JECH Online First, published on March 6, 2014 as 10.1136/jech-2013-203767

The association between green space and mental health varies across the lifecourse. A longitudinal study

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Received 20 December 2013
Revised 27 January 2014
Accepted 4 February 2014

To cite: Astell-Burt T, Mitchell R, Hartig T. *J Epidemiol Community Health* Published Online First: [*please include* Day Month Year] doi:10.1136/jech-2013-203767

ABSTRACT

Background Epidemiological studies on green space and health have relied almost exclusively on cross-sectional designs, restricting understanding on how this relationship could vary across the lifecourse.

Methods We used multilevel linear regression to analyse variation in minor psychiatric morbidity over nine annual waves of the British Household Panel Survey (1996–2004). The sample was restricted to residents of urban areas who remained within their neighbourhoods for at least 12 months. The 12-item General Health Questionnaire and confounders were reported for 29 626 male and 35 781 female observations (person-years). This individual-level dataset was linked to a measure of green space availability within each ward of residence. Regression models included age, gender, employment status, household tenure, marital status, education, smoking status and household income.

Results When not considering age, green space was associated with better mental health among men, but not women. Interaction terms fitted between age and green space revealed variation in the association between green space and mental health across the lifecourse and by gender. For men, the benefit of more green space emerged in early to mid-adulthood. Among older women, a curvilinear association materialised wherein those with a moderate availability of green space had better mental health.

Conclusions These findings illustrate how the relationship between urban green space and health can vary across the lifecourse, and they highlight the need for longitudinal studies to answer why green space may be better for health at some points in the lifecourse than others.

INTRODUCTION

Recently, commentary[1] has called for epidemiology to push beyond repeated documentation of the socioeconomic patterning of disease towards a focus on preventive health. In this regard, the 30+ years of collaboration between environmental psychologists, geographers and social epidemiologists to study the health impacts of parks and other 'green spaces' has broken new ground. Small-scale lab and field experiments have demonstrated the plausibility of stress-reduction mechanisms,[2 3] while large-scale observational research has reported that green space constrains socioeconomic differentials in mortality.[4] These positive outcomes are likely to be entwined with green space as a promoter of social interactions[5] and active lifestyles.[6 7] As a consequence, the old 'lungs of the city'[8] are now increasingly regarded as an important resource for promoting health and a lever for equalising socioeconomic disparities.[9–11]

The mainline of epidemiological investigation on green space and health, however, is arriving at a crossroads. Much of the previous research has exploited cross-sectional data to establish association,[12 13] but this has restricted exploration of the contingencies of place effects across the lifecourse, resulting in potentially misleading assumptions of universality and unconditional benefits. Questions such as 'do green spaces promote better health regardless of age?' remain untested,[12] but constitute important avenues for research if investments in green spaces are to be widely beneficial. Lifecourse epidemiology encourages the study of how biological, behavioural and psychosocial pathways change and interact to affect health as a person ages and transitions into and out of social systems.[14] As levels of stress are not consistent and some of the key pathways (eg, physical activity and social interaction) are engaged differently by age, then the strength of association between green space and health plausibly could vary across the lifecourse. In short, it is not a foregone conclusion that exposure to green space manifests in equal health benefits for all people, during all life phases. The purpose of this study was to explore the consistency of association between green space and health across the lifecourse.

METHODS

Design

In the absence of cohort data for people surveyed repeatedly across their entire lives, we adopted an accelerated longitudinal design in which people of widely varying ages were surveyed at an initial time point and then followed-up over several years.[15] The accelerated longitudinal design meant that rather than following-up the same people for 90+ years, study members of different ages followed-up over time could instead be pooled. This design enabled the use of highly detailed panel data from the British Household Panel Survey (BHPS).

Data

The BHPS is a nationally representative dataset tracking private households through time. The initial survey was conducted in 1991 on approximately 5500 households and 10 300 adult members, with annual follow-up thereafter. It was sampled via a stratified multistage design, with individual participants clustered within households and areas of residence. Further information on the BHPS and its sampling can be found in reference [16] and online at (http://www.iser.essex.ac.uk/survey/bhps).

Health status

Our focus was on a measure of minor psychiatric morbidity, derived from the 12-item General Health Questionnaire (GHQ).[17] The GHQ was developed as a screening instrument for use in primary care settings. It includes questions on concentration, sleep loss due to worry, perception of role, capability in decision making, whether constantly under strain, perception of problems in overcoming difficulties, enjoyment of day-to-day activities, coping resources, loss of confidence, self-worth, general happiness and whether suffering depression or unhappiness.[18] Responses to these items are summed to construct a continuous measure. The GHQ scores had a normal distribution. Sensitivity analyses were conducted with a binary version of this variable in which those with GHQ scores of 4 were classified as having clinically significant minor psychiatric morbidity, and contrasted with those scoring less than 4. This threshold has been identified as appropriate within the UK population.[19] While research on green space and mental health using GHQ has varied considerably in its definition of 'caseness', ranging from cut points of 2 and over[20] to 5 and above[21] out of 12, previous work has suggested that small variations in this threshold are unlikely to yield markedly different results.[22]

Green space

The measure of green space was estimated using data circa 2000. The measure was constructed at the ward level. Wards are small geographical areas that can range in population from less than 1000 to over 30 000 people. This measure gave the percentage total land cover of green and natural environment (excluding water and private gardens) within every ward in Britain in 2000,[23] and has compared favourably with alternative measures derived from other data sources.[24] Cross-sectional research has also reported association between this measure of green space, self-rated health and all-cause mortality.[24]

Other explanatory variables

Previous studies using the BHPS have found mental health associated with age, gender, employment status, household tenure (eg, owner occupied vs rental), marital status, highest educational qualification, smoking status and household income, equivalised before household costs according to size and composition using the McClements equivalence scale.[25] Our analyses thus adjusted for these variables.

Sample

The initial sample size was 54 327 and 62 864 person-years of observations for men and women, respectively. The geographical coverage of our measure of green space limited the scope of our investigation to England, Scotland and Wales. As the measure of green space was derived from data sources circa 2000, we restricted our sample to a 9-year timeframe centred on that year, including individuals surveyed in 1996–2004 inclusive. This precautionary measure guarded against bias incurred through change in green space availability within the same neighbourhood over time.

We focused our investigation on individuals living in urban neighbourhoods. Large proportions of the populations of economically developed nations, and the burden of disease among them, are concentrated in urban areas.[26] Also, in urban areas, much of the proximity to green environments is provided by discrete and bounded parks or river corridors, making it straightforward to quantify physical (versus visual) access in terms of proximity. In rural areas, the vast majority of the environment is 'natural', making it more difficult to measure 'availability'. The focus upon urban environment meant excluding approximately 32 000 person-year observations located in rural areas.

A final step in sample selection involved refining the measure of green space availability to adjust for possible changes in land-use through time. We omitted approximately 15 000 observations for people who had not spent at least 12 months resident at their current address reported at the time of the survey.[21] We also omitted approximately 4500 observations missing a valid GHQ score. Our final sample consisted of 29 626 male and 35 781 female observations from 1996 to 2004 (54.5% and 56.9% of the initial samples). Each participant, therefore, contributed a maximum of 9 years of observations to the analyses. People at risk of minor psychiatric morbidity (GHQ scores $\geq$4) were not disproportionately influenced by these selection criteria, however, those removed were more likely to be older, living in very green areas (ie, on the urban periphery), never married, unemployed, lacking educational qualifications, and/or living in privately rented housing. Totally, 65 407 person-years were attributable to participants resident in 2681 wards, ranging from 1 to 255 participants per ward (median count of participants per ward=10).

Analysis

Descriptive statistics were used to investigate the patterning of GHQ scores across neighbourhoods with different quantities of green space. To facilitate this description, we classified the measure of green space into three levels of proximity: 0–33% (low), 34–66% (moderate) and 67–100% (high). In recognition of known gender differences in mental health,[27] we conducted all our analyses separately for males and females.

Multilevel linear regression was then used to model the patterning of GHQ scores across the lifecourse. Level 1 in the model represented the time-specific GHQ score, nested within people at level 2. We developed these models first with the age parameter at level 1 to represent 'lifecourse'. GHQ scores follow curvilinear paths with age, that differ by gender.[28] We tested gender-stratified models fitted with square and cubic transformations of the age parameter. Thereafter, these models were adjusted sequentially for measures of socioeconomic circumstances and other potential confounders. All variables were considered time-dependent, except for gender.

The aforementioned models were fitted initially with a continuous measure of green space, which was then replaced by the three-level classification to test for curvilinear and threshold effects. We then introduced a cross-level interaction term between green space and age, to assess variation in the risk of minor psychiatric morbidity in relation to green space across the lifecourse. Growth curves for each level of green space proximity were plotted using the predicted probabilities of GHQ by age, separately for males and females and adjusted for all other explanatory variables.

We tested the sensitivity of our results to geographical clustering of participants within wards. Assessment of clustering was atypical, given the propensity for some people to move from one ward to another and, therefore, a cross-classified multilevel model[29] was estimated using Markov Chain Monte Carlo methods (MCMC).[30] These sensitivity analyses yielded very similar results, so we present those of the more conventional 2-level multilevel models for simplicity. All analyses were conducted using MLwIN V.2.24.[31]

RESULTS

Descriptive statistics for the study population are reported in table 1. A risk of minor psychiatric morbidity (GHQ scores ≥4) was less prevalent among residents of greener neighbourhoods. The age distributions across each level of green space exposure were reasonably consistent. In greener areas, residents were less likely to be in the lowest quintile of household income, less likely to be unemployed and more likely to be married or cohabiting. Conversely, persons with no educational qualifications were more common in greener areas (among women in particular), as were home owners and non-smokers.

We searched for linear and curvilinear trajectories in GHQ through the lifecourse using multilevel linear regression models. For men and women alike, GHQ was found to vary in a curvilinear fashion, with statistically significant linear, square and cubic age parameters (all $p<0.001$). These models were then augmented with the continuous measure of green space to test for an age-adjusted association with GHQ. The results are shown in figure 1. For men, higher green space exposure was linearly related to a significantly lower GHQ (ie, better mental health). By contrast, the age-adjusted relationship between green space and GHQ was curvilinear ('u-shaped') for women, with the most favourable GHQ scores observed among those with a moderate level of green space exposure. These associations between green space and GHQ were slightly attenuated after adjusting for measures of socioeconomic circumstances and other potential confounders, though remained statistically significant ($p<0.05$).

Having established that there were different associations between green space and GHQ for men and women, we then replaced the continuous measure with a set of exposure thresholds: 0–33% (low), 34–66% (medium), and 67–100% (high). For men, the linear association between green space and GHQ remained significant (table 2, Model 1). For women, the u-shaped association between green space and GHQ was evident, though not statistically significant (table 3, Model 3).

To investigate whether green space had a consistent association with GHQ across the lifecourse, interaction terms were fitted between age and green space. Variation in the association between green space and GHQ was revealed across the lifecourse for men (table 2, Model 2) and for women (table 3; Model 4). However, as with the main effects analysis, the nature of the age-moderated associations differed by gender. To help visualise

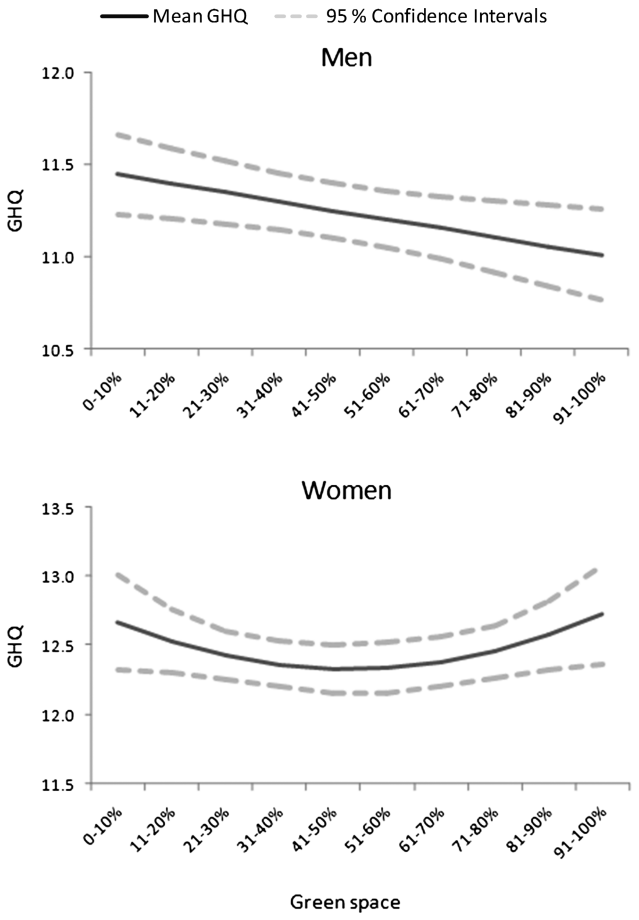

Figure 1 Association between green space availability and General Health Questionnaire (GHQ) scores, by gender.

Table 1 Study population characteristics

	Men (n=29 626 person-years)			Women (n=35 781 person-years)		
Green space	**0–33%**	**34–66%**	**>66%**	**0–33%**	**34–66%**	**>66%**
n	10 040	13 561	6025	12 171	16 465	7145
Minor psychiatric morbidity (GHQ ≥4)	17.6	15.7	16.0	24.6	23.4	23.6
Age (years)						
15–29	23.1	20.6	19.9	20.8	18.3	18.1
30–44	30.6	28.9	30.1	31.5	28.9	30.7
45–59	22.3	26.0	24.8	22.2	24.7	24.7
60–74	16.6	16.7	17.8	16.1	17.4	17.0
≥75	7.5	7.8	7.5	9.4	10.8	9.5
Socioeconomic circumstances and smoking status						
Household income (lowest quintile)	20.4	20.5	18.2	20.6	20.4	18.1
Unemployed	4.7	4.0	3.9	2.7	2.1	1.9
Married/cohabiting	64.7	70.3	72.3	58.7	61.6	65.9
No educational qualifications	19.7	20.7	20.3	24.9	29.6	29.1
Home owner/with mortgage	72.9	77.4	80.8	68.6	72.8	77.2
Non-smoker	69.7	72.2	74.8	71.0	73.3	74.4

Lowest household income quintile interval: (men) £0–£12 927; (women) £0–£11 317.
GHQ, General Health Questionnaire.

Table 2 Association between green space and GHQ among men, fully adjusted

	Model 1		Model 2	
Fixed effects	**Coefficient**	**SE**	**Coefficient**	**SE**
Constant	6.970	0.320***	6.558	0.363***
Age	1.897	0.134***	2.038	0.148***
Age^2	−0.254	0.021***	−0.263	0.021***
Age^3	0.010	0.001***	0.010	0.001***
Green space				
0–33%	(Ref)		(Ref)	
34–66%	−0.283	0.099**	0.345	0.300
67–100%	−0.333	0.124**	0.300	0.370
Age×green space				
Age×34–66%			−0.214	0.100*
Age^2×34–66%			0.013	0.007
Age×67–100%			−0.213	0.123*
Age^2×67–100%			0.013	0.009
Variances				
Level: person	11.991	0.281	11.983	0.280
Level: measure	13.143	0.121	13.142	0.121

Model 1: Age and green space categories, fully adjusted.
Model 2: Age×green space categories, fully adjusted.
Full adjustment: + Household income, economic activity, couple status, educational qualifications, household tenure; smoking status.
*p<0.05, **p<0.01, ***p<0.001.
GHQ, General Health Questionnaire.

these differences, figure 2 illustrates the mean GHQ scores by green space threshold, predicted from Models 2 and 4.

For men aged 15–20 years, green space exposure appeared to have little impact on mean GHQ scores. However, by age 30 years, an inequality had begun to emerge between the mean GHQ score of men living in the high and moderate versus low green space thresholds, peaking at age 41–45 years. This

Table 3 Association between green space and GHQ among women, fully adjusted

	Model 3		Model 4	
Fixed effects	**Coefficient**	**SE**	**Coefficient**	**SE**
Constant	9.946	0.324***	9.760	0.336***
Age	1.124	0.141***	1.157	0.142***
Age^2	−0.152	0.021***	−0.152	0.021***
Age^3	0.005	0.001***	0.005	0.001***
Green space				
0–33%	(Ref)			
34–66%	−0.077	0.102	0.365	0.192*
67–100%	0.093	0.128	0.077	0.244
Age×green space				
Age×34–66%			−0.073	0.027**
Age×67–100%			0.001	0.034
Variances				
Level: person	14.255	0.314	14.239	0.314
Level: measure	17.623	0.147	17.622	0.147

Model 3: Age and green space categories, fully adjusted.
Model 4: Age × green space categories, fully adjusted.
Full adjustment: + Household income, economic activity, couple status, educational qualifications, household tenure; smoking status.
*p<0.05, **p<0.01, ***p<0.001.
GHQ, General Health Questionnaire.

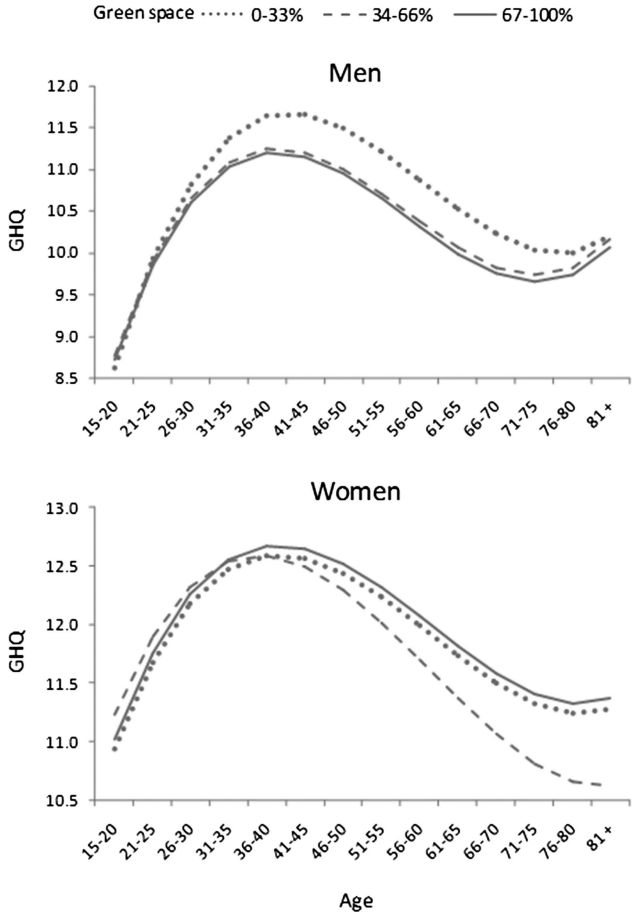

Figure 2 Trajectories in General Health Questionnaire (GHQ) scores, by green space exposure and age group.

inequality persisted up to age 60 years, and then slowly converged through into older age.

For women, the patterning of GHQ by green space threshold across the lifecourse was markedly different from that observed for men. Compared with women of 15–20 years of age living in urban neighbourhoods with a low level of green space (0–33%), those of the same age, but with a moderate exposure (34–66%) had a higher mean GHQ score (ie, poorer mental health). Mean GHQ scores between 20 and 40 years old were similar, irrespective of green space exposure. However, while the general pattern was for lower GHQ scores from age 41 years onward, diverging trajectories were observed, with better mental health sustained among women living in moderately green neighbourhoods through to older age. By contrast, no differences in mean GHQ scores were found between women with low or high levels of green space exposure through the life course.

Results from sensitivity analyses using multilevel logit regression of GHQ expressed as a binary variable (scores of 4 or more identifying a case of clinically significant minor psychiatric morbidity) were very similar to those reported with linear models.

DISCUSSION

Previous epidemiological studies have reported better mental health, as measured using the GHQ, among people living in neighbourhoods with more green space.[20 21 32 33] Our findings suggest that the association between urban green space and mental health varies across the lifecourse following gender-

specific trajectories. For males, the benefit of green space on GHQ scores emerged in early adulthood. Green space appeared to be protective for women, but not in a linear fashion and only among those in their mid-40s and older. Those women in the greenest and least green neighbourhoods reported similar GHQ scores, but those with a moderate degree of exposure had the most favourable levels of mental health. Our results, therefore, suggest a parabolic-like patterning of mental health across green space among women in middle to older age. These results were robust to adjustment for a range of confounders and, given the high degree of correlation between person-level and area-level socioeconomic circumstances, this would also have gone some way to adjust for potential impacts of neighbourhood deprivation and local population turnover.

Inevitably, this study raises new questions and challenges for future research. Not least is the exploration of how exposure to green space varies throughout different stages in life and how these differences manifest in health disparities. Studies of neighbourhoods and health often refer to the possibility of different effect sizes observed when neighbourhood level exposures are measured at different scales.[34] Few studies, however, have identified what the most appropriate geographical scale is for defining green space exposure, and it is quite plausible that no single scale is relevant across all stages of the lifecourse. Some work has linked low birth weight and health in later life,[35] and an encouraging development in this regard is that birth weight is positively associated with neighbourhood greenness.[36 37] It will be important to investigate whether early life exposure to green space translates into long-term health benefits. While our study was able to track change in mental health across parts of peoples' lives through an accelerated cohort design, a drawback of this design is the limited scope for separating cohort effects from those of age and period.[38] It is plausible that people growing up in different times may have contrasting relationships with urban green space. This may have important implications for health, and also for the appropriateness of investments in particular types of green spaces based upon the intentions to promote health and well-being. Perhaps the only avenue we have to address this issue is through the linkage of green space measures to birth cohorts containing fine-grained geographical information, though such ventures are likely to be restricted to more recent studies (eg, the Millennium Cohort Study) as it is likely to be difficult to accurately gauge exposure to urban green space for much earlier sources of cohorts (eg, the 1958 and 1970s British Birth Cohort Studies). Knowledge on the relationship between urban green space and health across the lifecourse is likely to evolve as current birth cohorts grow older.

A second crucial aspect to take into account is the issue of confounding. For example, children will not directly choose where they live, but the birth of a child can influence the moving intentions and types of local environments parents select into.[39] Parents who prefer more natural surroundings (eg, for participating in physical activity) may be more likely to select into neighbourhoods which fit those expectations. This means that opportunities to engage with green space from the earliest years of life are not randomly distributed throughout the population. These types of selection effects are severely under-researched in the context of green space and health but are likely to play out across the lifecourse in ways that are difficult to predict. In the context of our study, for example, it is impossible to conclude whether the diminished mental health among older women in the greenest neighbourhoods is the result of a direct effect, some form of indirect effect (eg, potential feelings of social isolation and lower levels of physical activity), or the manifestation of selective processes (eg, older women in need of regular healthcare moving to retirement villages located in very green areas).

Finally, given the increasing number of studies suggesting that different sorts of green space may promote different health responses,[40] possibly via different mediating pathways, it is highly plausible that people looking to move will actively discriminate between types of green spaces in the house-search (eg, parks vs cemeteries). Associations with health vary between different types of green spaces, but we know little about what types of green spaces matter at different stages of the lifecourse and whether these are genuinely causal effects or selective processes. Another important challenge will be refining measures of exposure that deal with whether mediating activities such as physical activity occur within green spaces, and also the definition of consistent measures of green space quantity, quality and type, as they, in addition to people, change across the lifecourse.

CONCLUSION

At a time when green spaces are being championed for health promotion, our study provides evidence to suggest that the relationship with mental health varies by gender and is not consistent across the lifecourse. Benefits from investments in green space may vary substantively within populations. We encourage more analyses of longitudinal data to investigate how and why the impact of green space on health varies by lifestage, and on the selective processes which determine who has access to what types of green spaces and when.

What is already known on this subject

It is plausible that the potential benefits of green space for health vary from person to person. Epidemiological studies on green space and health, however, tend to rely almost exclusively on cross-sectional designs, restricting understanding on how this relationship could vary across the lifecourse.

What this study adds

Our findings suggest that the association between urban green space and mental health varies across the lifecourse following gender-specific trajectories. For males, the benefit of green space on General Health Questionnaire (GHQ) scores emerged in early adulthood. No association between green space and mental health was observed for women until later in life. Older women in the greenest and least green neighbourhoods reported similar GHQ scores, but those with a moderate degree of exposure had the most favourable levels of mental health. These findings highlight the need for longitudinal studies to investigate how and why the impact of green space on health varies by lifestage, and on the selective processes which determine who has access to what types of green spaces and when.

Acknowledgements The BHPS data used in this study were collected by the ESRC Centre on Micro-social Change at the University of Essex, now incorporated within the Institute of Social and Economic Research (ISER). The data were made available through the UK Data Archive. The help provided by staff at ISER in linking the green space data to the BHPS is acknowledged. We are grateful to the Forestry Commission for funding the study. The funders had no sight of this article until after

submission. They have provided no input to the research process or reporting of this project. RM's contribution was funded by the Scottish Government's Rural and Environment Science and Analytical Services (RESAS) division, under the GreenHealth project. TAB's contribution was funded by a fellowship awarded by the National Heart Foundation of Australia.

Contributors TA-B led the design, analyses and wrote the initial draft of the manuscript. RM and TH each contributed to the study design, interpretation of findings and redrafting of the manuscript. All authors have confirmed the final version of the manuscript. TA-B is the guarantor.

Funding We are grateful to the Forestry Commission for funding the study. The funders had no sight of this article until after submission. They have provided no input to the research process or reporting of this project. RM's contribution was funded by the Scottish Government's Rural and Environment Science and Analytical Services (RESAS) division, under the GreenHealth project. TAB's contribution was funded by a fellowship awarded by the National Heart Foundation of Australia.

Competing interests None.

Provenance and peer review Not commissioned; externally peer reviewed.

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