Supplemental material

Green and blue spaces and physical functioning in older adults: Longitudinal analyses of the Whitehall II study

Authors: Carmen de Keijzer, Cathryn Tonne, Séverine Sabia, Xavier Basagaña, Antònia Valentín, Archana Singh-Manoux, Josep Maria Antó, Jordi Alonso, Mark J Nieuwenhuijsen, Jordi Sunyer, Payam Dadvand

Content

S1. Additional information on covariate and mediator data

i. Covariate data

The covariate data included age (continuous in years, reported at each follow-up), sex (male or female), and ethnicity (white or non-white). In addition, at every follow-up, marital status (married/cohabiting, single, divorced/separated, or widowed) and height (continuous) was recorded. For SES, we used two individual level and two area (neighborhood) level indicators. The individual level indicators included educational attainment (assessed in the follow-up of 1997-1999) and the employment grade (assessed at every follow-up). Following previous Whitehall II studies (Rusmaully et al., 2017; Singh-Manoux et al., 2017, 2012), education was categorized in three categories (lower secondary school or less, higher secondary school, and university or higher degree). The lower secondary school could be completed at age 16, while the higher secondary school was an additional two-year education, usually required for university admission (Trudel et al., 2016). The employment grade was based on the British civil service grades of employment including the categories high (administrative), middle (professional and executive), and low (clerical). Our characterization of neighbourhood SES was based on the Index of Multiple Deprivation (IMD) at LSOA level according to the 2001 Census (Noble et al., 2006). LSOAs were the finest spatial units for which IMD data is available. We used the two domains (employment and income) that are comparable between England, Scotland, and Wales (Abel et al., 2016). Lifestyle factors including smoking status (current, past, or never), alcohol consumption (frequency of consumption in the year prior to filling in the questionnaire; sometimes, daily, or never), and diet (intake of fresh fruit and vegetables; twice a day or less) were obtained at each follow-up. In addition, at each follow-up, the participants were asked whether they experienced any limitations in walking over a mile, with possible answers yes a lot, a little, or no.

Furthermore, we collected an indicator of rurality, defining rural areas using the definition by the Organization for Economic Co-operation and Development (OECD) as administrative units with a population density lower than 150 inhabitants per km2 (European Commission, 2017). Each participant was classified to be living in a rural area (yes or no) at each follow-up using data on the population density obtained at the

LSOA level from the 2001 Census data (National Records of Scotland, 2001; Office for National Statistics, 2001).

ii. Mediator data

Physical activity was assessed at every follow-up since 1997-1999 by a modified version of the Minnesota leisure-time physical activity questionnaire. It includes 20 items on frequency and duration of various activities (e.g. walking, cycling, sports). For each activity including the open-ended items, we assigned a metabolic equivalent (MET) value by using a compendium of activity energy costs. One MET reflects the intensity of activity relative to lying quietly: activities with MET≥3 were coded as moderate-and-vigorous physical activity (Sabia et al., 2012; Taylor et al., 1978). Each type of physical activity was assigned a metabolic equivalent (MET) value and the total number of MET-hours/week corresponding to moderate and vigorous physical activity was used in the analysis (Steinmo et al., 2014). For gardening, the participants were asked how often they had taken part in this activity in the last 12 months, with possible answers being weekly or less than weekly gardening. Furthermore, mental health and social functioning were assessed by the mental health and social functioning sub-scores of the SF-36 questionnaire (Ware et al., 1993) that the participants filled out at every follow-up. The mental health score was based on five items that asked "How much of the time during the past four weeks" the participant felt nervous, down in the dumps, calm and peaceful, downhearted and low, and happy. The social functioning score was based on two items that recorded the extent and time to which physical or emotional problems interfered with social activities during the past four weeks (see Table S1.1). The scores were on a scale of 0 to 100 with lower scores indicating worse mental health and social functioning (Ware et al., 1993). Lastly, we collected air pollution estimates based on the annual levels of particulate matter with an aerodynamic diameter up to 2.5 μm ($PM_{2.5}$) for each follow-up were obtained from the Department for Environment Food & Rural Affairs (Defra, 2016). The $PM_{2.5}$ concentrations were modeled at a spatial resolution of 1000 m by 1000 m (approach described elsewhere (Grice et al., 2010; Stedman et al., 2005)). Maps of a relevant year to each follow-up (2003, 2008, and 2012) were obtained. We abstracted the average concentration in a 1000 m buffer around each participant's postcode centroid for each follow-up (Tonne and Wilkinson, 2013).

Table S1.1. Items of the SF-36 mental health and social functioning scores

Sub-score	Item	Response categories
Social functioning	"During the past four weeks to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbours or groups?"	• Not at all • Slightly • Moderately • Quite a bit • Extremely
	"During the past four weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting friends, relatives, etc)?	• All of the time • Most of the time • Some of the time • A little bit of the time • None of the time
Mental health How much of the time during the past four weeks:	Have you been a very nervous person?	• All of the time • Most of the time • A good bit of the time • Some of the time • A little bit of the time • None of the time"
	Have you felt so down in the dumps that nothing could cheer you up?	
	Have you felt calm and peaceful?	
	Have you felt downhearted and low?	
	Have you been a happy person?	

S2. Additional information on the inverse probability weighting analysis

To investigate the impact of differential loss to follow-up on our findings, we used an inverse probability weighting approach (Weuve et al., 2012). This analysis was restricted to participants with a baseline observation for the physical functioning test (2002-2004 for walking speed and 2007-2009 for grip strength). For walking speed, we had to exclude 377 participants that did not have a baseline measurement of walking speed (N=5376) and for grip strength, we excluded 233 participants without a baseline measurement of grip strength (N=4860). Each participants' probability of completing the study (i.e. alive and participating in the physical functioning tests in all available follow-ups) was estimated by logistic regression models with completing the study (yes/no) as outcome together with baseline age, age squared, the physical function score, sex, ethnicity, marital status, educational, employment, income and employment area deprivation, alcohol consumption, fruit and vegetable consumption, smoking status, subjective general health status, medication use for cardiovascular conditions (yes/no), social functioning (SF-36), mental health (SF-36), physical component summary (SF-36), BMI, and residential surrounding greenness (EVI in the 500 m buffer) as predictors. To characterize subjective general health status, the participants were answered the question "In general, would you say your health is ..." with possible responses being one of the following five categories: excellent, very good, good, fair, or poor. The physical component summary of the SF-36 questionnaire is an aggregate score of the eight SF-36 subscales including physical function, role limitations due to physical health problems and due to emotional problems, bodily pain, general health, vitality, social functioning, and emotional wellbeing (Taft et al., 2001). We defined the weight for each participant as the inverse probability of completing the study period, and applied it in the main model.

S3. Additional information on the mediation analysis

We followed the four steps of Baron and Kenny (1986) as used in our previous studies of health benefits of green spaces (Dadvand et al., 2016; de Keijzer et al., 2018; Zijlema et al., 2017). First, we tested for an association between EVI and distance to natural environments and the physical functioning scores as described in the main analyses. Then, we tested the association between EVI and distance to natural environments and the mediators (one at a time) by using linear mixed effects models including an interaction between age and the indicator of exposure at each follow-up with an identical set of covariates to the main analyses to quantify the association of exposure to natural environments with the mediator at baseline and over the study period. Last, we added the mediator (one at a time) and the natural environment indicator and its interaction with age to the model to evaluate the association between the mediator and the physical functioning score adjusted for the natural environment indicator as well as the association between natural environment and the physical functioning score adjusted for the mediator.

We considered mediation if (i) the exposure variable (green space) was significantly associated with the outcome (walking speed or grip strength), (ii) the exposure variable was significantly associated with the mediator, (iii) the mediator was significantly associated with the outcome after controlling for exposure, and (iv) the association between the exposure and the outcome was eliminated or weakened when the mediator was included in the model. If these four conditions were met, we calculated the relative contribution of each mediator to the association between green space and physical functioning expressed as the proportion of the total effect that was mediated by the mediator using the mediation package of R (Tingley et al., 2014). This package estimates the direct, indirect and total effects of exposure by fitting a multilevel model for the mediator as a function of exposure and a model for the outcome given the mediator and the exposure, separately.

Figure S1. Geographical distribution of the participants' postcodes at the follow-ups

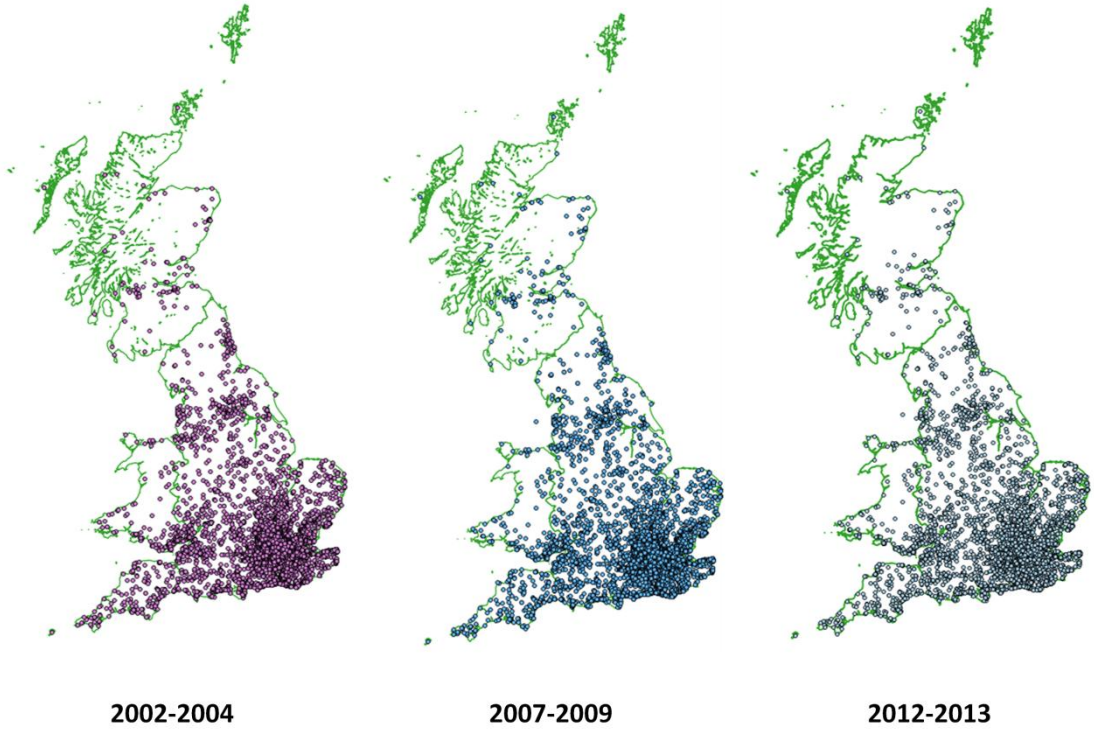

Table S1. Information on the exposure assessment: NDVI and EVI images used for the exposure assessment and information on missing values

Vegetation indices	**Follow-up years**	**Date**	**% cloud cover**	**Percentage of 500 m buffers without missing values***
Summer estimate				
NDVI & EVI	2002-2004	25/05/2003 - 09/06/2003	23	97.41
NDVI & EVI	2007-2009	24/05/2008 - 08/06/2008	7	96.80
NDVI & EVI	2012-2013	24/05/2012 - 08/06/2012	1	-
Winter estimate				
NDVI & EVI	2002-2004	03/12/2003 - 18/12/2003	11	97.47
NDVI & EVI	2007-2009	02/12/2008 - 17/12/2008	20	97.04
NDVI & EVI	2012-2013	02/12/2017 - 17/12/2012	22	-

*Information was abstracted for the first two follow-ups, but was not available for the last follow-up

Table S2. CORINE land cover classes

Natural environments	**Category**	**Codes**	***Description***
Blue spaces			
Inland water	Inland waters	511	*Water courses*
		512	*Water bodies*
Marine water	Marine waters	523	*Coastal lagoons*
		522	*Estuaries*
		521	*Sea and ocean*
Beaches, dunes, and coastal wetlands	Open spaces with little or no vegetation	331	*Beaches, dunes, and sand plains*
Green spaces			
Agricultural land	Arable land	211	*Non-irrigated arable land*
		212	*Permanently irrigated land*
		213	*Rice fields*
	Permanent crops	221	*Vineyards*
		222	*Fruit trees and berry plantations*
		223	*Olive groves*
	Pastures	231	*Pastures*
	Heterogeneous agricultural areas	241	*Annual crops associated with permanent crops*
		242	*Complex cultivation patterns*
		243	*Land principally occupied by agriculture, with significant areas of natural vegetation*
		244	*Agro-forestry areas*
Natural green	Forests	311	*Broad-leaved forest*
		312	*Coniferous forest*
		313	*Mixed forest*
	Shrub and/or herbaceous vegetation association	321	*Natural grassland*
		322	*Moors and heathland*
		323	*Sclerophyllous vegetation*
		324	*Transitional woodland shrub*
Urban green	Artificial non-agricultural vegetated areas	141	*Green urban areas*

Table S3. Description of Multiple Imputation

Software used and key setting: STATA 14 software (Stata Corporation, College Station, Texas) – Ice command (with 10 cycles)
Number of imputed datasets created: 25
Variables included in the imputation procedure: *Variables used in the main analyses (complete observations of outcome and exposure, and covariates which could have missing values) together with other relevant covariates:* Ethnicity, sex, BMI, height, IMD income score, IMD employment score, marital status, stroke, fruit and vegetable consumption, smoking status, CVD drug use, age, education, employment grade, limitation in walking >1 mile, alcohol use, frequency of vigorous physical activity, frequency of moderate physical activity, depression score, social function score, anxiety score, Mini-Mental State score, and $PM_{2.5}$ and PM_{10} concentration
Treatment of non-normally distributed variables: matching.
Treatment of binary/categorical variables: logistic models.
Statistical interactions included in imputation models: none.

Table S4. Description of the participants' exposure to residential surrounding greenness and residential distance to natural environments

	2002-2004		2007-2009		2012-2013	
	Median	(1st Q - 3rd Q)	Median	(1st Q - 3rd Q)	Median	(1st Q - 3rd Q)
NDVI						
500 m buffer	0.60	0.51 - 0.70	0.63	0.55 - 0.72	0.60	0.52 - 0.68
1000 m buffer	0.61	0.52 - 0.71	0.64	0.56 - 0.73	0.62	0.54 - 0.70
LSOA	0.61	0.52 - 0.72	0.64	0.55 - 0.74	0.62	0.52 - 0.72
EVI						
500 m buffer	0.39	0.32 - 0.48	0.38	0.31 - 0.48	0.37	0.31 - 0.45
1000 m buffer	0.40	0.33 - 0.50	0.40	0.32 - 0.51	0.39	0.33 - 0.48
LSOA	0.40	0.32 - 0.52	0.39	0.31 - 0.52	0.38	0.31 - 0.50
Distance to natural environments (m)						
Green space	324	113 – 745	308	104 – 731	299	100 – 710
Blue space	4955	2371 – 9193	4912	2323 – 9214	4933	2291 – 9248
Natural environment	305	110 – 671	291	101 – 659	279	96 – 640

Table S5. Correlations between A. EVI, NDVI, and distance to natural environments, B. EVI in the 500 meter buffer at different follow-ups, C. EVI in different buffer sizes and the LSOA, and D. EVI summer estimates and summer-winter estimates in the 500 m buffer

A.		*EVI*	*NDVI*	*Green space*	*Blue space*
	EVI (500 m buffer)	1			
	NDVI (500 m buffer)	0.93*	1		
	Green space	-0.75*	-0.71*	1	
	Blue space	0.35*	0.37*	-0.24*	1
	Natural environment	-0.70*	-0.66*	0.96*	-0.15*
B.	**EVI (500 m buffer)**	*2002-2004*	*2007-2009*	*2012-2013*	
	2002-2004	1			
	2007-2009	0.86*	1		
	2012-2013	0.82*	0.88*	1	
C.	**EVI**	*500 m*	*1000 m*	*LSOA*	
	500 m	1			
	1000 m	0.96*	1		
	LSOA	0.91*	0.91*	1	
D.	**EVI (500 m buffer)**	*Summer*	*Summer + winter*		
	Summer	1			
	Summer + winter	0.98*	1		

*p<0.05, spearman correlation efficient

Table S6. Sensitivity analyses - Difference (95% confidence interval) in the walking speed z-score at baseline and over 5 years associated with one interquartile range increase in residential surrounding greenness (EVI in 500 m buffer) and distance to natural environments.

	EVI 500 m		**Distance to natural environments**	
	Baseline	5-year difference	Baseline	5-year difference
MAIN	-0.01 (-0.04, 0.02)	0.02 (0.01, 0.04)*	0.01 (-0.01, 0.03)	-0.02 (-0.03, 0.00)*
a. Multiple imputation	-0.01 (-0.04, 0.02)	0.02 (0.01, 0.04)*	0.01 (-0.02, 0.03)	-0.02 (-0.03, 0.00)*
b. England	-0.01 (-0.04, 0.03)	0.02 (0.01, 0.04)*	0.01 (-0.02, 0.03)	-0.02 (-0.03, 0.00)*
c. Ethnicity	-0.01 (-0.04, 0.02)	0.02 (0.00, 0.04)*	0.01 (-0.02, 0.04)	-0.01 (-0.03, 0.00)*
d. No rural areas	0.00 (-0.04, 0.04)	0.02 (0.00, 0.03)	0.01 (-0.02, 0.03)	-0.02 (-0.03, 0.00)*
e. No change in postcode	0.00 (-0.04, 0.04)	0.02 (0.00, 0.04)*	0.01 (-0.02, 0.04)	-0.02 (-0.04, -0.01)*
f. No walking limitation	-0.01 (-0.04, 0.02)	0.02 (0.01, 0.04)*	0.01 (-0.01, 0.04)	-0.01 (-0.03, 0.00)
g. Summer-winter estimate	-0.02 (-0.05, 0.02)	0.02 (0.01, 0.04)*	-	-

* $p<0.05$

All estimates are from linear mixed effects models adjusted for age, age squared, sex, ethnicity, marital status, height, alcohol use, diet, smoking, rurality, education, employment grade, and tertiles of the area IMD employment and income domain.

Table S7. Sensitivity analyses- Difference (95% confidence interval) in the grip strength z-score at baseline and over 5 years associated with one interquartile range increase in residential surrounding greenness (EVI in the 500 m buffer) and distance to natural environments.

	EVI 500 m		**Distance to natural environments**	
	Baseline	5-year difference	Baseline	5-year difference
MAIN	0.03 (0.00, 0.07)*	0.00 (-0.02, 0.02)	-0.02 (-0.05, 0.01)	-0.02 (-0.04, 0.00)*
a. Multiple imputation	0.05 (0.02, 0.08)*	-0.01 (-0.03, 0.01)	-0.03 (-0.05, -0.01)*	-0.01 (-0.02, 0.01)
b. England	0.04 (0.01, 0.07)*	0.00 (-0.02, 0.02)	-0.02 (-0.05, 0.01)	-0.02 (-0.04, 0.00)*
c. Ethnicity	0.04 (0.00, 0.07)*	0.00 (-0.02, 0.02)	-0.02 (-0.05, 0.01)	-0.01 (-0.03, 0.01)
d. No rural areas	0.05 (0.01, 0.09)*	-0.01 (-0.04, 0.01)	-0.02 (-0.04, 0.01)	-0.02 (-0.04, 0.00)*
e. No change in postcode	0.05 (0.01, 0.08)*	0.00 (-0.02, 0.02)	-0.04 (-0.07, -0.00)*	-0.02 (-0.04, 0.00)*
f. No walking limitation	0.04 (0.00, 0.07)*	-0.01 (-0.03, 0.02)	-0.02 (-0.05, 0.01)	-0.02 (-0.04, 0.00)
g. Summer-winter estimate	0.04 (0.01, 0.08)*	0.00 (-0.02, 0.02)	-	-

* $p<0.05$

All estimates are from linear mixed effects models adjusted for age, age squared, sex, ethnicity, marital status, height, alcohol use, diet, smoking, rurality, education, employment grade, and tertiles of the area IMD employment and income domain.

Table S8. Inverse probability weighting

	EVI 500 m		**Distance to natural environments**	
	Baseline	5-year difference	Baseline	5-year difference
Walking speed (N=5376)				
a. Main model	-0.01 (-0.05, 0.02)	0.02 (0.00, 0.04)*	0.01 (-0.01, 0.04)	-0.02 (-0.03, 0.00)*
b. Inverse probability weighting	-0.02 (-0.05, 0.01)	0.02 (0.01, 0.04)*	0.01 (-0.01, 0.04)	-0.02 (-0.03, 0.00)*
Grip strength (N=4860)				
a. Main model	0.03 (-0.01, 0.06)	0.00 (-0.02, 0.02)	-0.02 (-0.04, 0.01)	-0.02 (-0.04, 0.00)
b. Inverse probability weighting	0.02 (-0.02, 0.05)	0.00 (-0.02, 0.02)	-0.01 (-0.04, 0.01)	-0.02 (-0.04, 0.00)

Table S9. Mediation analysis of the association between green space (EVI 500 m or distance to natural environments) and the walking speed z-score (ZWS).

Predictor	Out-come	EVI 500 m		Distance to any natural environment	
		Baseline	5-year difference	Baseline	5-year difference
Main model , association with green space (GS, per interquartile range increase)					
GS (not adjusted for mediators)	ZWS	-0.008 (-0.039, 0.023)	0.020 (0.005, 0.035)*	0.010 (-0.014, 0.034)	-0.016 (-0.029, -0.003)*
Mediation by moderate-to-vigorous physical activity (PA, continuous per MET hr/week)					
GS	PA	1.650 (1.160, 2.141)*	0.144 (-0.088, 0.375)	-0.944 (-1.338, -0.550)*	-0.048 (-0.248, 0.153)
PA (adjusted for GS)	ZWS	0.005 (0.004, 0.006)*		0.005 (0.004, 0.006)*	
GS (adjusted for PA)	ZWS	-0.018 (-0.050, 0.013)	0.020 (0.004, 0.035)*	0.015 (-0.009, 0.039)	-0.016 (-0.029, -0.003)*
Mediation by gardening (GA, weekly or less/never)					
GS (results from a logistic mixed model)	GA (OR)	2.032 (1.760, 2.346)*	1.020 (0.952, 1.093)	0.655 (0.583, 0.736)*	0.991 (0.933, 1.053)
GA (adjusted for GS)	ZWS	0.123 (0.090, 0.156)*		0.124 (0.091, 0.157)*	
GS (adjusted for GA)	ZWS	-0.018 (-0.049, 0.013)	0.020 (0.004, 0.035)*	0.017 (-0.007, 0.042)	-0.015 (-0.028, -0.002)*
Mediation by air pollution ($PM_{2.5}$, per µg/m^3 increase)					
GS	$PM_{2.5}$	-0.533 (-0.604, -0.462)*	-0.190 (-0.221, -0.160)*	0.416 (0.349, 0.483)*	0.163 (0.136, 0.190)*
$PM_{2.5}$ (adjusted for GS)	ZWS	0.058 (0.051, 0.064)*		0.057 (0.051, 0.064)*	
GS (adjusted for $PM_{2.5}$)	ZWS	0.030 (-0.001, 0.062)	0.027 (0.011, 0.042)*	-0.018 (-0.042, 0.007)	-0.024 (-0.037, -0.011)*
Mediation by mental health component of SF-36 (MH, on a scale of 0-100)					
GS	MH	0.214 (-0.056, 0.485)	0.102 (-0.025, 0.230)	-0.003 (-0.219, 0.214)	-0.113 (-0.224, -0.002)*
MH (adjusted for GS)	ZWS	0.004 (0.002, 0.006)*		0.004 (0.002, 0.006)*	
GS (adjusted for MH)	ZWS	-0.012 (-0.044, 0.019)	0.019 (0.004, 0.035)*	0.013 (-0.012, 0.037)	-0.014 (-0.027, -0.001)*
Mediation by social functioning scale of SF-36 (SF, on a scale of 0-100)					
GS	SF	0.232 (-0.395, 0.859)	0.358 (0.054, 0.662)*	0.314 (-0.171, 0.799)	-0.332 (-0.594, -0.070)*
SF (adjusted for GS)	ZWS	0.006 (0.005, 0.007)*		0.006 (0.005, 0.007)*	
GS (adjusted for SF)	ZWS	-0.010 (-0.041, 0.021)	0.018 (0.003, 0.033)*	0.009 (-0.015, 0.033)	-0.014 (-0.027, -0.001)*

* $p<0.05$

Note: Estimates are from linear mixed effects models (except where otherwise indicated) adjusted for age, age squared, sex, ethnicity, marital status, height, alcohol use, diet, smoking, rurality, education, employment grade, and tertiles of the area IMD employment and income domain.

List of abbreviations: GS, green space; EVI, enhanced vegetation index; ZWS, z-score walking speed; PA, physical activity; GA, gardening; OR, odds ratio; $PM_{2.5}$, particulate matter with a diameter of less than 2.5 micrometers; MHC, mental health; SF, social functioning.

Table S10. Mediation analysis of the association between green space (GS; distance to any natural environment) and the grip strength z-score (ZGS).

Predictor	Out-come	Distance to any natural environment	
		Baseline	5-year difference
Main model			
GS (not adjusted for mediators)	ZGS	-0.018 (-0.045, 0.008)	-0.018 (-0.035, 0.000)*
Mediation by moderate-to-vigorous physical activity (PA, continuous per MET hr/week)			
GS	PA	-1.033 (-1.490, -0.576)*	0.058 (-0.252, 0.369)
PA (adjusted for GS)	ZGS	0.005 (0.004, 0.006)*	
GS (adjusted for PA)	ZGS	-0.013 (-0.040, 0.014)	-0.019 (-0.036, -0.001)
Mediation by gardening (GA, weekly or less/never)			
GS (results from a logistic mixed model)	GA (OR)	0.641 (0.559, 0.734)*	0.918 (0.836, 1.007)
GA (adjusted for GS)	ZGS	0.079 (0.042, 0.116)*	
GS (adjusted for GA)	ZGS	-0.015 (-0.042, 0.013)	-0.017 (-0.035, 0.000)
Mediation by air pollution ($PM_{2.5}$, per $\mu g/m^3$ increase)			
GS	$PM_{2.5}$	0.719 (0.676, 0.761)*	-0.043 (-0.066, -0.021)*
$PM_{2.5}$ (adjusted for GS)	ZGS	-0.009 (-0.023, 0.005)	
GS (adjusted for $PM_{2.5}$)	ZGS	-0.011 (-0.040, 0.018)	-0.018 (-0.036, -0.001)*
Mediation by mental health component of SF-36 (MH, on a scale of 0-100)			
GS	MH	-0.016 (-0.250, 0.218)	-0.198 (-0.358, -0.038)*
MH (adjusted for EVI)	ZGS	0.004 (0.001, 0.006)*	
GS (adjusted for MH)	ZGS	-0.017 (-0.045, 0.010)	-0.016 (-0.034, 0.002)
Mediation by social function (SF, on a scale of 0-100)			
GS	SF	-0.001 (-0.528, 0.525)	-0.286 (-0.656, 0.084)
SF (adjusted for EVI)	ZGS	0.003 (0.002, 0.004)*	
GS (adjusted for SF)	ZGS	-0.019 (-0.046, 0.008)	-0.017 (-0.035, 0.000)

* $p<0.05$

Note: Estimates are from linear mixed effects models (except where otherwise indicated) adjusted for age, age squared, sex, ethnicity, marital status, height, alcohol use, diet, smoking, rurality, education, employment grade, and tertiles of the area IMD employment and income domain.

List of abbreviations: GS, green space; ZGS, z-score grip strength; PA, physical activity; GA, gardening; OR, odds ratio; $PM_{2.5}$, particulate matter with a diameter of less than 2.5 micrometers; MHC, mental health; SF, social functioning.

References

Abel, G.A., Barclay, M.E., Payne, R.A., 2016. Adjusted indices of multiple deprivation to enable comparisons within and between constituent countries of the UK including an illustration using mortality rates. BMJ Open 6, e012750. doi:10.1136/bmjopen-2016-012750

Baron, R.M., Kenny, D.A., 1986. The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. J. Pers. Soc. Psychol. 51, 1173–1182. doi:http://dx.doi.org/10.1037/0022-3514.51.6.1173

Dadvand, P., Bartoll, X., Basagana, X., Dalmau-Bueno, A., Martinez, D., Ambros, A., Cirach, M., Triguero-Mas, M., Gascon, M., Borrell, C., Nieuwenhuijsen, M.J., 2016. Green spaces and General Health: Roles of mental health status, social support, and physical activity. Environ. Int. 91, 161–167. doi:10.1016/j.envint.2016.02.029

de Keijzer, C., Tonne, C., Basagaña, X., Valentín, A., Singh-Manoux, A., Alonso, J., Antó, J.M., Nieuwenhuijsen, M.J., Sunyer, J., Dadvand, P., 2018. Residential surrounding greenness and cognitive decline: A 10-year follow-up of the Whitehall II cohort. Env. Heal. Perspect 126. doi:DOI:10.1289/EHP2875

Defra, 2016. Modelled background pollution data [WWW Document]. URL https://uk-air.defra.gov.uk/data/pcm-data (accessed 2.24.17).

European Commission, 2017. Urban-rural typology [WWW Document]. URL http://ec.europa.eu/eurostat/statistics-explained/index.php?title=Archive:Urban-rural_typology (accessed 6.20.18).

Grice, S., Brookes, D., Stedman, J., Kent, A., Walker, H., Cooke, S., Vincent, K., Lingard, J., Bush, T., Abbott, J., Yap, F.W., 2010. UK modelling under the Air Quality Directive (2008/50/EC) for 2009 covering the following air quality pollutants: SO2, NOx, NO2, PM10, PM2.5, lead, benzene, CO, and ozone. Harwell, UK.

National Records of Scotland, 2001. Population Estimates - Census 2001 [WWW Document]. URL http://statistics.gov.scot/data/census-population-2001 (accessed 2.15.17).

Noble, M., Wright, G., Smith, G., Dibben, C., 2006. Measuring Multiple Deprivation at the Small-Area Level. Environ. Plan. A 38, 169–185. doi:10.1068/a37168

Office for National Statistics, 2001. Population density [WWW Document]. URL https://data.gov.uk/dataset/population_density (accessed 2.15.17).

Rusmaully, J., Dugravot, A., Moatti, J.-P., Marmot, M.G., Elbaz, A., Kivimaki, M., Sabia, S., Singh-Manoux, A., 2017. Contribution of cognitive performance and cognitive decline to associations between socioeconomic factors and dementia: A cohort study. PLOS Med. 14, e1002334.

Sabia, S., Dugravot, A., Kivimaki, M., Brunner, E., Shipley, M.J., Singh-Manoux, A., 2012. Effect of Intensity and Type of Physical Activity on Mortality: Results From the Whitehall II Cohort Study. Am. J. Public Health 102, 698–704. doi:10.2105/AJPH.2011.300257

Singh-Manoux, A., Fayosse, A., Sabia, S., Canonico, M., Bobak, M., Elbaz, A., Kivimaki, M., Dugravot, A., 2017. Atrial fibrillation as a risk factor for cognitive decline and dementia. Eur. Heart J. ehx208. doi:10.1093/eurheartj/ehx208

Singh-Manoux, A., Kivimaki, M., Glymour, M.M., Elbaz, A., Berr, C., Ebmeier, K.P., Ferrie, J.E., Dugravot, A., 2012. Timing of onset of cognitive decline: results from Whitehall II prospective cohort study. BMJ 344, d7622. doi:doi: https://doi.org/10.1136/bmj.d7622

Stedman, J., Bush, T., Vincent, K., Kent, A., Grice, S., Abbott, J., 2005. UK air quality modelling for annual reporting 2003 on ambient air quality assessment under Council Directives 96/62/EC, 1999/30/EC and 2000/69/EC. Harwell, UK.

Steinmo, S., Hagger-Johnson, G., Shahab, L., 2014. Bidirectional association between mental health and physical activity in older adults: Whitehall II prospective cohort study. Prev. Med. (Baltim). 66, 74–79. doi:10.1016/j.ypmed.2014.06.005

Taft, C., Karlsson, J., Sullivan, M., 2001. Do SF-36 summary component scores accurately summarize subscale scores? Qual. Life Res. 10, 395–404. doi:10.1023/A:1012552211996

Taylor, H.L., Jacobs, D.R.J., Schucker, B., Knudsen, J., Leon, A.S., Debacker, G., 1978. A questionnaire for the assessment of leisure time physical activities. J. Chronic Dis. 31, 741–755.

Tingley, D., Yamamoto, T., Hirose, K., Keele, L., Imai, K., 2014. mediation: R Package for Causal Mediation Analysis. J. Stat. Software, Artic. 59, 1–38. doi:10.18637/jss.v059.i05

Tonne, C., Wilkinson, P., 2013. Long-term exposure to air pollution is associated with survival following acute coronary syndrome. Eur. Heart J. 34, 1306–1311. doi:10.1093/eurheartj/ehs480

Trudel, X., Shipley, M.J., McEniery, C.M., Wilkinson, I.B., Brunner, E.J., 2016. Socioeconomic status, education, and aortic stiffness progression over 5 years: the Whitehall II prospective cohort study. J. Hypertens. 34, 2038–2044. doi:10.1097/HJH.0000000000001057

Ware, J.E., Snow, K.K., Kosinski, M., Gandek, B., Institute, N.E.M.C.H.H., 1993. SF-36 health survey: manual and interpretation guide. The Health Institute, New England Medical Center, Boston, Massachusetts.

Weuve, J., Tchetgen Tchetgen, E.J., Glymour, M.M., Beck, T.L., Aggarwal, N.T., Wilson, R.S., Evans, D.A., Mendes de Leon, C.F., 2012. Accounting for bias due to selective attrition: the example of smoking and cognitive decline. Epidemiology 23, 119–128. doi:10.1097/EDE.0b013e318230e861

Zijlema, W.L., Triguero-Mas, M., Smith, G., Cirach, M., Martinez, D., Dadvand, P., Gascon, M., Jones, M., Gidlow, C., Hurst, G., Masterson, D., Ellis, N., van den Berg, M., Maas, J., van Kamp, I., van den Hazel, P., Kruize, H., Nieuwenhuijsen, M.J., Julvez, J., 2017. The relationship between natural outdoor environments and cognitive functioning and its mediators. Environ. Res. 155, 268–275. doi:10.1016/j.envres.2017.02.017