inconsistent associations being found for intake of saturated fats, polyunsaturated fats, and cholesterol [44]. Like Forsyth et al, Diez-Roux and colleagues [44] concluded that ‘public health efforts to change dietary habits may benefit from further research into possible community level determinants of diet’ (p62, 1999).

Number of cigarette smoked per week but not whether current smoking varied significantly over all population groups by area. This finding differs from those of several other studies which have found significant but small area effects on whether a smoker, using various different sizes of area, e.g. counties in the Western US [7], electoral wards or regions in Great Britain [8]. We found that current smoking, but not the quantity of tobacco smoked, was associated in adult cohorts with area deprivation after controlling for a range of household characteristics. This is similar to the finding reported by Duncan et al (1996) to the effect that there was significant variation between electoral wards in the probability of being a smoker but not in the number of cigarettes smoked.

Neither the number of alcohol units consumed in the last week or whether respondents consumed over the safe limits recommended at that time showed significant area variation nor were related to area deprivation. This is consistent with an early study of four neighbourhoods in Glasgow, which found no significant neighbourhood differences for alcohol consumption after individual controls, although such differences were observable for diet, smoking and participation in sport [23]. However it is not consistent with the findings in the UK Health and Lifestyle Survey of larger regional variation in alcohol consumption than for
smoking [8], and from the Health Survey for England, which found significant but small differences between enumeration districts in drinking patterns (Rice et al 1998) and the finding of variations in alcohol consumption between local government districts in Scotland [19].

Finally, there was no significant variation between postcodes for either ‘good’ or ‘bad’ exercise patterns, but ‘bad’ exercise patterns were significantly related to area level deprivation. In a previous study in four localities in Glasgow, exercise behaviour showed neighbourhood effects after individual controls [23], but we are not aware of many other studies of area variations in exercise.

**Effects of area per se (area effects) versus effects of area deprivation.**

What is the explanation for the finding of significant linear relationships to area deprivation when no area effect is found (in models which do and which do not include area deprivation)? It is tempting in such cases to suggest that the area deprivation variable may represent, at least in part, individual level variables, not in the model, which would have explanatory power given the individual level variables already in the model. An example of this is shown in the debate (e.g. [45], [46]) as to whether effects of area deprivation on health are a proxy for the effects of smoking. This is certainly possible, and so acknowledged in the similar analysis of health outcomes in this sample [32].

However the finding of effects of such area level variables is consistent with area effects which may exist but are not detectable on the sample itself. This lack of
detectability is most likely to be due to a relative lack of power in the random effects analysis [40] although other possibilities are model mis-specification, particularly of the random or error distribution at the area level, for example when the assumption of a normal distribution is inappropriate. Such assumptions can be tested using diagnostic tests [39, 40].

The implications of this are that a strategy of assessment of the possible existence of an area effect prior to an attempt at explanation of it, through consideration of its possible components through area characteristics, such as area deprivation, social cohesion, migration history, infrastructures, or indeed further contextual attributes, may be misguided.

*Multilevel data versus multilevel models*

The recent interest in the joint effects of health of individual level, household level and data at higher levels of aggregation (for example, area or residence, workplace, school), and of the ways in which these variables might interact - modifying the effects of each other - can be seen as a welcome recapturing of the ‘proper’ role of medical sociology, aptly illustrated by Mechanic [47], and as a correction in part to the movement in the 1980’s to concerns with individualism and economic explanations. The inclusion of data at multiple levels into models of health does not logically require multilevel models for their analysis – indeed the move towards joint inclusion of variables measured at a number of levels into analysis at the individual level is illustrated through text books prior to the technical innovation of multilevel modelling (e.g. [48]). However in the presence of area effects of the type examined
in this paper it is likely that overestimation of precision of empirical results will have occurred, whether or not area level variable were or were not incorporated into individual level models [49].

Amongst issues remaining for further investigation, particularly in the context of health related behaviours is the proper recognition of the supra-individual structures for example place - of work – of residence – of education, and the incorporation of these structures into the databases and analyses used. A relatively neglected aspect of multilevel modelling has been their use in allocating unexplained variation to a number of hierarchical levels. Such analyses (e.g. of the relative role of individual, household and area influence of alcohol consumption in adults [20]) has implications for the most effective design of policies for intervention to ‘improve’ health related behaviours.

Concluding comments

The dependence of the existence of area effects on the particular division point for one of the two ordinal health related behaviours examined (diet) suggests that careful consideration should be given to the binary division point used when ordinal outcomes are analysed. In addition this study, like previous research on this dataset [32], has demonstrated the need to take account of variability at the individual level in respect of age and sex when examining continuously distributed intensity measures (number of units drunk in last week, number of cigarettes per week).

Further examination of ordinal measures such as of diet and exercise examined here could usefully utilise the ordinal nature of the dependent variable in the analysis and
software is currently being developed within MIWin for these purposes [52]. The
dependence of the findings on the division point used in dichotomous splits shown in
this paper suggests, however, that this should be taken account in the construction of
such ordinal response models. Further insights into the manner of operation of area
effects can be obtained through models which consider alternative definitions of a
particular health related behaviour, or indeed a number of health related behaviours
as simultaneous, multivariate responses, thus allowing the relationship between the
residuals at the area level corresponding to different behaviours to be estimated and
plotted (Goldstein, 1995). We have also noted that the definitions of area we have
used here are essentially arbitrary, being determined by the postal distribution
bureaucracy. However these area units may have attractive homogeneity properties
(Raab, Pers. Comm.) in comparison to other administratively defined entities (e.g.
wards). Nevertheless the size of the area effect found may relate to the size of the
areas chosen and some preliminary work of ours [53] has suggested that this may
be the case.

We have noted that, apart from differences in the size of the estimate of area effect of
'bad' diet according the marital status, we found no differences in effects of area by
either age or sex or by any of the further explanatory variables examined (social
class, household deprivation, education, whether recently moved, marital status).
Moreover effects of area deprivation on most of the health related behaviours under
consideration differed little according to age, significant differences in effect
between 15 year and 35/55 year age groups being found only for 'good' exercise and
current smoking.
The general lack of effects in 15 year olds is noteworthy as we may have hypothesised larger area effects on health related behaviours which are illegal for the youngest (15 year) cohort (i.e. smoking, alcohol consumption), due to possible variation in supply side factors (local availability, shop keepers prepared to break the law for example), and in the social networks which enable these young people to get access to these substances.

We conclude that relatively fine grained approaches are more appropriate in this field than an approach which assumes similar area variation (or lack of it) across behaviours, ways of measuring them, and types and size of areas. We also believe that we need better theoretical models and conceptualisations of ‘area effects’ which incorporate hypotheses about possible causal pathways and determinants of behaviours. Health promotion policies may need to take into account contextual influences on health damaging or enhancing behaviours, but in order to do this effectively we need more information about the nature of these contextual influences, how they work, and the scale at which they operate.
Acknowledgements

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Table 1. Prevalence of health related behaviours by age and sex groups (percentages, except for smoking and for alcohol consumption; number of cigarettes or equivalent per day, number of units in last week respectively)

<table>
<thead>
<tr>
<th>Age</th>
<th>Sex</th>
<th>Exercise ('good' %)</th>
<th>Exercise ('bad' %)</th>
<th>Smoking Consumption mean</th>
<th>Smoking Current %</th>
<th>Diet ('good' %)</th>
<th>Diet ('bad' %)</th>
<th>Alcohol Consumption Mean</th>
<th>Alcohol over limits %</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:</td>
<td>male</td>
<td>83</td>
<td>5</td>
<td>5.5</td>
<td>17</td>
<td>7</td>
<td>14</td>
<td>9.0</td>
<td>5</td>
</tr>
<tr>
<td>15:</td>
<td>female</td>
<td>65</td>
<td>11</td>
<td>4.5</td>
<td>18</td>
<td>13</td>
<td>11</td>
<td>6.1</td>
<td>8</td>
</tr>
<tr>
<td>35:</td>
<td>male</td>
<td>21</td>
<td>65</td>
<td>22.8</td>
<td>33</td>
<td>13</td>
<td>20</td>
<td>17.9</td>
<td>56</td>
</tr>
<tr>
<td>35:</td>
<td>female</td>
<td>10</td>
<td>77</td>
<td>17.3</td>
<td>45</td>
<td>23</td>
<td>12</td>
<td>5.4</td>
<td>13</td>
</tr>
<tr>
<td>55:</td>
<td>male</td>
<td>8</td>
<td>87</td>
<td>6.3</td>
<td>49</td>
<td>8</td>
<td>14</td>
<td>10.1</td>
<td>16</td>
</tr>
<tr>
<td>55:</td>
<td>female</td>
<td>6</td>
<td>88</td>
<td>2.5</td>
<td>41</td>
<td>15</td>
<td>14</td>
<td>2.8</td>
<td>2</td>
</tr>
</tbody>
</table>
Table 2. Variance of random terms at individual and area levels\(^1\), and derived statistics for reference group

<table>
<thead>
<tr>
<th>Health related behaviour</th>
<th>Individual level</th>
<th>Area level</th>
<th>Test of non-zero variance at area level(^2)</th>
<th>Logit for reference group(^3)</th>
<th>Raw measure: (90%-10% of posterior distribution)</th>
<th>Mean of posterior distribution</th>
<th>Normed Measure: (90%-10%/Mean) of posterior distribution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diet: 'good'</td>
<td>0.99 (0.03)</td>
<td>0.02 (0.04)</td>
<td>non. sig.</td>
<td>-2.10</td>
<td>0.011</td>
<td>0.109</td>
<td>10.4</td>
</tr>
<tr>
<td>Diet: 'bad'</td>
<td>0.97 (0.03)</td>
<td>0.17 (0.07)</td>
<td>6.20 (0.05)</td>
<td>-1.36</td>
<td>0.123</td>
<td>0.204</td>
<td>60.1</td>
</tr>
<tr>
<td>Exercise: 'good'</td>
<td>0.98 (0.04)</td>
<td>0.04 (0.04)</td>
<td>non. sig.</td>
<td>-1.17</td>
<td>0.043</td>
<td>0.237</td>
<td>18.1</td>
</tr>
<tr>
<td>Exercise: 'bad'</td>
<td>0.97 (0.04)</td>
<td>0.05 (0.04)</td>
<td>non. sig.</td>
<td>0.78</td>
<td>0.057</td>
<td>0.686</td>
<td>8.3</td>
</tr>
<tr>
<td>Drinking: over limits</td>
<td>1.01 (0.03)</td>
<td>0.03 (0.05)</td>
<td>non. sig.</td>
<td>0.25</td>
<td>0.042</td>
<td>0.562</td>
<td>7.4</td>
</tr>
<tr>
<td>Drinking: number of units/week</td>
<td>Male: 15</td>
<td>40.2 (4.7)</td>
<td>0.29 (0.27)</td>
<td>non. sig.</td>
<td>0.64</td>
<td>3.03</td>
<td>21.3</td>
</tr>
<tr>
<td></td>
<td>Female: 15</td>
<td>29.2 (3.7)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Male: 35</td>
<td>361.0 (24.5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female: 35</td>
<td>70.9 (4.4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Male: 55</td>
<td>145.1 (9.5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female: 55</td>
<td>20.2 (1.2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoking: current</td>
<td>1.00 (0.03)</td>
<td>0.03 (0.02)</td>
<td>non. sig.</td>
<td>-1.34</td>
<td>0.040</td>
<td>0.206</td>
<td>19.4</td>
</tr>
<tr>
<td>Smoking: number of cigarettes/week</td>
<td>Male: 15</td>
<td>19.1 (3.06)</td>
<td>0.85 (0.40)</td>
<td>4.38 (0.05)</td>
<td>0.96</td>
<td>11.4</td>
<td>8.4</td>
</tr>
<tr>
<td></td>
<td>Female: 15</td>
<td>12.0 (1.80)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Male: 35</td>
<td>163.7 (20.2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female: 35</td>
<td>86.8 (8.0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Male: 55</td>
<td>61.9 (8.7)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female: 55</td>
<td>12.6 (1.8)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Figures corresponding to behaviours for which the area level variance is significantly different to zero are shown in bold.

\(^2\) Chi-square with 1 degree of freedom and p value given when statistically significant at 5% level.

\(^3\) For smoking (no cigarettes per week) and drinking (number of units per week) this figure is omitted as outcome is continuous.
Table 3. Relationship (regression coefficient) of area level deprivation index (Carstairs-Morris) to health related behaviour⁴⁵

<table>
<thead>
<tr>
<th>Health related behaviour</th>
<th>Coefficient</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>diet; 'good'</td>
<td>-0.085</td>
<td>0.040</td>
</tr>
<tr>
<td>‘‘;’bad’</td>
<td>0.106</td>
<td>0.050</td>
</tr>
<tr>
<td>exercise; 'good'</td>
<td>-0.006</td>
<td>0.040</td>
</tr>
<tr>
<td>‘‘;’bad’</td>
<td>0.123</td>
<td>0.037</td>
</tr>
<tr>
<td>drinking; number units</td>
<td>0.053</td>
<td>0.046</td>
</tr>
<tr>
<td>drinking; over limits</td>
<td>0.054</td>
<td>0.047</td>
</tr>
<tr>
<td>smoking; number</td>
<td>0.205</td>
<td>0.127</td>
</tr>
<tr>
<td>smoking; current</td>
<td>0.139</td>
<td>0.029</td>
</tr>
</tbody>
</table>

⁴ statistically significant (in bold).
⁵ For bad diet, model includes interaction between area level deprivation and individual deprivation - coefficient for area deprivation is therefore for individuals with average individual levels of deprivation in the sample.
Table 4  Interactions of area deprivation with sex, age and household deprivation\(^6\)

<table>
<thead>
<tr>
<th>Health related behaviour</th>
<th>Area deprivation*sex param. (st. err)</th>
<th>Area deprivation*household deprivation param (st. err)</th>
<th>Area deprivation (35, 55 years only) param (st. err)</th>
<th>Area deprivation* (15 versus 35, 55 years) param (st. err)</th>
</tr>
</thead>
<tbody>
<tr>
<td>diet; ' good'</td>
<td>-0.011 (0.077)</td>
<td>0.001 (0.039)</td>
<td>-0.097 (0.046)</td>
<td>0.049 (0.090)</td>
</tr>
<tr>
<td>diet; ' bad'</td>
<td>-0.075 (0.075)</td>
<td>-0.103 (0.040)</td>
<td>0.118 (0.056)</td>
<td>-0.041 (0.086)</td>
</tr>
<tr>
<td>exercise; ' good'</td>
<td>-0.026 (0.067)</td>
<td>0.034 (0.035)</td>
<td>-0.089 (0.053)</td>
<td>0.180 (0.075)</td>
</tr>
<tr>
<td>exercise; ' bad'</td>
<td>-0.002 (0.066)</td>
<td>-0.002 (0.035)</td>
<td>0.148 (0.041)</td>
<td>-0.132 (0.088)</td>
</tr>
<tr>
<td>drinking; number units</td>
<td>0.014 (0.260)</td>
<td>0.172 (0.092)</td>
<td>0.037 (0.112)</td>
<td>-0.031 (0.251)</td>
</tr>
<tr>
<td>drinking; over limits</td>
<td>0.043 (0.052)</td>
<td>0.004 (0.044)</td>
<td>0.052 (0.048)</td>
<td>0.025 (0.168)</td>
</tr>
<tr>
<td>smoking; number</td>
<td>0.217 (0.269)</td>
<td>0.051 (0.054)</td>
<td>0.028 (0.171)</td>
<td>0.356 (0.233)</td>
</tr>
<tr>
<td>smoking; current</td>
<td>0.043 (0.052)</td>
<td>0.026 (0.027)</td>
<td>0.182 (0.032)</td>
<td>-0.206 (0.070)</td>
</tr>
</tbody>
</table>

\(^6\) Bold indicates statistically significant at the 5% level
Fig. 1. Probability of 'bad' diet in relation to categorical area deprivation index for high (1 standard deviation above mean) and low (1 standard deviation below the mean household deprivation.)
References


