Neighbourhood characteristics and trajectories of health functioning: a multilevel prospective analysis

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Background: Prospective data from over 10 years of follow-up were used to examine neighbourhood deprivation, social fragmentation and trajectories of health. Methods: From the third phase (1991–93) of the Whitehall II study of British civil servants, SF-36 health functioning was measured on up to five occasions for 7834 participants living in 2046 census wards. Multilevel linear regression models assessed the Townsend deprivation index and social fragmentation index as predictors of initial health and health trajectories. Results: Independent of individual socioeconomic factors, deprivation was inversely associated with initial SF-36 physical component summary (PCS) score. Social fragmentation was not associated with PCS scores. Deprivation and social fragmentation were inversely associated with initial mental component summary (MCS) score. Neighbourhood characteristics were not associated with trajectories of PCS score or MCS score for the whole set. However, restricted analysis on longer term residents revealed that residents in deprived or socially fragmented neighbourhoods had lowest initial and smallest improvements in MCS score. Conclusions: This longitudinal study provides evidence that residence in a deprived or fragmented neighbourhood is associated with poorer mental health and that longer exposure to such neighbourhood environments has incremental effects. Associations between physical health functioning and neighbourhood characteristics were less clear. Mindful of the importance of individual socioeconomic factors, the findings warrant more detailed examination of materially and socially deprived neighbourhoods and their consequences for health.

Keywords: area inequalities, hierarchical analysis, longitudinal, neighbourhood

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Introduction

large literature now documents associations of neighbour-Ahood deprivation with mortality, morbidity and perceived health.¹⁻⁸ These associations are seen in many developed countries, using many different indicators of deprivation and controlling for a wide range of individual-level explanatory factors. The research evidence linking neighbourhood characteristics, including deprivation, to health is overwhelmingly based on cross-sectional analysis. Such studies cannot discount the possibility that the illness or condition developed in a different neighbourhood to the one in which the illness was counted. The selective migration into deprived neighbourhoods of those with illness potentially confounds the relationship between deprivation and illness.9,10 Over the long term, selective migration may have a substantial effect on arealevel differences in mortality and morbidity. Although too numerous to list them all here, relatively few studies have used longitudinal data to assess whether residence in certain kinds of neighbourhoods is associated with disease incidence or a relative worsening of health over time and the overwhelming majority of these are based on data from just two time points.^{4,6,11-14} With two time points it is possible to identify incident disease and to assess the temporality of any association between neighbourhood deprivation and disease. It is possible to conclude from such studies that selective

migration is not the driver of the association between deprivation and disease. We would expect that greater exposure to deprived neighbourhood would be incrementally associated with poorer health. The association between deprivation and health should be greater for people who have lived in deprived neighbourhoods for longer (assuming that length of residence is a suitable proxy for exposure). Longitudinal studies may provide information on length of exposure which may help refine estimates of the association between neighbourhood deprivation and health. Additionally, with more than two time points it is possible to model linear and non-linear change in health and to assess whether differences between types of neighbourhood widen over time. A widening would indicate that residence in a deprived neighbourhood has on-going implications for health, such that residents in deprived neighbourhoods at baseline would likely experience greater declines in health than those in less deprived neighbourhoods at baseline. A plausible explanation for such a finding might be that the physical, economic or social characteristics of deprived neighbourhoods accelerate the ageing process, over and above individual ageing-related factors.¹⁵ This could be as a result of physical exposures affecting biological processes or lack of amenities and opportunity structures preventing healthpromoting behaviours which protect against ageing, for example. Here we use prospective data from over 10 years of follow-up at up to five measurement occasions to examine neighbourhood effects on trajectories of health functioning.

Deprivation indices may not fully capture the characteristics of neighbourhoods that are important for all aspects of health. Indices such as the Townsend deprivation index were designed to capture material disadvantage and are based on indicators such as unemployment rates and overcrowding.¹⁶ In recent years there has been renewed interest in the role of sociorelational characteristics, such as social capital, social cohesion and social fragmentation in explaining health differences across areas.^{17–21} Although highly correlated with socioeconomic deprivation, social fragmentation is conceptually distinct.

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Social fragmentation refers to a lack of social integration into society. Socially fragmented communities provide less stable social institutions and social bonds, including the family and religion. These institutions and bonds are thought to contribute to the creation of stable identities, permanency in social connections, access to resources that promote healthy behaviours and good physical and mental health.^{19–29}

We hypothesized that both neighbourhood deprivation and social fragmentation are associated with poorer physical and mental health functioning. We further hypothesized that these associations would be greater in magnitude for those with greater exposure to deprived or fragmented neighbourhoods. Using a hierarchical growth curve model, we explored the shape of trajectories of functioning in different types of neighbourhood.

Methods

The Whitehall II study

Prospective health data come from the Whitehall II study of British civil servants. In 1985, all those aged 35–55 years working in London were invited to participate. Of those invited, 10 308 (73%) participated in the first phase. Data from the third (1991–93), fourth (1995–96), fifth (1997–99), sixth (2001) and seventh (2002–04) phases of the study were analysed. The health functioning measures were not introduced before phase 3. Average follow-up was 10.7 years (95% range 3.0–12.7 years). The University College London Medical School Committee on the Ethics of Human Research approved the protocol.

Neighbourhood deprivation and social fragmentation

Data from the 1991 UK census accessed through Manchester Information and Associated Services (MIMAS) were used to measure deprivation in neighbourhoods defined by census ward boundaries (average population \sim 5000). Whilst administrative boundaries may not correspond directly to a person's perception and experience of their neighbourhood, census wards are used for public service organization and delivery and are convenient for analytical purposes. Two indices were derived from the census data. The Townsend index of deprivation is based on proportions of unemployed, lacking access to a car, overcrowding and renting.16 The social fragmentation index is based on proportions of single person households (aged <65 years), persons not married or cohabiting, private renting and residential mobility in the previous ⁷ It is intended to capture lack of stable social bonds and year.1 the four proxy variables used here indicate lack of couple relationships and lack of permanency in local social relations. The variables were transformed to a standard normal distribution and summed with equal weighting to create a social fragmentation score. For analysis, the Townsend and social fragmentation indices were transformed to a standard normal distribution to allow estimation of the effect of a 1 SD increase in deprivation or social fragmentation. These scores were categorized into four equal groups (quartiles) of deprivation and social fragmentation for presentation in the descriptive table but were included in regression models as continuous variables as there was no evidence of non-linearity in their association with health.

Individual health functioning and covariates

The UK standard version of the Short Form 36 (SF-36) questionnaire was administered at each of the five phases under study. This validated tool measures health functioning on eight scales (physical function, role limitations due to physical problems, pain, general health perceptions, general mental health, role limitations due to emotional problems, vitality and social functioning) which can be combined into two higher order summary scales capturing physical and mental health components.^{30–32} The physical component summary (PCS) and mental component summary (MCS) scores ranged from 0 to 100, with 100 indicating maximal functioning.

Participants' sex, age, socioeconomic position captured by 12 levels of civil service employment grade and collapsed into three groups (high, i.e. senior administrators and managers; intermediate, i.e. professional, technical and executive staff; and low, i.e. clerical officers and office support staff), and longterm illness were ascertained by questionnaire. At each phase, time in the study was calculated as current age minus age at phase 3. Individual-level data were linked to neighbourhood data via participant's postcode at phase 3 using a postcodecensus ward look-up table from MIMAS.

Statistical analysis

Multilevel linear regression was used to model the relationship between SF-36 PCS and MCS scores and neighbourhood deprivation and social fragmentation. Three-level linear regression models (study phase nested within participant nested within neighbourhood) models were built sequentially. The base model included intercept and time in the study (centred at the mid-point of 5.6 years) as fixed and random effects and partitioned the variation in the intercept and slope of healthrelated functioning into that which was between neighbourhoods (σ_{v0}^2 , σ_{v1}^2 , respectively), between individuals in the same neighbourhood (σ_{u0}^2 , σ_{u1}^2), and within individuals (σ_{e0}^2 , σ_{e1}^2). The base model can be written as:

 $PCS_{ijk} = \beta_{00} + \beta_{10} time_{ijk} + v_{0k} + u_{0jk} + e_{0ijk} + v_{1k} time_{ijk}$ $+ u_{1jk} time_{ijk} + e_{1ijk} time_{ijk}$

where β_{00} = overall mean PCS score, β_{10} = increase in PCS per 1-year increase in follow-up time (the overall slope), v_{0k} = difference from overall mean PCS in neighbourhood k, u_{0ik} = difference from neighbourhood mean PCS for *j*th person in neighbourhood k, v_{1k} = difference from overall slope in neighbourhood k, u_{1ik0} = difference from neighbourhood slope for *j*th person in neighbourhood k. The term e_{0ijk} represents the within-person error and the term e_{1ijk} allows for the within-person variation to change over time. According to this model, an intercept and slope is estimated for each participant and for each neighbourhood. The first two terms in the equation above are fixed parameters and the remaining terms are random parameters. The random parameters form a distribution; e.g. the neighbourhood level intercepts, v_{0k} , are assumed to be normally distributed with mean 0 and variance $\sigma_{\nu 0}^{2}$. Higher values of $\sigma_{\nu 0}^{2}$ indicate greater variation between neighbourhoods in average PCS. Similarly, $v_{1k} \sim N(0, \sigma_{v1}^2)$ and higher values of σ_{v1}^{2} indicate greater variation between neighbourhoods in the PCS-time slope.

The model was then extended by adding fixed parameters for individual level variables (sex, age and socioeconomic position) which were each allowed to vary over time. Finally, neighbourhood level variables (deprivation and social fragmentation) were added in separate models to avoid collinearity problems. These fixed parameters provided estimates of (i) an association between initial SF-36 scores and neighbourhood characteristics; and (ii) widening differences in SF-36 scores over time by neighbourhood characteristics (by including interaction terms for time by deprivation and time by social fragmentation). The main analyses are based on 32 724 observations on 7834 participants living in 2046 neighbourhoods. All participants with SF-36 scores at baseline were included and provided from zero to four subsequent measures. The models were then re-run excluding (i) excluding the 3672 participants who moved before the end of follow-up; and (ii) excluding those with long-term illness at baseline. The latter analysis aimed to isolate the effect of neighbourhood on those who were illness-free at baseline to remove the possibility that illness preceded exposure to deprived or fragmented neighbourhood. All models were essentially unchanged when men and women were analysed separately so results are presented for the combined model. Modelling was performed using MLwiN 2.02.

Results

A total of 7834 participants had complete data at baseline, reducing to 6785 (Phase 4), 6262 (Phase 5), 5917 (Phase 6) and 5926 (76% of original at Phase 7). In univariate analyses (table 1), PCS and MCS scores were lower for those living in more deprived or more socially fragmented neighbourhoods. PCS scores were higher and MCS scores were lower for younger participants.

Analysis of movers and non-movers combined

PCS declined at a rate of 2.7 units for each 10 years of follow up (table 2). Table 2 shows significant variation in PCS scores between neighbourhoods, between individuals and within individuals. The variation in average PCS between neighbourhoods was small in magnitude (1.241) compared with variation within neighbourhoods (40.270 and 28.842). There was no evidence that the change in PCS over time (i.e. the slope) varies across neighbourhoods. However, there was evidence that the slope varied across individuals. This could be interpreted as evidence that the ageing process is heterogeneous across individuals although this is not the focus of the present study. On average, small improvements in MCS scores were seen over time at a rate of \sim 1.0 unit every 10 years. There was significant variation in MCS scores between neighbourhoods which, as for PCS scores, was small in magnitude compared with the variation within neighbourhoods. The change in MCS over time also varied across neighbourhoods (shown by variation in slope of 0.010 and SE 0.005). The covariance between the intercept and slope was positive (0.088 from table 2), indicating that neighbourhoods with high initial levels of PCS saw greater improvements in PCS over time. In other words, there was a fanning out of PCS scores across neighbourhoods over time.

Table 3 summarizes the full models for physical component scores which add neighbourhood and individual fixed effects. Each one standard deviation increase in Townsend deprivation score was associated with a drop in PCS score of 0.311 points (P < 0.001) (Model 1). The relationship between PCS score and time did not differ by Townsend deprivation. In other words, the time-Townsend interaction term was not statistically significant. Social fragmentation was not associated with PCS scores (Model 2). Older people and those in lower socioeconomic positions had lower PCS scores compared with older and more advantaged participants and they also experienced greater declines in PCS over time. Trajectories did not differ for men and women so a gender by time interaction was not included. No significant variation between neighbourhoods remained.

Each 1 SD increase in Townsend deprivation score was associated with a drop in MCS score of 0.5 points (P < 0.001) (table 4, Model 1). Although there was a suggestion that this effect got larger over time, the Townsend-time interaction term was not statistically significant [estimate (SE) -0.014 (0.010)]. Social fragmentation was also associated with MCS scores but trajectories did not differ by social fragmentation (Model 2, table 4). MCS scores increased over time and older cohorts saw higher initial scores and greater increases over time. Those in lower socioeconomic positions had lower MCS scores and these socioeconomic differences widened over time. After adjustment for individual and neighbourhood characteristics, variation in the intercept and slope of MCS was of borderline statistical significance.

Table 1Description of study cohort and mean (standard error) SF-36 scores at baseline (Phase 3, 1991–93) and 10 year follow-up(Phase 7, 2002–04)

	Participants at baseline	SF-36 PCS score		SF-36 MCS score	
Characteristics Men Women	5382 2452	Baseline 53.0 (0.09) 49.9 (0.18)	Follow-up 49.8 (0.12) 46.2 (0.25)	Baseline 51.4 (0.11) 50.2 (0.19)	Follow-up 52.5 (0.13) 51.4 (0.23)
Age at Phase 3 35–45 years 45–55 years 55–65 years	2530 3507 1797	53.4 (0.13) 51.9 (0.13) 50.4 (0.19)	50.5 (0.18) 48.8 (0.17) 45.8 (0.27)	49.5 (0.18) 50.9 (0.15) 53.4 (0.18)	50.0 (0.21) 53.0 (0.17) 53.9 (0.23)
Socioeconomic position at phase 3 High Intermediate Low	2940 3559 1335	53.2 (0.11) 52.1 (0.12) 49.3 (0.25)	50.0 (0.16) 48.6 (0.17) 45.0 (0.27)	51.5 (0.15) 50.7 (0.16) 51.1 (0.25)	52.9 (0.17) 51.7 (0.18) 54.6 (0.36)
Long-term illness at Phase 3 No long-term illness	2662 5172	48.3 (0.17) 53.9 (0.08)	45.5 (0.23) 50.4 (0.13)	50.0 (0.19) 51.6 (0.11)	50.8 (0.23) 52.9 (0.13)
Townsend deprivation score ^a Quartile 1 (least deprived) Quartile 2 Quartile 3 Quartile 4 (most deprived)	2046 2029 1943 1816	52.8 (0.14) 52.5 (0.15) 51.7 (0.17) 51.0 (0.19)	49.3 (0.21) 49.3 (0.22) 48.5 (0.24) 47.5 (0.27)	51.4 (0.19) 51.6 (0.18) 50.9 (0.20) 50.2 (0.22)	52.9 (0.21) 52.7 (0.22) 51.8 (0.24) 50.9 (0.29)
Social fragmentation score ^b Quartile1 (least fragmented) Quartile 2 Quartile 3 Quartile 4 (most fragmented)	2038 1984 1928 1884	52.3 (0.16) 52.4 (0.15) 51.9 (0.17) 51.5 (0.19)	49.1 (0.22) 48.9 (0.22) 48.5 (0.25) 48.3 (0.25)	51.5 (0.19) 51.4 (0.20) 50.7 (0.20) 50.5 (0.21)	52.8 (0.22) 52.6 (0.22) 51.7 (0.25) 51.4 (0.26)

^aDerived from 1991 census data on unemployment, non-ownership of car, overcrowding and renting.

^bDerived from 1991 census data on private renting, single person households, persons not married or cohabiting and residential mobility in last 12 months.

parameters and no other covariates)			
	SF-36 PCS scores	SF-36 MCS scores	
Fixed estimates			
Intercept	50.354 (0.086)	51.069 (0.090)	
Slope	-0.274 (0.008)	0.098 (0.010)	
Variation (SE) between neighb	ourhoods		
Intercept (σ_{v0}^2)	1.241 (0.346)	1.280 (0.410)	
Slope (σ_{y1}^2)	0.000 (0.000)	0.010 (0.005)	
Covariance intercept-slope	0.000 (0.000)	0.088 (0.031)	
Variation (SE) between individ	uals within a neight	ourhood	
Intercept (σ_{u0}^2)	40.270 (0.820)	43.665 (0.940)	
Slope (σ_{u1}^2)	0.174 (0.010)	0.166 (0.013)	
Covariance intercept-slope	1.031 (0.061)	0.198 (0.076)	
Variation (SE) within individua	ls		
Intercept (σ_{e0}^2)	28.842 (0.451)	44.812 (0.668)	
Slope (σ_{e1}^2)	-0.149 (0.023)	-0.319 (0.032)	
Covariance intercept-slope	0.219 (0.034)	-0.129 (0.049)	

intercept and length of follow-up as fixed and random

Table 3 Neighbourhood characteristics and SF-36 PCS scores

	Model 1: Townsend deprivation	Model 2: Social fragmentation
	Multilevel regression estimate (SE)	Multilevel regression estimate (SE)
Intercept Time (per year of follow up) Townsend deprivation Score (per 1 SD increase)	53.4 (0.18) -0.189 (0.019) -0.311 (0.083)	53.5 (0.18) -0.187 (0.019)
Score × Time	-0.008 (0.009)	
Social fragmentation Score (per 1 SD increase) Score × time		-0.083 (0.079) 0.000 (0.008)
Female Age at Phase 3	-2.202 (0.177)	-2.250 (0.176)
Age 45–55 Age 55–65 Age 45–55 × time Age 55–65 × time	-1.612 (0.185) -3.371 (0.210) -0.048 (0.020) -0.148 (0.023)	-1.593 (0.185) -3.338 (0.210) -0.048 (0.020) -0.147 (0.023)
Socioeconomic position Intermediate Low Intermediate × time Low × time	-0.818 (0.170) -2.433 (0.257) -0.035 (0.018) -0.072 (0.027)	-0.879 (0.169) -2.648 (0.250) -0.036 (0.018) -0.079 (0.026)
Variation (SE) between neight Intercept (σ_{v0}^2) Slope (σ_{v1}^2) Covariance intercept-slope	oourhoods 0.264 (0.260) 0.000 (0.000) 0.000 (0.000)	0.373 (0.268) 0.000 (0.000) 0.000 (0.000)
Variation (SE) between individ Intercept (σ_{u0}^2) Slope (σ_{u1}^2) Covariance intercept-slope	luals 36.602 (0.748) 0.172 (0.010) 0.923 (0.058)	36.560 (0.749) 0.172 (0.010) 0.925 (0.058)
Variation (SE) within individual Intercept (σ_{e0}^2) Slope (σ_{e1}^2) Covariance intercept-slope	als 29.037 (0.451) —0.162 (0.023) 0.221 (0.033)	29.037 (0.451) -0.161 (0.023) 0.221 (0.033)

Multilevel regression estimates are adjusted for all other variables listed in the Table.

Analysis of non-movers only

When analyses were confined to participants who were still in the same neighbourhood after 10 years of follow-up, the regression estimates for associations between PCS and neighbourhood deprivation and social fragmentation were a little Table 4 Neighbourhood characteristics and SF-36 MCS scores

	Model 1: Townsend deprivation Multilevel regression estimate (SE)	Model 2: Social fragmentation Multilevel regression estimate (SE)
Intercept	49.5 (0.20)	49.6 (0.20)
Townsend deprivation Score (per 1 SD increase) Score × time	-0.500 (0.091) -0.014 (0.010)	0.044 (0.022)
Social fragmentation Score (per 1 SD increase) Score × time		-0.446 (0.087) -0.011 (0.010)
Female Age 45–55 Age 55–65 Age 45–55 × time Age 55–65 × time	-1.100 (0.197) 2.422 (0.200) 4.695 (0.226) 0.155 (0.023) 0.029 (0.026)	-1.098 (0.197) 2.432 (0.200) 4.708 (0.226) 0.155 (0.023) 0.030 (0.026)
Socioeconomic position Intermediate Low Intermediate × time Low × time	-0.799 (0.184) -0.784 (0.280) -0.023 (0.020) -0.102 (0.030)	-0.906 (0.183) -1.080 (0.272) -0.026 (0.020) -0.109 (0.029)
Variation (SE) between neight Intercept (σ_{v0}^2) Slope (σ_{v1}^2) Covariance intercept-slope	oourhoods 0.677 (0.349) 0.008 (0.005) 0.051 (0.028)	0.743 (0.353) 0.009 (0.005) 0.053 (0.029)
Variation (SE) between individ Intercept (σ_{u0}^2) Slope (σ_{u1}^2) Covariance intercept-slope	uals 40.466 (0.880) 0.156 (0.013) 0.195 (0.073)	40.434 (0.880) 0.157 (0.013) 0.195 (0.073)
Variation (SE) within individua Intercept (σ_{e0}^2) Slope (σ_{e1}^2) Covariance intercept-slope	ls 44.414 (0.661) –0.293 (0.032) –0.134 (0.049)	44.427 (0.661) -0.294 (0.032) -0.134 (0.049)

Multilevel regression estimates are adjusted for all other variables listed in the Table.

larger in magnitude [-0.445 (SE 0.116) and -0.228 (0.113) per 1 SD increase, respectively]. Estimates of the associations between MCS and both deprivation and social fragmentation were similar to those for the full dataset $[-0.457 \text{ (SE 0.125)} \text{ and } -0.458 \text{ (0.123)}, \text{ respectively]} \text{ and terms representing the interaction between these neighbourhood characteristics and time indicated significant widening over time <math>[-0.028 \text{ (SE 0.014)} \text{ and } -0.037 \text{ (0.013)}, \text{ respectively]} \text{ (figure 1)}.$

Analysis of participants who were illness-free at baseline

Table 5 summarizes the associations between neighbourhood characteristics and functioning for those who reported no long-term illness at baseline. Neither neighbourhood characteristic was associated with PCS score among those who were free of long-term illness at baseline. However, neighbourhood deprivation and social fragmentation remained significantly associated with initial MCS scores for participants who were illness-free at baseline.

Discussion

This study shows an inverse relationship between physical and mental components of health-related functioning (captured by the SF-36) and neighbourhood deprivation, independent of individual socioeconomic characteristics. In contrast, social fragmentation was associated with mental health functioning but not with physical health functioning, independently of



Figure 1 Mean predicted SF-36 PCS scores (upper graphs) and MCS scores (lower graphs) for Whitehall II participants through years of follow up by level of neighbourhood deprivation and social fragmentation. Data correspond to all participants living in the same neighbourhood for the last 10 years illustrated for man aged 35–45 in the highest socioeconomic position. The short-dashed line represent trajectories for people living in the least deprived or fragmented area (lowest score), the solid line represents an increase of 1 SD in the deprivation or fragmentation score, and the long-dashed line represents an increase of 2 SD in the scores.

Table 5 Nei	ghbourhooc	l characteristic	s and SF-36	scores for
participants	with and w	ithout long-te	rm illness a	t baseline

	SF-36 PCS scores Multilevel regression estimate (SE)	SF-36 MCS scores Multilevel regression estimate (SE)
Time (per year of follow-up)	-0.197 (0.021)	0.067 (0.025)
Townsend deprivation Score (per 1 SD increase) Score × time	-0.114 (0.078) -0.004 (0.010)	-0.355 (0.104) -0.011 (0.012)
Social fragmentation Score (per 1 SD increase) Score × time	-0.018 (0.075) 0.003 (0.010)	-0.381 (0.100) -0.006 (0.011)

Multilevel regression estimates are adjusted for gender, age, age by time, socioeconomic position and socioeconomic position by time.

individual socioeconomic characteristics. A previous study also found that social fragmentation is more closely related to mental rather than physical health outcomes.²⁴

For participants who had lived in the same neighbourhood for more than 10 years, there was evidence that neighbourhood deprivation and social fragmentation were associated with both baseline mental health functioning and change in mental health functioning throughout follow-up. Mental health functioning tended to improve throughout follow-up in this cohort of middle-aged workers but the improvements were smaller in deprived and socially fragmented neighbourhoods. Mental health functioning actually declined over time in the most deprived and fragmented neighbourhoods (those with scores of 2 SD). This supports the notion that those with greater cumulative exposure to deprived or fragmented neighbourhoods experience smaller age-related improvements in mental health functioning, although we did not have information on the destination neighbourhoods of movers. In the analysis of non-movers, health-related selective migration cannot explain the associations seen between neighbourhood characteristics and functioning. The results are also consistent with the hypothesis that the local neighbourhood influences the ageing process, in this case by diminishing the ageing-related gains in mental health functioning. Data were not available to examine the processes which may explain this finding. However, it is interesting to note that neighbourhood characteristics were not associated with trajectories of change in physical health functioning.

Previous cross-sectional studies have described associations between neighbourhood deprivation and SF-36 scores in line with those seen here.^{21,33–35} Our findings suggest that differences in mental health functioning for people remaining in deprived vs. less deprived areas or fragmented vs. less

fragmented areas widen over time. The SF-36 is a subjective assessment of health which focuses on the extent to which health problems limit daily activities. It is plausible that a person's local neighbourhood constrains the way that person copes with any health conditions and the extent to which that condition results in functional impairment. This possibility should be explored in future studies. Neighbourhood deprivation has been hypothesized to be a marker for a range of characteristics including poor public services, decaying urban fabric and social disorder. Given the available data, we can only speculate as to the pathways linking neighbourhood deprivation to health functioning and echo calls for more research to illuminate this.³⁶ The Townsend deprivation and social fragmentation indices are differently related to SF-36 scores, suggesting that they are capturing different elements of the residential environment. It has been argued that social fragmentation seeks to measure lack of social integration into institutions such as the family, religion and the community and that this can occur in affluent as well as deprived areas.³ However, with a correlation coefficient of 0.69 for England in 1991 and even higher in other countries,²⁷ they are clearly closely associated constructs.

Strengths and limitations

Study strengths include its size, its prospective design with over 10 years of follow up, its multilevel approach and its inclusion of two neighbourhood indices capturing both fragmentation and deprivation. Some limitations must be acknowledged. The study was observational in nature so the possibility of selfselection into certain kinds of neighbourhoods as an explanation for the findings is an important consideration. However, we have adjusted for employment grade, which is a highly accurate measure of individual socioeconomic position, being highly correlated with income and education and a most consistent predictor of health and disease in the Whitehall II cohort,³⁸ and is likely a major determinant of people's ability to choose where they live. Sixty percent of participants were initially resident in London and a further 37% in the southeast of England. There is no reason to suppose that the relationships between deprivation/social fragmentation and health would be different in other parts of the country and the range of values for these indices was very similar for areas included in this study and for England as a whole. However, the extent to which these indices truly capture deprivation and social fragmentation may vary across the country. Car access, included in the Townsend deprivation index, may be a less valid indicator of material deprivation in urban areas.³⁹ Imprecision in the measurement of deprivation or social fragmentation might lead to underestimation of their associations with health. The use of administrative boundaries, rather than theoretically-driven or participant defined neighbourhood boundaries, might also lead to imprecision in the neighbourhood measures although other studies which compared different areal units suggest that this might not have a large impact on the estimation of the association between area deprivation and health.^{40,41} The omission of important individual or neighbourhood level variables might lead to under- or overestimation for the variables that were included. We elected not to include individual health behaviours and social support as we conceived these to be on the explanatory pathway linking neighbourhood characteristics to health. Differential loss to follow-up can lead to bias but drop-out was greatest amongst those in lower socioeconomic positions, living in more deprived or socially fragmented areas and having lower initial PCS and MCS scores so associations between neighbourhood characteristics and SF-36 scores are unlikely to be overestimated here. Confining the analysis to non-movers reduces the possibility that selective migration by health status is driving any associations seen but a full exploration of this issue requires longitudinal information on neighbourhood characteristics at each residential location and on the changing nature of neighbourhoods over time. Our study did not have information on the destination neighbourhood of movers so we are unable to confirm that their exposure to deprivation or fragmentation was lower than non-movers.

Implications and conclusions

These prospective findings are indicative of a dose response relationship between mental health and neighbourhood deprivation or fragmentation. In the absence of intervention studies, they provide one piece in the jigsaw of evidence linking neighbourhood characteristics to health. It is important to remember that the largest differences in physical and mental functioning can be attributed to gender, age and socioeconomic position and initiatives to reduce functional impairment should not ignore these individual level determinants. Nevertheless, the large numbers of people that are resident in deprived and fragmented neighbourhoods means that neighbourhood-based interventions have the potential to have an important public health effect. Our findings highlight the need for greater understanding and more detailed studies of deprived and fragmented neighbourhoods and their consequences for health.

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Conflicts of interests: None declared.

Key points

- Independent of personal socioeconomic characteristics, residence in a deprived neighbourhood is associated with sub-optimal physical and mental health functioning, as captured by the SF-36.
- Neighbourhood social fragmentation is additionally associated with deficits in mental health functioning.
- Mental health functioning improves with age but those with greater cumulative exposure to deprived or fragmented neighbourhoods experience smaller agerelated improvements.
- This contributes further evidence that social and economic features of the neighbourhood may be important for health and functioning.

References

- Waitzman NJ, Smith KR. Separate but lethal: the effects of economic segregation on mortality in metropolitan America. *Milbank Q* 1998;76:341–73.
- 2 Diez-Roux A, Merkin SS, Arnett D, et al. Neighbourhood of residence and incidence of coronary heart disease. N Engl J Med 2001;345:99–106.
- 3 Ross CE. Neighborhood disadvantage and adult depression. J Health Soc Behav 2000;41:177–87.
- 4 Pickett KE, Pearl M. Multilevel analyses of neighbourhood socioeconomic context and health outcomes: a critical review. J Epidemiol Community Health 2001;55:111–22.
- 5 Stafford M, Marmot M. Neighbourhood deprivation and health: does it affect us all equally? *Int J Epidemiol* 2003;32:357–66.
- 6 Sundquist K, Malmstrom M, Johansson SE. Neighbourhood deprivation and incidence of coronary heart disease: a multilevel study of 2.6 million women and men in Sweden. J Epidemiol Community Health 2004;58:71–7.
- 7 Cubbin C, Winkleby MA. Protective and harmful effects of neighbourhoodlevel deprivation on individual-level health knowledge, behavior changes, and risk of coronary heart disease. *Am J Epidemiol* 2005;162:559–68.
- 8 Franzini L, Caughy M, Spears W, Esquer MEF. Neighborhood economic conditions, social processes, and self-rated health in low-income neighborhoods in Texas: a multilevel latent variables model. *Soc Sci Med* 2005;61:1135–50.
- 9 Boyle P, Duke-Williams O. Does migration exaggerate the relationship between deprivation and self-reported limiting long-term illness? In: Boyle P, Curtis S, Gatrell A, et al., editors. *The geography of health inequalities in the developed world*. London: Ashgate, 2004.
- 10 Norman P, Boyle P, Rees P. Selective migration, health and deprivation: a longitudinal analysis. *Soc Sci Med* 2005;60:2755–71.
- 11 Yen IH, Kaplan GA. Poverty area residence and changes in physical activity level: evidence from the Alameda County study. Am J Public Health 1998;88:1709–12.
- 12 Drukker M, Krabbendam L, Driessen G, van Os J. Social disadvantage and schizophrenia. A combined neighbourhood and individual-level analysis. Soc Psychiatry Psychiatr Epidemiol 2006;41:595–604.
- 13 Galea S, Ahern J, Nandi A, et al. Urban neighborhood poverty and the incidence of depression in a population-based cohort study. Ann Epidemiol 2007;17:171–9.
- 14 Winkleby M, Sundquist K, Cubbin C. Inequities in CHD incidence and case fatality by neighborhood deprivation. Am J Prev Med 2007;32:97–106.
- 15 Andrews GJ, Phillips DR. Geographical studies in ageing: progress and connections to social gerontology. In: Andrews GJ, Phillips DR, editors. *Ageing and place*. London: Routledge, 2005.
- 16 Townsend P, Phillimore P, Beattie A. Health and deprivation: inequality and the North. London: Croom Helm, 1988.
- 17 Congdon P. Suicide and parasuicide in London: a small-area study. Urban Stud 1996;33:137–58.
- 18 Kawachi I, Kennedy BP, Lochner K, Prothrow-Stith D. Social capital, income inequality and mortality. Am J Public Health 1997;87:1491–8.
- 19 Whitley E, Gunnell D, Dorling D, Davey Smith G. Ecological study of social fragmentation, poverty and suicide. *Br Med J* 1999;319:1034–7.
- 20 Fagg J, Curtis S, Stansfeld S, Congdon P. Psychological distress among adolescents, and its relationship to individual, family and area characteristics in East London. Soc Sci Med 2006;63:636–48.

- 21 Fone D, Dunstan F, Lloyd K, et al. Does social cohesion modify the association between area income deprivation and mental health? A multilevel analysis. *Int J Epidemiol* 2007;36:338–45.
- 22 Durkheim E. In: Spalding JA, Simpson G, trans. *Suicide: a study in sociology*. London: Routledge & Kegan Paul, 1952.
- 23 Hawton K, Harriss L, Hodder K, et al. The influence of the economic and social environment on deliberate self-harm and suicide: an ecological and person-based study. *Psychol Med* 2001;31:827–36.
- 24 Davey Smith G, Whitley E, Dorling D, Gunnell D. Area based measures of social and economic circumstances: cause specific mortality patterns depend on the choice of index. J Epidemiol Community Health 2001;55:149–50.
- 25 Pols H. Anomie in the Metropolis: the city in American sociology and psychiatry. *Osiris* 2003;18:194–211.
- 26 Dorling D, Gunnell D. Suicide: the spatial and social components of despair in Britain 1980–2000. Trans Inst Br Geog 2004;28:442–60.
- 27 Stjarne MK, Ponce de Leon A, Hallqvist J; for the SHEEP study group. Contextual effects of social fragmentation and material deprivation on risk of myocardial infarction – results from the Stockholm Heart Epidemiology Program (SHEEP)Int J Epidemiol 2004;33:732–41.
- 28 Evans J, Middleton N, Gunnell D. Social fragmentation, severe mental illness and suicide. Soc Psychiatry Psychiatr Epidemiol 2004;39:165–70.
- 29 Allardyce J, Gilmour H, Atkinson J, et al. Social fragmentation, deprivation and urbanicity: relation to first-admission rates for psychoses. *Br J Psychiatry* 2005;187:401–6.
- 30 Ware JE Jr, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I Conceptual framework and item selection. *Med Care* 1992;30:473–83.
- 31 Ware JE, Kosinski M, Keller SD. SF-36 Physical and Mental Health Summary Scales: a user manual. Massachusetts: The Health Institute: New England Medical Center, 1994.
- 32 Hemingway H, Stafford M, Stansfeld S, et al. Is the SF-36 a valid measure of change in population health? Results from the Whitehall II study. *Br Med J* 1997;315:1273–9.
- 33 Marsh P, Carlisle R, Avery AJ. How much does self-reported health status, measured by the SF-36, vary between electoral wards with different Jarman and Townsend scores? Br J Gen Pract 2000;50:630–4.
- 34 Wainwright NWJ, Surtees PG. Places, people, and their physical and mental functional health. J Epidemiol Community Health 2004;58:333–9.
- 35 Skapinakis P, Lewis G, Araya R, et al. Mental health inequalities in Wales, UK: multi-level investigation of the effect of area deprivation. *Br J Psychiatry* 2005;186:417–22.
- 36 Macintyre S, Ellaway A, Cummins S. Place effects on health: how can we conceptualise, operationalise and measure them? *Soc Sci Med* 2002;55:125–39.
- 37 Congdon P. Commentary: contextual effects: index construction and technique. *Int J Epidemiol* 2004;33:741–2.
- 38 Marmot MG, Davey Smith G, Stansfeld S, et al. Health inequalities among British civil servants: the Whitehall II study. *Lancet* 1991;337:1387–93.
- 39 Haynes R, Gale S. Deprivation and poor health in rural areas: inequalities hidden by averages. *Health Place* 2000;6:275–85.
- 40 Reijneveld SA, Verheij RA, de Bakker DH. The impact of area deprivation on differences in health: does the choice of the geographical classification matter? J Epidemiol Community Health 2000;54:306–13.
- 41 Stafford M, Duke-Williams O, Shelton N. Small area inequalities in health: are we underestimating them? Soc Sci Med 2008;67:891–9.

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