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Perceived and objectively measured environmental correlates of domain specific physical  
activity in older English adults

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## Abstract

We examine the relative importance of both objective and perceived environmental features for physical activity in older English adults. Self-reported physical activity levels of 8281 older adults were used to compute volumes of outdoor recreational and commuting activity. Perceptions of neighborhood environment supportiveness were drawn from a questionnaire survey and a geographical information system was used to derive objective measures. Negative binomial regression models were fitted to examine associations. Perceptions of neighborhood environment were more associated with outdoor recreational activity (over 10% change per standard deviation) than objective measures (5~8% change). Commuting activity was associated with several objective measures (up to 16% change). We identified different environmental determinants of recreational and commuting activity in older adults. Perceptions of environmental supportiveness for recreational activity appear more important than actual neighborhood characteristics. Understanding how older people perceive neighborhoods might be key to encouraging outdoor recreational activity.

*Keywords:* Environmental correlates, GIS, Neighborhood, Perception

## Introduction

Being physically active has been shown to reduce the risk of obesity, cardiovascular disease, some cancers and type 2 diabetes (Durstine et al., 2013; Warburton et al., 2010). Despite this, the majority of adults in high income countries are not sufficiently active (UK Department of Health, 2005; US Department of Health, 2008). In England, just 40% of men and 28% of women meet the current recommended levels of physical activity (UK Department of Health, 2011). It is of particular concern that a recent systematic review reported substantial variations in the percentage of non-institutional older adults meeting recommended physical activity levels (Sun, Norman & White, 2013). Although the definition of recommended level of physical activity varies somewhat across different countries, most UK-based studies report less than 25% of older adults meeting recommended levels of at least 150 minutes of moderate intensity activity per week (Harris et al., 2009; Allender, Foster & Boxer, 2008).

The socio-ecological model, which posits that contextual factors such as the local environment may influence health and related behaviors, has been widely used to explore determinants of health (Barton & Grant, 2006) as well as many drivers of physical activity, including individual, societal and environmental factors (Sallis et al., 2001). Based on the widespread adoption of this model, there is an increasing recognition of the importance of the neighborhood environment (Bennie et al., 2010). Individuals make use of a range of different environments on a regular basis and previous studies have shown that the workplace (Jones et



al, 2007) and commuting route (Panter et al., 2013) can influence physical activity levels. In addition, the role of the neighborhood around the home is also of particular interest, as adults on average spend approximately 56% of their waking time in this setting (Lader, Short & Gershuny, 2006). To take into account the variety of physical activity in daily life, researchers in this field have highlighted the importance of increasing the specificity of ecological models by investigating different domains of physical activity which may have distinct associations with environmental characteristics (Giles-Corti, Timperio, Bull, & Pikora, 2005).

The home neighborhood may be particularly important in older adults as there is evidence that those aged 70 or over typically spend 80% of their time in the local surrounding environment (Horgas, Wilms & Baltes, 1998). Older adults typically experience declines in physical functions and health which can lead to changing interactions with the built and social environment in neighborhoods (Lawton & Nahemow, 1973; Li, Cardinal, & Acock, 2013). For example, older people have been reported to be more vulnerable to concerns associated with crime and insecurity and experience multiple exclusion from social relationships and access to resources and services (Whitley & Prince, 2005; Scharf, Phillipson, Smith & Kingston, 2014). Both perceptions and objectively measured characteristics of the neighborhood environment may therefore play an important role in the level of physical activity they undertake, with a potential associated impact on levels of healthy ageing (Scharf, Phillipson, Smith & Kingston, 2014).

Amongst the studies which have been undertaken investigating the environmental

determinants of physical activity, the majority use either objective (such as those derived using a Geographical Information System (GIS)) (Van Holle et al, 2014) or subjective (e.g. perceptions of the environment determined using a questionnaire) (Mendes de Leon et al., 2009) environmental measures, with few attempting to examine both (van Cauwenberg et al, 2011; Nyunt et al., 2015).

Although several objective environmental features such as walkable areas, land use mix and street connectivity have been suggested to encourage transportation and recreational physical activity (van Cauwenberg et al., 2011; Cunningham & Michael, 2004; Ribeiro et al., 2015), perceptions of the supportiveness of the local environment with respect to these features have been shown to vary across individuals (Macintyre, Ellaway & Cummins, 2002). At the same time, there is evidence that environmental perceptions are not always closely aligned to objective environmental measures generated by researchers, and one reason for this is that these perceptions may be more related to factors such as feelings of individual self-efficacy and personal security (Bartholomew, Loukas, Jowers & Allua, 2006; van Cauwenberg et al., 2014) which may in turn influence physical activity behavior. Poor agreement between objective and perceived measures of the neighborhood environment has thus suggested they measure different aspects of environmental determinants of physical activity (Ball et al., 2008; Gebel, Bauman, Sugiyama & Owen, 2011).

A number of recent initiatives have focused on environmental modification to create an age-friendly environment to promote active and healthy ageing (European Commission,

2013). These have generally been started in community-based settings and have focused on whether certain changes in local environments could particularly support older people in their daily life and activities. Whilst changes to the physical environments of communities may be relevant, previous studies have identified important features related to physical activity based on residents' perception of local environments, measured using tools such as the Neighborhood Environment Walkability Scale (Cerin et al., 2006), which is a valid measure of perceived walk friendliness of the environment and has been widely used in different settings (Cerin et al., 2013). Hence, although both objective environmental characteristics and perceptions of local environments are suggested to be important for active ageing (World Health Organization, 2007), it is unclear what their relative importance is for physical activity in older adults and hence which aspect should be the initial focus of public health interventions.

A previous study using the European Prospective Investigation into Cancer and Nutrition (EPIC) Norfolk included both environmental and psychological factors and investigated their actual associations with active commuting (Panter et al., 2011). That work found those reporting walking or cycling habits and living less than 1.5 km from work were likely to commute by bicycle or on foot. However, the focus was limited to commuting activity and did not compare the importance of objective and perceived environmental measures other domains of physical activity. To provide a more nuanced understanding of the association between different domains of physical activity and neighborhood characteristics in this group,

1 this study incorporates both perceived and objective measures of neighborhoods to explore  
2 the relative importance of perceived and objective characteristics of local neighborhoods in  
3 the same English cohort.

## 4 **Methods**

### 5 **Study population**

6 The European Prospective Investigation into Cancer and Nutrition (EPIC) Norfolk study  
7 is one of a number of large population cohorts which form EPIC, the original aim of which  
8 was to examine the associations between diet and cancer, but which has since been expanded  
9 to investigate other outcomes and exposures. Details of sampling and recruitment of the  
10 cohort have been described elsewhere (Day et al., 1999; Hayat et al., 2013). Briefly, EPIC  
11 Norfolk participants were recruited aged 40-79 between 1993 and 1997 from GP practices  
12 across the county of Norfolk, an environmentally heterogeneous county with an area of  
13 approximately 2000 square miles. Norfolk has a population of around 850,000 residents but is  
14 largely rural, with a density of approximately 400 residents per square mile, the tenth lowest  
15 in England. Around 40% of the county's population live in the three largest built up areas of  
16 Norwich (population 213,200), Great Yarmouth (71,700) and King's Lynn (43,100).

17 Data were collected from EPIC participants at various times. For this study, data from  
18 three time points were used. At baseline (Health Check 1: 1993 to 1997), personal data on  
19 participants was collected, which included gender, date of birth, social class, level of  
20 education, and postcode. A second health check was undertaken between 1998 and 2000,

where BMI was measured. In 2006/7 participants completed a previously validated Physical Activity Questionnaire (EPAQ2) (Wareham et al, 2002), along with a questionnaire on their perceptions of the environment. Altogether, 10193 participants completed both surveys and were eligible for inclusion in the current analysis.

### **Measure of physical activity**

EPAQ2 includes questions on self-reported participation in physical activities. Participants were asked how frequently they took part in a wide range of activities, and their responses were converted into a measure of metabolic equivalent task hours per week by multiplying the frequency of each stated activity by its metabolic equivalent (MET) obtained from published tables (Ainsworth et al., 2002). EPAQ2 was validated by comparing estimated daytime energy expenditure calculated with mean four day energy expenditure from heart rate monitoring with individual calibration (Wareham et al, 2002). The validation study showed EPAQ2 to have high levels of validity and repeatability comparable to other physical activity instruments.

In this study, the measure of physical activity used was weekly MET hours, a measure of physical activity energy expenditure, which was divided into two types: commuting activity for those still in employment, which included walking and cycling to work, and outdoor recreational activity, which for the purpose of this study was taken to be outdoor recreational walking, pleasure cycling and jogging. These activities were selected as they were deemed to be the ones most likely to be influenced by the supportiveness of the neighborhood around the

home. Occupational and indoor activity was excluded from the outcome of interest because participation in these forms of activity is unlikely to be influenced by features of the home neighborhood environment.

#### **Individual covariates**

Information on age, gender and dog ownership were recorded using a questionnaire completed by participants in 2006/7, around the time of the third health check. Dog owners tend to have higher levels of physical activity (Christian et al., 2013) and were identified using the question “Does your household have a dog?” Although it is not hypothesized that workplace activity would be directly influenced by perceived or objectively measured neighborhood characteristics, there is evidence that individuals with high level of workplace activity tend to have lower level of non-work activity (Christian et al., 2013; Burton & Turrell, 2000). Workplace activity, extracted from EPAQ2, was therefore also included as covariate. Non-working individuals were coded as having zero workplace activity to avoid excluding them from analyses.

#### **Subjective and objective measures of neighborhood environment**

The questionnaire on the perceived environment provided information on EPIC participant’s perception of the supportiveness of their local neighborhood environment for physical activity. There was a particular focus on walking as this is the predominant activity undertaken by older adults (Sun, Norman & White, 2013). The questionnaire instrument used was the NEWS (Neighborhood Environment Walkability Scale), a widely used and previously

validated tool which was adapted to a UK context (for example by replacing mention of ‘sidewalk’ with ‘pavement’) from the version presented elsewhere (Saelens, Sallis, Black & Chen, 2003). Participants were asked about their views of their local neighborhood, including the types of residence in the area and their level of agreement with 24 statements, which were grouped into eight categories. Table 1 provides a brief description of these measures, which were scored so that higher values indicated areas which were perceived to be more conducive to physical activity.

In order to determine objective measures of the environmental supportiveness of the local neighborhood for physical activity amongst cohort members, a GIS (ESRI ArcGIS 9.2) was used to compute a range of objective measures of neighborhood characteristics amongst the participants for whom valid home postcodes (zip-codes) were available. English postcodes are geographical units which are used to locate groups of approximately 15 households, and are hence small in size. For this study, the population weighted center of each postcode was identified and mapped as a point. Neighborhoods around each point were created using a street network containing publically accessible roads as well as streets which are accessible to pedestrians and public footpaths, and were defined as the area within an approximately 10 minute walk (equivalent to 800m) along this network from the postcode location, a distance commonly employed elsewhere (van Dyck, Deforche, Cardon & De Bourdeaudhuij, 2009).

Objective environmental measures generated for these neighborhoods (Table 1) were based on data collected from a range of sources. The presence of gardens around homes, the

percentage neighborhood composition of different land uses, and the densities of pedestrian infrastructure and pavements were computed in ArcGIS using the Ordnance Survey Mastermap database, which provides detailed topographical information at an equivalent scale of 1:1250 (Ordnance Survey, 2015). Using this data, the Herfindahl-Hirschman Index was used to estimate land diversity where, higher index scores represent lower diversity (Hirschman, 1964). Measures of road traffic accidents and crimes were taken from information on the location of events provided by the traffic law enforcement agencies covering the study area. The road accident data covered the period 1997-2006 whilst crimes were for 2005-2006, the most temporally coincident with the data collection period.

For the measure of the location of streetlights, the local administrative authority (Norfolk County Council) provided a database of the precise location of each light, expressed as a geographical coordinate. Data on the road network was computed using the Ordnance Survey Integrated Transport Network (ITN) layer, a component of Mastermap. Road density and the proportion of roads that were 'A' class (i.e. major roads) were calculated as a proxy of traffic density, as used previously (Panter et al. 2011). Two measures of walkability were computed; junctions per km<sup>2</sup> (whereby higher values represent more connected and potentially more walkable networks) and the 'effective walkable area' which is the ratio of the neighborhood area when boundaries are measured using an 800m distance along the road network vs a straight line radius of 800m around the home postcode location (Panter et al., 2013). Again higher values are taken to represent a more connected, walkable environment. The ITN was



also used to compute shortest road network distances to four types of facility as a measure of local service accessibility. Finally, deprivation was measured using the 2007 English Index of Deprivation, a measure of area disadvantage based on 7 different domains (UK Government, 2015), and household measures were taken from the 2001 UK Census of Population.

The definition of urban and rural status used was based on the UK Rural/Urban Classification produced by Bibby and Shepherd (Bibby & Shepherd, 2004). This definition has been developed following the 2001 Census to classify rural/urban status for small area units and it defines areas as rural if they fall outside of settlements with a residential population of more than 10,000. In this study, urban/rural status was based on the Lower-layer Super Output Areas census zones which the postcodes of participants were located in.

## **Analysis**

The distribution of the physical activity outcomes were examined and found to be over-dispersed, so negative binominal regression was used to examine the associations between commuting and outdoor recreational activity energy expenditure, individual covariates and the perceived and objective environmental measures. Individual covariates included age, gender, dog ownership and workplace activity. Stratified analyses were undertaken that separated participants from rural and urban areas, as early analysis indicated that predictors of activity differed by location.

Initially univariate associations between the outcome and each predictor were examined (Stage 1, Table S1 and S2). Due to the large number of variables examined, environmental

factors were grouped into domains, as detailed in Table 1, based on theoretical relationships. Any variables showing a statistically significant unadjusted association ( $p < 0.1$ ) were put into a stepwise model containing the other measures in their domain that also showed an association of at least this strength (Stage 2). Once non-significant variables were dropped from these sub-models, any variables still showing a statistically significant association ( $p < 0.1$ ) were put forward for inclusion in the final multivariable regression model (Stage 3).

For both rural and urban locations, five models were fitted: the first contained individual level covariates only, the second included objectively measured environmental attributes, the third replaced objective measures with environmental perceptions, and the fourth contained statistically significant variables from any of these models. To compare the relative importance of similar environmental characteristics across perceived vs objective domains, all perceived measures were matched to corresponding objective measures except aesthetics, which could not be measured objectively using the available data. This was examined using a fifth model which included the objective and perceived measures of the similar environmental characteristics adjusting for individual level factors. To compare the relative predictive magnitude of the objective and perceived environmental measures, the parameter estimates in the final model were standardized so that they showed changes in activity per standard deviation (SD) of each measure allowing them to be directly compared.

This modelling method was separately conducted for outdoor recreational and commuting activity energy expenditure outcomes. The coefficients from all models are

presented as incidence rate ratios. To compare the goodness-of-fit between different models, Akaike's Information Criterion (AIC) was calculated for the four models. Lower AIC estimates indicate a better fit of regression models. All statistical analyses were conducted using Stata 10, and a significance level of  $p < 0.05$  was used.

## Results

Of the 10,529 EPIC Norfolk Health Check 3 participants, 10,193 (96.8%) had both valid EPAQ2, environmental questionnaire and GIS data. Of these, 1912 were excluded from analysis due to participants reporting a physical disability or limitation which precluded them from walking. Altogether 78.6% ( $N=8281$ ) of the Health Check 3 participants were available for inclusion in this study. Compared to those included in the study, those excluded were older (average age 73 years), more likely to be female, and significantly less active (all  $p < 0.001$ ), which reflects the exclusion criteria used.

Table 2 shows the characteristics of those included participants by urban and rural neighborhood status. The age range was between 49 and 88 years. Nearly 60% were female, although this did not differ by setting. Compared to those living in urban areas, rural participants reported higher average MET hours per week (MET hours/week) of occupational physical activity (Mean: 65.9, Standard deviation (SD): 50.0), higher MET hours/week of outdoor recreational activity (Mean: 9.9, SD: 14.2) but lower MET hours/week of commuting activity (Mean: 2.1, SD: 5.5). In rural areas, there was a higher percentage of dog ownership (27% vs 14%).

Unadjusted associations between environmental factors and physical activity are reported in Table S1 (outdoor recreational activity) and S2 (commuting activity) by urban and rural status and the results are summarized in Figure 1 which focuses on the percentage of significant associations detected in the perceived and objective domains. Compared to objective measures, perceptions of the neighborhood environment were more likely to be statistically significantly associated with outdoor recreational activity in an expected direction for both urban and rural residents. Conversely, commuting activity was more likely to be associated with objective measurements, particularly in urban areas.

Results of the adjusted associations in urban and rural areas are reported in Tables 3 and 4, respectively. To provide a comparison of goodness-of-fit between objective and perceived environment models, the percentage reduction in the AIC estimates are reported in Figure 2. Models including all the perceived and objective environmental measures (Model 4) were expected to have the lowest AIC estimates and hence the largest percentage AIC reduction compared to the model only including individual level factors. For the model of outdoor recreational activity, the percentage reduction was larger for the perceived relative to objective models, whilst the opposite was the case for the model of commuting activity.

The magnitude of associations between physical activity, objective and perceived environmental measures was examined in the full model including all individual and environmental factors (Model 4). Positive associations between outdoor recreational activity and two perceived measures (access to services and aesthetics) were found, with the

1 standardized regression coefficient showing an over 10% increased level of activity per  
2 standard deviation (SD) change in exposure for both urban and rural areas. Commuting  
3 activity in urban areas was associated with a number of objective measures, with stronger  
4 relationships (up to 16% change in activity per SD) compared to perceived measurements.

5 In the comparison of seven similar environmental characteristics (Table 5), recreational  
6 outdoor activity showed two statistically significant associations with both objective and  
7 perceived domains in urban areas and three in rural areas (Model 5). Commuting activity in  
8 urban areas had significant associations with six objective measurements versus two  
9 perceived measurements. Although the two negative associations for objective measures were  
10 not in the expected direction, the magnitude of relationships was generally stronger for  
11 objective measures than their perceived counterparts. The associations with commuting  
12 activity in rural areas were unclear.

## 13 Discussion

### 14 Main findings

15 This study focused on exploring the relative importance of objective and perceived  
16 measures of neighborhood environments as correlates of the physical activity of older adults.  
17 Two types of physical activity (outdoor recreational activity and commuting activity) and  
18 several objective and perceived measures of neighborhood environment were included.  
19 Associations with outdoor recreational activity were generally stronger for perceived  
20 compared to objective measures in both urban and rural settings. Conversely, commuting

1 activity had strong associations with objective measures particularly in urban areas.

2 Although we tested a large number of variables, after adjustment we found that relatively

3 few environmental measures were associated with the measured domains of physical activity.

4 This is to be expected given that many of the measures we employed capture similar

5 constructs and are hence associated with each other. The direction of associations were mixed

6 and sometimes in a counterintuitive direction. For example, in terms of objective measures,

7 we found that a higher density of street lighting was associated with greater commuting

8 activity in urban areas whilst residents of more walkable rural neighborhoods reported greater

9 levels of outdoor recreational activity, both associations that socio-ecological theory would

10 predict (see Stokols, 1996). At the same time, higher objectively measured density of

11 pedestrian infrastructure was associated with lower recreational activity in urban populations

12 and lower commuting activity in rural residents, both contrary to the expected direction. It is

13 also noteworthy that the variables associated with the different activity domains were not

14 stable across models; all these inconsistencies may reflect the relatively low magnitude of

15 importance of environmental factors compared to individual level measures in the models.

#### 16 **Outdoor recreational activity, commuting activity and the neighborhood**

17 Although some objective environmental measures were associated with outdoor

18 recreational activity, the magnitude of association was generally weaker than perceived

19 measures with more associations in an unexpected direction. This suggests that perceptions of

20 neighborhood environments may be more important than actual neighborhood characteristics

1 as determinants of outdoor recreational activity in older residents.

2       Since recreational activity is at least in part optional, older adults who have a more  
3 positive view of their local neighborhood environment might partake of more outdoor leisure  
4 activity while those with negative perceptions might be less inclined to leave home. For  
5 example, a recent study in Australian older adults reported that perceptions of a poor walkable  
6 environment in neighborhoods predicted longer TV viewing time, a typical homebound  
7 activity, after seven year follow-up (Shibata et al., 2015). An investigation of 600 English  
8 older people (age 60 or over) living in deprived neighborhoods reports potential issues of  
9 loneliness and exclusion from social relations, civic activities and local services (Scharf,  
10 Phillipson, Smith & Kingston, 2014). Particularly in the domain of neighborhood exclusion,  
11 44% of older residents reported that they would feel very unsafe when out alone after dark  
12 and 20% expressed negative views about their neighborhoods. Perceptions of insecurity in  
13 neighborhoods might therefore be an important factor that reduces outdoor activity in later  
14 life, whilst the objectively measured crime rate may have a comparatively small influence on  
15 outdoor activity. For example, a recent study of 532 Portuguese older adults showed that the  
16 objectively measured crime rate in neighborhoods was not associated with participation in and  
17 frequency of leisure-time physical activity (Ribeiro et al., 2015).

18       Although both objective and perceived environmental measures have been suggested to  
19 be related to walking for transportation in older adults (Nyunt et al., 2015; van Cauwenberg et  
20 al., 2014; van Dyck et al., 2015), our findings were that commuting activity had stronger

associations with objective environmental measures compared to perceived measurements. Unlike recreational activity, traveling to the workplace is necessary and therefore the nature of local infrastructures could be an important influence on choice of commuting methods rather than participation in commuting itself. A high density of walkable facilities (street lights, effective walkable areas) was associated with a higher prevalence of commuting activity in this study. These findings correspond to previous research on the environmental determinants of commuting activity (van Cauwenberg et al., 2011; Kwarteng et al., 2014). Although a wide range of local infrastructures such as street connectivity, pavement density and traffic have been recognized to support non-motorized commuting behavior in younger people (Wendel-Vos et al., 2007; Dalton et al., 2013) and older adults (Panter et al., 2013; Van Holle et al., 2014; Pliakas et al., 2014), our study found some negative associations in this study population. It is possible that these inconsistent findings might be related to not only demographic characteristics (Van Dyck et al., 2015) but also different urban/rural, cultural and societal context across individual studies (Giles-Corti, Timperio, Bull, & Pikora, 2005).

### **Strengths and limitations**

This study has a number of strengths and weaknesses. Its strengths lie in our use of a large cohort of well characterized adults living in a variety of rural and urban environments. We were able to examine independent associations with both perceived and objectively measured environmental characteristics. We made small adaptations to the previously validated NEWS tool for the measurements of perceptions which made it more appropriate to



the English context, and we generated a large number of objective environmental measures using a GIS which enabled a wide range of possible environmental influences on physical activity to be examined.

Limitations of the study include that the physical activity measures were based on self-reported recall over 12 months, and it is known that self-report measures are prone to measurement error (Adamo et al., 2009). Since perceptions of the neighborhood environment were also self-reported, there could be a risk of correlated errors in self-reported outcomes and exposures. However, the use of a questionnaire allowed us to derive domain specific activity and identify types of activity that may be particularly focused around neighborhood environment, and has previously been validated within the cohort (Wareham et al., 2002). A possibly more serious form of error could be if our objective environmental exposures were either inappropriately selected or not measured with sufficient precision, either of which may reduce the magnitude of association. Although we were guided by theoretical models and the existing literature in their selection and we developed the measures using high quality data and standard protocols, the apparent lesser importance of these measures compared to perceptions could at least partly be driven by any measurement imprecision that may be present. In particular, to be consistent with other studies and with our understanding of activity patterns of older adults, we defined neighborhoods as being the area within an approximate 10 minute walk from the home of participants. It may be that this was not the most appropriate scale for our study participants although the absence of data from global

1 positioning systems in this group did not allow us to test this.

2 Our study was cross sectional in nature and thus suffers from the limitation that causality  
3 cannot be determined from observed associations. All our participants were based in Norfolk,  
4 which is a predominately rural county with only one particularly urban city and a largely  
5 white population, limiting the generalizability of the findings to other settings. Since the  
6 investigation was conducted nearly 10 years ago, the findings might be less applicable to  
7 contemporary older populations, with differences possibly being associated with increasing  
8 use of assistive technologies in older adults acting to help overcome environmental barriers.  
9 Other environmental factors such as traffic outside the home may act as determinants of  
10 activity, but in common with many studies, the fact that we based locations on postcodes  
11 rather than individual building locations meant we were not able to capture street level factors.  
12 We intentionally tested associations with a wide range of environmental measures, but an  
13 implication of this was that some of the indicators chosen were strongly correlated. Although  
14 techniques such as principal components analysis were considered as a way of managing this,  
15 they were not employed as the aim here was to understand associations with individual  
16 environmental indicators rather than the bundles they would have produced. A further  
17 limitation was that we undertook a large number of statistical tests and thus some of the  
18 associations we observed may be the result of multiple testing although we were careful to  
19 consider both strength and direction of associations when drawing our conclusions.

20 **Implications and future research directions**

1 Outdoor recreational activity is an important requirement for active and healthy ageing  
2 after retirement. This study suggests that improving perceptions of neighborhood might have  
3 a positive influence on increasing outdoor recreational activity, whilst infrastructure  
4 improvements may be more important to support active commuting. It is important that  
5 planning policy considers the needs and opinions of older people, who have historically been  
6 absent in projects utilizing community regeneration (Phillipson, 2012).

7 Over the last 20 years or so, various researchers have begun to explore how the physical  
8 environment can be designed in such a way as to allow older people to age in place, and  
9 terminology such as “age-friendly” and “lifetime” neighborhoods has been used to describe  
10 age-supportive places (Lui et al., 2009). In their review of literature from North America,  
11 Alley et al. (2007) describe lifetime neighborhoods as places which moderate the demands of  
12 the environment by providing infrastructure and services that accommodate the needs of older  
13 adults. Despite the potential of such places, relatively little work has attempted to document  
14 the characteristics of neighborhood that older people value (UK Department of Communities  
15 and Local Government, 2011). Our findings suggest that the potential of such initiatives may  
16 not be fully reached without work to better understand how more positive attitudes towards  
17 environmental supportiveness can be formed. A comprehensive investigation of moderating  
18 and mediating mechanisms underlying associations between physical activity, objective and  
19 perceived environmental measures may provide robust evidence on how best to support active  
20 ageing. Future research is needed to investigate negative experiences amongst older residents

1 and potential interventions to address poor perception of their neighborhoods.

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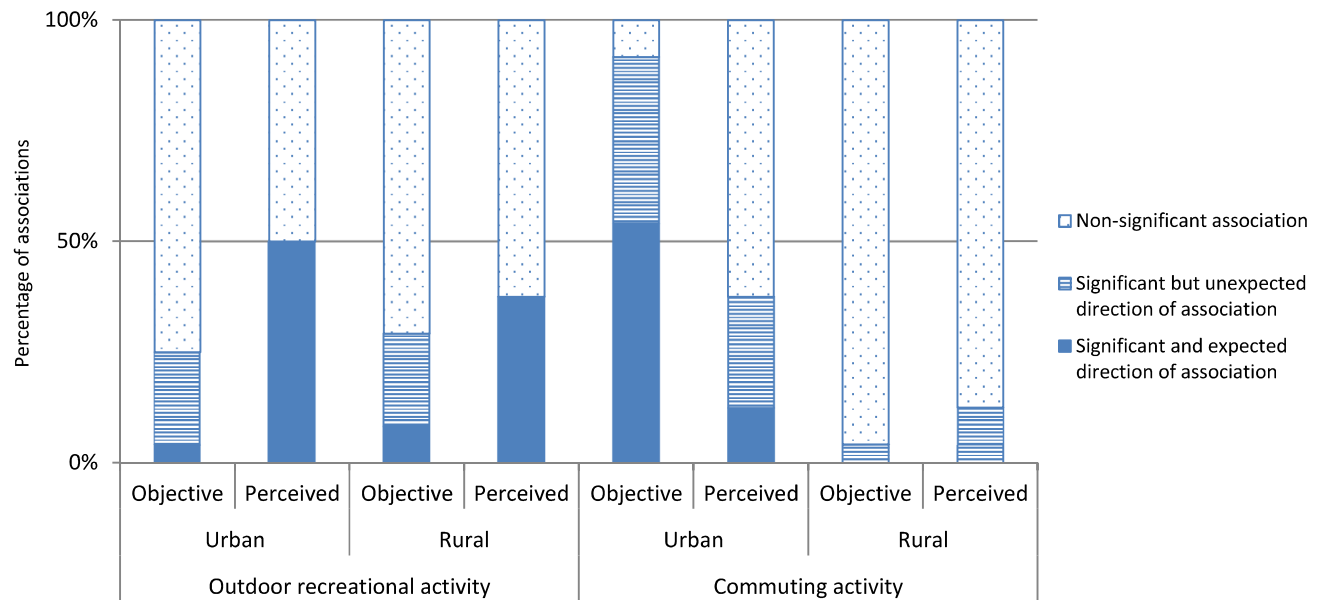
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**Figure 1** The percentage of significant unadjusted associations between physical activity, objectively (N=24) and perceived (N=8) measured environmental measurements



**Figure 2** Reduction in AIC estimate (%) by three adjusted models: objective measurements, perceived measurements or both

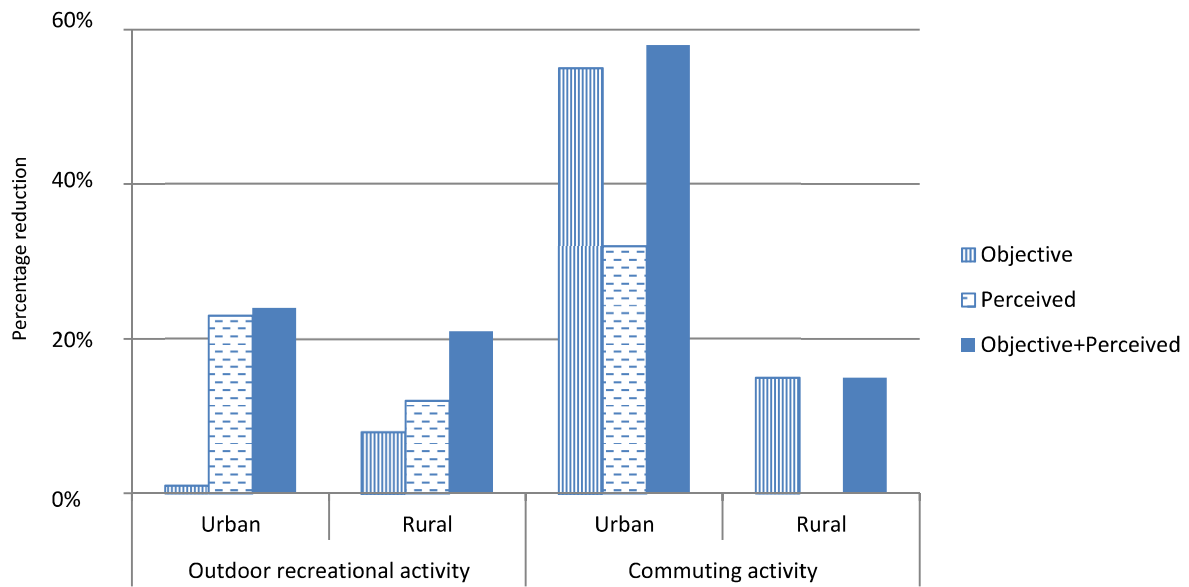


Table 1

*Description of environmental measures*

Domain	Measure	Min	Range Max	Mean (SD) or percentage (n)
<b>Objective characterized environment</b>				
Home	Home has a garden (% Yes)			96.98 (8021)
Safety	Number of serious and fatal road traffic accidents in neighborhood (per km of road)	0	3.57	0.33 (0.38)
	Total crimes per 1000 population in area of residence	17	2368	63.81 (97.85)
	Density of streetlights in neighborhood (per km of road)	0	56.97	11.71 (12.49)
Deprivation	Index of Multiple Deprivation (Score)	1.86	47.23	13.64 (7.36)
Road network	Road density in neighborhood (km/km2)	0.69	20.20	10.17 (3.63)
	Proportion of roads in neighborhood that are A roads	0	1	0.06 (0.09)
	Junctions per km2 in the neighborhood	0.01	0.68	0.23 (0.12)
	Effective Walkable area in the neighborhood (ratio)	0.07	0.71	0.36 (0.12)
Pedestrian infrastructure	Density of all pedestrian infrastructure in neighborhood (ratio)	0	12.16	4.59 (1.01)
	Density of pavements in neighborhood (ratio)	0	5.43	2.31 (1.25)
Land use	Natural greenspace in neighborhood (% area)	0	98.90	36.83(29.12)
	Parks in neighborhood (% area)	0	96.75	1.48 (4.26)
	Buildings in neighborhood (% area)	0	29.36	8.08 (5.54)
	Herfindahl-Hirschman Index (Score)	1241.07	9681.07	2930.27 (1168.20)
Accessibility	Distance to nearest travel (transit) facility (km)	0.05	17.3	3.80 (3.24)
	Distance to nearest recreational facility (km)	0.01	6.04	1.50 (0.85)
	Distance to nearest place of interest (km)	0.26	9.16	2.39 (1.64)
	Distance to nearest town or city center (km)	0.05	19.76	5.28 (3.75)
Households	Detached houses in neighborhood (%)	0.89	97.32	45.97 (22.07)
	Semi-detached houses in neighborhood (%)	1.67	75.15	31.11 (14.82)
	Terraced houses in neighborhood (%)	0	71.56	14.00 (12.23)
	Flats in neighborhood (%)	0	82.80	8.67 (11.71)
	Households with one or more cars in neighborhood (%)	42.59	100	82.35 (10.11)
<b>Perceptions from Environment and Physical Activity Questionnaire</b> (higher score: more conducive to physical activity)				
	Access to services (Mean Score - 4 items)	1	4	2.96 (0.78)
	Street connectivity (Mean Score - 4 items)	1	4	2.86 (0.52)
	Walking and cycling facilities (Mean Score - 3 items)	1	4	2.44 (0.85)
	Aesthetics (Mean Score - 3 items)	1	4	2.89 (0.69)
	Pedestrian and traffic safety (Mean Score - 5 items)	1	4	2.59 (0.58)
	Detached houses in neighborhood (% Yes)			97.43 (8009)
	Terraced houses in neighborhood (% Yes)			51.79 (4228)
	Flats in neighborhood (% Yes)			35.43 (2897)



Table 2

*Characteristics of the study sample*

Measure	Mean (SD) or percentage (n)	
	Urban (5587)	Rural (2690)
Age (years)	67.8 (8.4)	66.4 (8.3)
Males	42.6 (2381)	44.0 (1184)
Workplace activity of workers (MET hours/week)	60.4 (47.7)	65.9 (50.0)
Dog Owner	14.4 (803)	27.3 (734)
Outdoor Recreational Activity* (MET hours/week)	8.7 (14.8)	9.9 (14.2)
Commuting activity (MET hours/week)**	3.0 (6.0)	2.1 (5.5)

\*Includes pleasure walking, pleasure cycling and jogging activity

\*\*only for working participants, n=2974

Table 3

*The adjusted association between physical activity (MET hours/week), perceived and objective environmental measures in urban areas*

	Model 1 IRR	95%CI	Model 2 IRR	95%CI	Model 3 IRR	95%CI	Model 4 IRR	95%CI	Std. IRR
<b>Outdoor recreational activity</b>									
<b>Individual</b>									
Age (years)	<b>0.983†</b>	(0.976, 0.990)	<b>0.983†</b>	(0.976, 0.990)	<b>0.986†</b>	(0.979, 0.993)	<b>0.987†</b>	(0.980, 0.993)	0.893
Gender									
Male (reference)									
Female	<b>0.818†</b>	(0.747, 0.897)	<b>0.819†</b>	(0.747, 0.897)	<b>0.826†</b>	(0.754, 0.906)	<b>0.827†</b>	(0.754, 0.907)	0.910
Workplace activity (MET hours/ week)	<b>0.997†</b>	(0.995, 0.998)	<b>0.997†</b>	(0.995, 0.998)	<b>0.997†</b>	(0.996, 0.998)	<b>0.997†</b>	(0.996, 0.998)	0.876
Owns Dog									
No (reference)									
Yes	<b>2.438†</b>	(2.188, 2.717)	<b>2.446†</b>	(2.196, 2.725)	<b>2.389†</b>	(2.142, 2.664)	<b>2.397†</b>	(2.149, 2.674)	1.359
<b>Objective Environment</b>									
Density of all pedestrian infrastructure in neighborhood			<b>0.950*</b>	(0.908, 0.993)			<b>0.945*</b>	(0.904, 0.989)	0.951
<b>Perceived Environment</b>									
Access to services (Mean Score – 4 items)					<b>1.188†</b>	(1.093, 1.291)	<b>1.187†</b>	(1.092, 1.290)	1.110
Aesthetics (Mean Score - 3 items)					<b>1.205†</b>	(1.122, 1.294)	<b>1.208†</b>	(1.125, 1.298)	1.134
AIC	33722		33718		33645		33640		
Change in AIC estimates (%)	-		0.01		0.23		0.24		
<b>Commuting activity</b>									
<b>Individual</b>									
Age (years)	<b>0.954†</b>	(0.940, 0.969)	<b>0.956†</b>	(0.940, 0.971)	<b>0.953†</b>	(0.938, 0.968)	<b>0.953†</b>	(0.938, 0.969)	0.743
Gender									
Male (reference)									
Female	0.989	(0.821, 1.191)	1.019	(0.837, 1.241)	1.038	(0.857, 1.258)	1.058	(0.868, 1.291)	1.029
Workplace activity (MET hours/ week)	1.002	(1.000, 1.004)	1.002	(0.999, 1.004)	1.002	(0.999, 1.004)	1.001	(0.999, 1.004)	1.073
Owns Dog									
No (reference)									
Yes	0.792	(0.622, 1.008)	0.865	(0.671, 1.116)	0.824	(0.643, 1.057)	0.862	(0.668, 1.112)	0.945
<b>Objective Environment</b>									
Density of streetlights in neighborhood (per km of road)			<b>1.014**</b>	(1.055, 1.249)			<b>1.012**</b>	(1.034, 1.232)	1.164
Junctions per km2 in the neighborhood			<b>0.251**</b>	(0.093, 0.674)			<b>0.281*</b>	(0.104, 0.760)	0.873
Effective Walkable area in the neighborhood (m2)			<b>2.485*</b>	(1.137, 5.431)			2.076	(0.934, 4.614)	1.093
Buildings in neighborhood (%)			<b>1.043**</b>	(1.017, 1.069)			<b>1.033*</b>	(1.005, 1.060)	1.153
Distance to nearest town or city center (km)			<b>0.955*</b>	(0.921, 0.991)			<b>0.955*</b>	(0.920, 0.992)	0.955
<b>Perceived Environment</b>									
Access to services (Mean Score – 4 items)					<b>1.231*</b>	(1.043, 1.452)	1.130	(0.954, 1.340)	1.071
Detached houses in neighborhood (Yes/No)					<b>0.398†</b>	(0.288, 0.550)	<b>0.498†</b>	(0.342, 0.725)	0.886
Flats in neighborhood (Yes/No)					<b>1.436†</b>	(1.196, 1.724)	1.145	(0.931, 1.407)	1.070
AIC	6910		6872		6888		6870		
Change in AIC estimates (%)	-		0.55		0.32		0.58		

\*p<0.05; \*\*p<0.01; †p<0.001.; Std. IRR: standardized incidence rate ratio

Model 1: The association between physical activity and the individual level factors; Models 2: The associations between physical activity, objective environmental measures with adjustment for individual level factors; Model 3: The associations between physical activity and perceived environmental measures with adjustment for individual level factors; Model 4: The associations between physical activity and all the objective and perceived environmental measures with adjustment for individual level factors.

Table 4

*The adjusted association between physical activity (MET hours/week), perceived and objective environmental measures in rural areas*

	Model 1 IRR	95%CI	Model 2 IRR	95%CI	Model 3 IRR	95%CI	Model 4 IRR	95%CI	Std. IRR
<b>Outdoor recreational activity</b>									
<b>Individual</b>									
Age (years)	0.983‡	(0.976, 0.991)	0.983‡	(0.976, 0.991)	0.986‡	(0.978, 0.993)	0.985‡	(0.978, 0.993)	0.885
Gender									
Male (reference)									
Female	0.863**	(0.773, 0.963)	0.858**	(0.769, 0.957)	0.869*	(0.777, 0.971)	0.863**	(0.773, 0.964)	0.930
Workplace activity (MET hours / week)	0.997‡	(0.996, 0.999)	0.997‡	(0.996, 0.999)	0.997‡	(0.996, 0.999)	0.997‡	(0.995, 0.999)	0.875
Owns Dog									
No (reference)									
Yes	2.144‡	(1.920, 2.395)	2.120‡	(1.897, 2.370)	2.183‡	(1.947, 2.447)	2.161‡	(1.927, 2.423)	1.410
<b>Objective Environment</b>									
Effective walkable area in the neighborhood (m2)			1.824*	(1.117, 2.980)			1.767*	(1.077, 2.897)	1.060
Distance to nearest place of interest (km)			1.042*	(1.001, 1.086)			1.036	(0.994, 1.081)	1.052
Flats in neighborhood (%)			0.977**	(0.964, 0.990)			0.975‡	(0.962, 0.988)	0.918
<b>Perceived Environment</b>									
Aesthetics (Mean Score - 3 items)					1.189‡	(1.089, 1.298)	1.191‡	(1.092, 1.298)	1.130
AIC	17043		17029		17022		17008		
Change in AIC estimates (%)	-		0.08		0.12		0.21		
<b>Commuting activity</b>									
<b>Individual</b>									
Age (years)	0.999	(0.972, 1.027)	0.996	(0.970, 1.024)	No model		0.996	(0.970, 1.024)	0.977
Gender									
Male (reference)									
Female	0.793	(0.563, 1.118)	0.805	(0.573, 1.132)			0.805	(0.573, 1.132)	0.897
Workplace activity (MET hours / week)	1.006**	(1.002, 1.009)	1.001‡	(1.003, 1.010)			1.001‡	(1.003, 1.010)	1.366
Owns Dog									
No (reference)									
Yes	1.441*	(1.041, 1.996)	1.527*	(1.101, 2.118)			1.527*	(1.101, 2.118)	1.218
<b>Objective Environment</b>									
Density of all pedestrian infrastructure in neighborhood			0.783**	(0.679, 0.902)			0.783**	(0.679, 0.902)	0.754
AIC	2662		2658				2658		
Change in AIC estimates (%)	-		0.15				0.15		

\*p<0.05; \*\*p<0.01; ‡p<0.001.; Std. IRR: standardized incidence rate ratio

Model 1: The association between physical activity and the individual level factors; Models 2: The associations between physical activity, objective environmental measures with adjustment for individual level factors; Model 3: The associations between physical activity and perceived environmental measures with adjustment for individual level factors; Model 4: The associations between physical activity and all the objective and perceived environmental measures with adjustment for individual level factors.

Table 5

*A comparison of relative importance of the matched objective and perceived environmental characteristics*

Corresponding objective and perceived environmental measures		Urban (Model 5)				Rural (Model 5)			
		Std. IRR (95% CI)				Std. IRR (95% CI)			
Objective (O)	Perceived (P)	O		P		O		P	
<b>Outdoor recreational activity</b>									
Distance to nearest place of interest	Access to services	<b>1.046*</b>	(1.004, 1.089)	<b>1.143‡</b>	(1.087, 1.204)	<b>1.108‡</b>	(1.046, 1.174)	<b>1.111‡</b>	(1.047, 1.178)
Effective Walkable area in the neighborhood	Street connectivity	0.970	(0.927, 1.102)	1.041	(0.997, 1.087)	<b>1.061*</b>	(1.008, 1.117)	<b>1.108‡</b>	(1.047, 1.172)
Density of all pedestrian infrastructure	Walking and cycling facilities	<b>0.933**</b>	(0.896, 0.972)	<b>1.084‡</b>	(1.038, 1.132)	1.024	(0.966, 1.086)	0.970	(0.920, 1.022)
Number of serious and fatal road traffic accidents	Pedestrian and traffic safety	0.989	(0.947, 1.032)	1.002	(0.958, 1.047)	1.007	(0.952, 1.066)	<b>1.057*</b>	(1.002, 1.116)
Density of detached houses	Detached houses	0.999	(0.957, 1.042)	0.981	(0.948, 1.014)	1.007	(0.953, 1.063)	1.031	(0.982, 1.081)
Density of terraced houses	Terraced houses	1.014	(0.967, 1.063)	1.001	(0.956, 1.049)	1.021	(0.965, 1.080)	1.016	(0.959, 1.076)
Density of flats	Flats	1.024	(0.981, 1.069)	0.998	(0.950, 1.048)	<b>0.926**</b>	(0.884, 0.971)	0.972	(0.920, 1.027)
<b>Commuting activity</b>									
Distance to nearest place of interest	Access to services	<b>0.838*</b>	(0.747, 0.962)	1.075	(0.974, 1.200)	1.061	(0.913, 1.229)	1.170	(0.976, 1.412)
Effective Walkable area in the neighborhood	Street connectivity	<b>1.228‡</b>	(1.128, 1.334)	0.946	(0.864, 1.034)	1.135	(0.954, 1.361)	1.006	(0.854, 1.186)
Density of all pedestrian infrastructure	Walking and cycling facilities	1.054	(0.966, 1.144)	1.020	(0.928, 1.121)	<b>0.774**</b>	(0.653, 0.912)	0.883	(0.727, 1.056)
Number of serious and fatal road traffic accidents	Pedestrian and traffic safety	<b>1.314‡</b>	(1.208, 1.428)	1.045	(0.958, 1.144)	0.957	(0.815, 1.120)	0.842	(0.701, 0.998)
Density of detached houses	Detached houses	<b>0.758‡</b>	(0.688, 0.832)	<b>0.894‡</b>	(0.851, 0.944)	0.971	(0.820, 1.147)	0.963	(0.848, 1.089)
Density of terraced houses	Terraced houses	<b>1.404‡</b>	(1.347, 1.566)	0.933	(0.843, 1.032)	1.044	(0.907, 1.202)	0.983	(0.837, 1.155)
Density of flats	Flats	<b>1.286‡</b>	(1.172, 1.379)	<b>1.106*</b>	(1.000, 1.099)	0.890	(0.775, 1.021)	1.102	(0.932, 1.312)

\*p<0.05; \*\*p<0.01; ‡p<0.001.; Std. IRR: standardized incidence rate ratio

Model 5: the associations between physical activity and the corresponding objective and perceived environmental measures with adjustment for individual level factors

## Supporting information

Table S1

*Unadjusted regression associations with Outdoor Recreational Activity (walking, pleasure cycling, jogging) (MET hours/week) in urban and rural areas*

Domain	Measure	Urban				Rural			
		n	Incidence Rate Ratio	SE	p	n	Incidence Rate Ratio	SE	p
<b>Individual</b>	Age (years)	5536	0.989	0.003	<0.001	2663	0.990	0.003	0.002
	Gender								
	Male (reference)	2369				1175			
	Female	3167	0.913	0.042	0.045	1488	0.970	0.054	0.588
	Workplace physical activity (MET hours / week)	5536	0.999	0.001	0.163	2663	0.999	0.001	0.117
<b>Objective Environment</b>	Owns Dog								
	No (reference)	4739				1933			
	Yes	793	2.407	0.127	<0.001	726	2.130	0.118	<0.001
<b>Home</b>	Home has a garden (Yes/No)								
	No (reference)	215				30			
	Yes	5314	1.032	0.103	0.757	2633	1.201	0.295	0.455
<b>Safety</b>	Number of serious and fatal road traffic accidents in neighborhood (per km of road)	5536	0.931	0.050	0.180	2663	1.033	0.144	0.813
	Total crimes per 1000 population in area of residence	5536	1.000	<0.000	0.414	2663	1.001	0.001	0.676
	Density of streetlights in neighborhood (per km of road)	5536	0.998	0.002	0.246	2663	1.002	0.008	0.828
<b>Deprivation</b>	Index of Multiple Deprivation (Score)	5536	1.001	0.003	0.826	2663	1.013	0.006	0.019
<b>Road network</b>	Road density in neighborhood (km/km2)	5536	0.993	0.008	0.435	2663	0.972	0.016	0.084
	Proportion of roads in neighborhood that are A roads	5536	0.724	0.181	0.197	2663	0.789	0.242	0.441
	Junctions per km2 in the neighborhood	5536	1.005	0.211	0.980	2663	0.479	0.198	0.076
	Effective Walkable area in the neighborhood (ratio)	5536	0.709	0.139	0.080	2663	1.886	0.489	0.014

Domain	Measure	Urban				Rural			
		n	Incidence Rate Ratio	SE	p	n	Incidence Rate Ratio	SE	p
Pedestrian infrastructure	Density of all pedestrian infrastructure in neighborhood	5536	0.957	0.023	0.063	2663	0.975	0.022	0.273
	Density of pavements in neighborhood	5536	0.915	0.028	0.003	2663	0.970	0.034	0.386
Land use	Natural Greenspace in neighborhood (% area)	5536	1.004	0.001	0.007	2663	1.002	0.001	0.121
	Parks in neighborhood (% area)	5536	1.010	0.007	0.167	2663	1.000	0.004	0.910
	Buildings in neighborhood (% area)	5536	0.991	0.005	0.087	2663	0.982	0.014	0.203
	Herfindahl-Hirschman Index (Score)	5536	1.000	<0.000	0.044	2663	1.000	<0.000	0.182
Accessibility	Distance to nearest travel facility (km)	5536	1.015	0.009	0.104	2663	1.002	0.007	0.734
	Distance to nearest recreational facility (km)	5536	1.031	0.038	0.404	2663	1.026	0.027	0.330
	Distance to nearest place of interest (km)	5536	1.028	0.021	0.177	2663	1.073	0.022	0.001
	Distance to nearest town or city center (km)	5536	1.010	0.007	0.168	2663	1.009	0.007	0.251
Households	Detached houses in neighborhood (%)	5536	1.001	0.001	0.616	2663	1.000	0.002	0.877
	Semi-detached houses in neighborhood (%)	5536	0.998	0.001	0.204	2663	0.999	0.003	0.793
	Terraced houses in neighborhood (%)	5536	1.000	0.002	0.671	2663	1.004	0.004	0.350
	Flats in neighborhood (%)	5536	1.000	0.001	0.828	2663	0.975	0.007	0.001
	Households with one or more cars in neighborhood (%)	5536	0.999	0.002	0.751	2663	1.011	0.006	0.066
<b>Perceived Environment†</b>									
	Access to services (Mean Score – 4 items)	5511	1.241	0.052	<0.001	2647	1.042	0.043	0.319
	Street connectivity (Mean Score – 4 items)	5444	1.097	0.054	0.058	2612	1.128	0.065	0.036
	Walking and cycling facilities (Mean Score - 3 items)	5513	1.074	0.033	0.021	2645	0.989	0.041	0.795
	Aesthetics (Mean Score - 3 items)	5512	1.275	0.050	<0.001	2645	1.155	0.063	0.008
	Pedestrian and traffic safety (Mean Score - 5 items)	5385	0.994	0.043	0.889	2576	1.059	0.058	0.297
	Detached houses in neighborhood (Yes/No)	5494	0.915	0.094	0.388	2651	1.087	0.199	0.650
	Terraced houses in neighborhood (Yes/No)	5452	0.975	0.045	0.579	2636	1.000	0.056	0.999
	Flats in neighborhood (Yes/No)	5462	0.961	0.044	0.380	2637	0.821	0.066	0.014

†for all perceived environment measures, a high score indicates a more positive attribute.

Table S2

*Unadjusted regression associations with commuting activity (MET hours/week) in urban and rural areas*

Domain	Measure	Urban				Rural			
		n	Incidence Rate Ratio	SE	p	n	Incidence Rate Ratio	SE	p
<b>Individual</b>	Age (years)	1956	0.951	0.007	<0.001	1018	0.992	0.014	0.573
	Gender								
	Male (reference)	914				501			
	Female	1042	1.010	0.094	0.918	517	0.629	0.103	0.005
	Workplace physical activity (MET hours / week)	1956	1.004	0.001	<0.001	1018	1.007	0.002	<0.001
	Owns Dog								
<b>Objective Environment</b>	No (reference)	1618				694			
	Yes	337	0.815	0.103	0.105	322	1.527	0.262	0.014
	<b>Home</b>								
	Home has a garden (Yes/No)								
	No (reference)	63				9			
	Yes	1892	0.520	0.106	<0.001	1009	1.310	0.709	0.618
<b>Safety</b>	Number of serious and fatal road traffic accidents in neighborhood (per km of road)	1956	1.875	0.207	<0.001	1018	0.914	0.322	0.799
	Total crimes per 1000 population in area of residence	1956	1.001	0.000	<0.001	1018	0.997	0.006	0.586
	Density of streetlights in neighborhood (per km of road)	1956	1.025	0.004	<0.001	1018	0.985	0.024	0.526
<b>Deprivation</b>	Index of Multiple Deprivation (Score)	1956	1.030	0.005	<0.001	1018	1.008	0.019	0.687
<b>Road network</b>	Road density in neighborhood (km/km2)	1956	1.106	0.021	<0.001	1018	1.011	0.049	0.823
	Proportion of roads in neighborhood that are A roads	1956	7.064	3.744	<0.001	1018	0.369	0.309	0.233
	Junctions per km2 in the neighborhood	1956	2.255	0.940	0.051	1018	1.746	2.334	0.677
	Effective Walkable area in the neighborhood (ratio)	1956	6.811	2.553	<0.001	1018	3.690	3.293	0.144
<b>Pedestrian infrastructure</b>	Density of all pedestrian infrastructure in neighborhood	1956	1.084	0.057	0.123	1018	0.825	0.058	0.006
	Density of pavements in neighborhood	1956	1.347	0.091	<0.001	1018	0.843	0.099	0.145

Domain	Measure	Urban				Rural			
		n	Incidence Rate Ratio	SE	p	n	Incidence Rate Ratio	SE	p
Land use	Natural Greenspace in neighborhood (% area)	1956	0.987	0.003	<0.001	1018	1.002	0.005	0.600
	Parks in neighborhood (% area)	1956	1.032	0.019	0.085	1018	1.016	0.013	0.230
	Buildings in neighborhood (% area)	1956	1.066	0.011	<0.001	1018	1.003	0.045	0.939
	Herfindahl-Hirschman Index (Score)	1956	1.000	0.000	0.285	1018	1.000	0.000	0.872
Accessibility	Distance to nearest travel facility (km)	1956	0.938	0.015	<0.001	1018	0.976	0.018	0.189
	Distance to nearest recreational facility (km)	1956	0.634	0.063	<0.001	1018	0.929	0.075	0.360
	Distance to nearest place of interest (km)	1956	0.823	0.056	0.004	1018	1.040	0.054	0.453
	Distance to nearest town or city center (km)	1956	0.920	0.017	<0.001	1018	0.987	0.021	0.544
Households	Detached houses in neighborhood (%)	1956	0.984	0.002	<0.001	1018	0.999	0.006	0.919
	Semi-detached houses in neighborhood (%)	1956	0.991	0.003	0.003	1018	1.002	0.009	0.780
	Terraced houses in neighborhood (%)	1956	1.024	0.003	<0.001	1018	1.002	0.011	0.875
	Flats in neighborhood (%)	1956	1.024	0.003	<0.001	1018	0.982	0.022	0.425
	Households with one or more cars in neighborhood (%)	1956	0.971	0.004	<0.001	1018	1.026	0.021	0.221
Perceived Environment†									
	Access to services (Mean Score – 4 items)	1952	1.313	0.108	0.001	1013	1.141	0.123	0.223
	Street connectivity (Mean Score – 4 items)	1934	0.927	0.089	0.432	1009	1.142	0.175	0.386
	Walking and cycling facilities (Mean Score - 3 items)	1952	1.093	0.079	0.216	1013	0.793	0.097	0.057
	Aesthetics (Mean Score - 3 items)	1952	0.989	0.071	0.879	1013	1.117	0.125	0.322
	Pedestrian and traffic safety (Mean Score - 5 items)	1934	1.097	0.091	0.266	992	0.848	0.137	0.305
	Detached houses in neighborhood (Yes/No)	1947	0.405	0.066	<0.001	1016	0.751	0.394	0.538
	Terraced houses in neighborhood (Yes/No)	1931	1.186	0.115	0.079	1010	0.972	0.164	0.866
	Flats in neighborhood (Yes/No)	1940	1.627	0.153	<0.001	1012	1.025	0.259	0.923

†for all perceived environment measures, a high score indicates a more positive attribute.