Associations of neighbourhood greenness with physical and mental health: do walking, social coherence and local social interaction explain the relationships?

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ABSTRACT

Background: Studies have shown associations between health indices and access to "green" environments but the underlying mechanisms of this association are not clear.

Objectives: To examine associations of perceived neighbourhood "greenness" with perceived physical and mental health and to investigate whether walking and social factors account for the relationships.

Methods: A mailed survey collected the following data from adults (n = 1895) in Adelaide, Australia: physical and mental health scores (12-item short-form health survey); perceived neighbourhood greenness; walking for recreation and for transport; social coherence; local social interaction and sociodemographic variables.

Results: After adjusting for sociodemographic variables, those who perceived their neighbourhood as highly green had 1.37 and 1.60 times higher odds of better physical and mental health, respectively, compared with those who perceived the lowest greenness. Perceived greenness was also correlated with recreational walking and social factors. When walking for recreation and social factors were added to the regression models, recreational walking was a significant predictor of physical health; however, the association between greenness and physical health became non-significant. Recreational walking and social coherence were associated with mental health and the relationship between greenness and mental health remained significant.

Conclusions: Perceived neighbourhood greenness was more strongly associated with mental health than it was with physical health. Recreational walking seemed to explain the link between greenness and physical health, whereas the relationship between greenness and mental health was only partly accounted for by recreational walking and social coherence. The restorative effects of natural environments may be involved in the residual association of this latter relationship.

Studies have demonstrated associations of health outcomes with access to natural or "green" environments, typically defined as vegetated areas such as parks, open spaces and playgrounds. For example, studies in The Netherlands have shown that the amount of green space in a neighbourhood was associated with better perceived general health.[1 2] Other studies have found various indices of the availability or use of natural environments to be associated with stress levels,[3 4] with depression[5] and with perceived general health status.[6] It can be argued that restorative experiences of natural environments, which are known to have health benefits,[7–9] play a role in this relationship. It is also possible, however, that physical activity, such as walking, which is encouraged or facilitated by the presence of neighbourhood green spaces, may be a factor explaining the health benefits of natural environments. It has been shown that adults who have better access to green environments such as parks tend to walk more,[10 11] although studies have also reported a gender difference in this association[12] or no significant association.[13] There is also a substantial body of evidence demonstrating that walking has significant benefits to physical and mental health.[14–17] It is thus possible to hypothesise that walking in and around neighbourhood green spaces may be involved in the greenness–health relationship. A longitudinal study in Japan indeed found that older people who lived near "walkable" green spaces had higher survival rates.[18] Another potential explanation is that the presence of green space might influence social factors within a community, such as social coherence and social interaction among neighbours. Evidence suggests that green features in neighbourhoods can enhance social ties or the sense of community,[19–21] which has been shown to be conducive to better health.[22–24] Little research has, however, examined in what way walking and social factors are involved in the relationship between neighbourhood greenness and health.

In this study, we first examined associations of perceived greenness of a neighbourhood with perceptions of physical and mental health. Then we examined whether the amount of walking (for recreation and for transport) and social factors (social coherence and local social interaction) might account for such relationships.

METHODS

Sample

This study is part of an observational epidemiological study conducted during 2003–2004 in urban areas of Adelaide, Australia. Detailed methods of recruitment have been described elsewhere.[25] A spatially based sampling methodology using a household as a sampling unit (rather than individuals) was used to recruit study participants from neighbourhoods with a range of variation in their environmental attributes. The study sample was drawn from residential addresses within 32 neighbourhoods, each of which consists of several contiguous census collection districts. In each

Table 1 Sociodemographic characteristics, health scores, time spent in walking and social factor scores of the sample, by perceived greenness category

	Greenness category*				
	Low (n = 555)	Medium (n = 710)	High (n = 630)	Total	p
Age in years, mean (SD)	43.7 (12.0)	45.2 (11.7)	47.2 (11.7)	45.4 (11.9)	<0.001
Gender, % men	34%	39%	36%	37%	0.25
Education, % tertiary educated	44%	48%	51%	48%	<0.05
Work status, % working	63%	66%	70%	67%	<0.05
Household income, % $A41 600 per annum or more	44%	53%	60%	52%	<0.001
Marital status, % single	48%	43%	34%	41%	<0.001
SF-12, PCS mean (SD)	49.1 (10.3)	49.4 (9.5)	50.5 (9.4)	49.7 (9.7)	<0.05
SF-12, MCS mean (SD)	48.7 (10.4)	49.6 (9.5)	51.4 (9.3)	49.9 (9.7)	<0.001
Walking for recreation, mean (SD), minutes/day	12.9 (21.2)	15.2 (22.8)	17.8 (23.4)	15.4 (22.6)	<0.01
Walking for transport, mean (SD), minutes/day	23.0 (33.1)	21.8 (29.6)	24.2 (28.7)	22.9 (30.4)	0.39
Social coherence score,† mean (SD)	3.0 (0.7)	3.2 (0.6)	3.5 (0.6)	3.3 (0.7)	<0.001
Local social interaction,‡ mean (SD)	8.5 (7.8)	9.1 (7.6)	10.4 (8.3)	9.4 (7.9)	<0.001

MCS, 12-item short-form health survey (SF-12) mental component score; PCS, SF-12 physical component score.
*Greenness category was created by dividing the perceived greenness score into tertiles (low, medium, high).
†Social coherence score ranges from 1 (lowest) to 5 (highest).
‡Mean number of days participants engaged in local social interaction in the past month.

neighbourhood, 250 addresses were randomly selected and sent a letter requesting participation in the study. One person from each address was asked to participate. Those who met the eligibility criteria (living in private dwellings, aged between 20 and 65 years, able to walk without assistance and able to take part in surveys in English) and agreed to participate were sent a survey including questions about health status, perception of greenness, walking for recreation and for transport, social coherence, local social interaction and sociodemographic characteristics. A total of 2194 eligible participants from 154 census collection districts returned the questionnaire. The return rate for those who completed the survey as a proportion of those who responded to our initial request was 74.2%. The overall response rate as a proportion of the total effective sample (the households that received our survey request) was 11.5%. A detailed account of the response rates is reported elsewhere.[26]

Measures and instruments

The outcome measures of this study were participants' ratings of their perceived physical and mental health. From the 12-item short-form health survey (SF-12) version 1,[27] the physical component scores (PCS) and mental component scores (MCS) were computed and examined separately. Both scores were divided into low and high levels around the median.

To identify the perceived greenness of a neighbourhood, five questions from the Neighborhood Environment Walkability Scale[28] were used. The items included the following attributes: access to a park or nature reserve; access to bicycle or walking paths; presence of greenery; presence of tree cover or canopy along footpaths and presence of pleasant natural features. The response format was a four-point scale ranging from "strongly disagree" (score 1) to "strongly agree" (score 4). The internal consistency (Cronbach's alpha) of the scale was 0.67. The mean score of these items was used as the score of perceived greenness. A higher score on the overall scale signified that respondents perceived more green features in their neighbourhoods. For regression analyses, the mean score was divided into tertiles (low, medium and high).

To capture the salient elements of outdoor physical activity, the amount of walking for recreation and for transport were assessed separately, using the relevant items in the long form of the International Physical Activity Questionnaire.[29] Participants were asked to recall the frequency in the past week (number of days) and usual duration per day (hours and minutes) of these two types of walking. The average daily duration (minutes/day) of each type of walking was calculated and dichotomised around the median for regression analysis.

The social factors assessed in the present study were social coherence and local social interaction. To measure social coherence, participants were asked to respond to the following six questions on a five-point scale ranging from "strongly disagree" (score 1) to "strongly agree" (score 5). "I would be willing to work together with others on something to improve

Table 2 Mean (SD) of perceived greenness, time spent in walking, social coherence score and local social interaction, by the SF-12 physical and mental component score categories

	PCS			MCS		
	Low (n = 950)	High (n = 945)	p	Low (n = 945)	High (n = 950)	p
Perceived greenness*	3.1 (0.6)	3.2 (0.5)	<0.001	3.1 (0.6)	3.3 (0.5)	<0.001
Walking for recreation, minutes/day	13.6 (21.6)	17.2 (23.5)	<0.001	14.0 (22.0)	16.8 (23.2)	<0.01
Walking for transport, minutes/day	22.2 (30.5)	23.6 (30.2)	0.33	22.8 (30.2)	23.1 (30.5)	0.84
Social coherence score†	3.2 (0.7)	3.3 (0.7)	<0.01	3.1 (0.7)	3.4 (0.7)	<0.001
Local social interaction‡	9.5 (8.2)	9.2 (7.7)	0.40	8.7 (7.8)	10.0 (8.1)	<0.001

MCS, 12-item short-form health survey (SF-12) mental component score; PCS, SF-12 physical component score.
*Perceived greenness ranges from 1 (lowest) to 4 (highest).
†Social coherence score ranges from 1 (lowest) to 5 (highest).
‡Mean number of days participants engaged in local social interaction in the past month.

the living environment of my neighbourhood.'' ''Living in my neighbourhood gives me a sense of community.'' ''It is easy to make friends in my neighbourhood.'' ''People around my neighbourhood are willing to help their neighbours.'' ''This is a close-knit neighbourhood.'' ''People in this neighbourhood can be trusted.'' The first three items were adapted from the Neighborhood Quality of Life Study[30] and the last three items were from a scale developed by Sampson *et al*.[31] These items were merged because they were found to form a single dimension (Cronbach's alpha 0.82). Individuals' mean scores on these items were used as a social coherence score. To identify the level of local social interaction, the number of days participants did each of the following informal social activities in the past month was asked: waved to a neighbour; said hello to a neighbour and stopped and talked with a neighbour.[32] The internal consistency was 0.90. The mean number of days undertaking these activities was used as a measure of local social interaction with neighbours. These social factors were also dichotomised around the median for regression analysis.

The sociodemographic variables collected were age, gender, educational attainment, work status, household income and marital status.

Data analyses

Stepwise logistic regression analyses were carried out to predict the odds of belonging to the higher category of SF-12 health scores. Separate analyses were conducted for PCS and MCS. In each analysis, perceived greenness was entered first as a single predictor (model 1). In the next step, the model controlled for the sociodemographic variables that were found to be associated with greenness (model 2). The duration of walking and social factors were introduced in the final model, to examine the association of perceived greenness with the SF-12 measures of physical and mental health, after adjusting for the influence of these variables (model 3).

RESULTS

Table 1 shows the sociodemographic characteristics, SF-12 PCS and MCS, time spent in walking for recreation and for transport and social factor scores, by the perceived greenness category. After excluding participants with missing values (n = 299), data from 1895 participants were analysed. The highest proportion of missing data was for items relating to walking for recreation (4.3%) and walking for transport (4.9%). The other key variables on health measures, greenness score and social factors had a lower percentage of missing values (1–2%). This table shows that the greenness category was associated with both physical and mental health scores, walking for recreation, social coherence and local social interaction but not with walking for transport.

Compared with the general adult population of the city of Adelaide aged between 20 and 65 years[33] from which our sample was drawn, the study sample was higher in the proportion of women (63%; Adelaide: 51%), older people (mean age, 45 years; Adelaide: 41 years), people with tertiary education (48%; Adelaide: 42%). The sample was, however, comparable to the population in work status (67% working; Adelaide: 68%), household income (52% earning $A41 600 per annum or more; Adelaide: 50%) and marital status (41% single; Adelaide: 42%).

Table 2 shows the mean values of the key variables (perceived greenness, time spent in walking and social factors) according to the low and high categories of PCS and MCS, respectively. These univariate analyses show that both the PCS and MCS were positively associated with perceived greenness, recreational walking and social coherence. The MCS was also positively associated with local social interaction. As walking for transport was related neither to greenness nor to the health scores, it was excluded from further analysis.

Table 3 shows the logistic regression analyses predicting the odds of having a higher physical health score (PCS). Model 1, which is unadjusted, indicates that those who perceived their neighbourhoods to have the highest degree of greenness had approximately a 40% higher odds of belonging to the better physical health category, compared with those who reported the lowest degree of greenness. The level of association did not change substantially after controlling for age, education, work status, household income and marital status (model 2). After further adjusting for walking for recreation, social coherence and local social interaction (model 3), the association between greenness and physical health became non-significant ($p = 0.06$). In this model, recreational walking was a significant predictor of participants' physical health but neither social coherence nor local social interaction was associated with physical health. Correlation coefficients between predictors

Table 3 Odds ratios (95% CI) for better physical health scores (SF-12, PCS), according to the level of perceived greenness, walking for recreation, social coherence and local social interaction

	n	Model 1 (unadjusted)	Model 2 (adjusted)†	Model 3 (adjusted)‡
Perceived greenness				
Low	555	1.00	1.00	1.00
Medium	710	0.96 (0.77 to 1.20)	0.93 (0.74 to 1.18)	0.90 (0.71 to 1.14)
High	630	1.41 (1.12 to 1.77)**	1.37 (1.08 to 1.74)*	1.27 (0.99 to 1.62)
Walking for recreation§				
Low	935			1.00
High	960			1.72 (1.42 to 2.08)***
Social coherence score				
Low	891			1.00
High	1004			1.14 (0.93 to 1.40)
Local social interaction				
Low	950			1.00
High	945			0.99 (0.81 to 1.22)

*$p<0.05$, **$p<0.01$, ***$p<0.001$.
†Adjusted for age, education, work status, household income and marital status.
‡Adjusted for age, education, work status, household income, marital status, walking for recreation, social coherence score and local social interaction.
§Low: 8.6 minutes/day or less; High: more than 8.6 minutes/day.

Table 4 Odds ratios (95% CI) for better mental health scores (SF-12, MCS), according to the level of perceived greenness, walking for recreation, social coherence and local social interaction

	n	Model 1 (unadjusted)	Model 2 (adjusted)†	Model 3 (adjusted)‡
Perceived greenness				
Low	555	1.00	1.00	1.00
Medium	710	1.22 (0.97 to 1.52)	1.12 (0.89 to 1.41)	1.07 (0.84 to 1.35)
High	630	1.93 (1.53 to 2.44)***	1.60 (1.26 to 2.04)***	1.44 (1.13 to 1.85)**
Walking for recreation§				
Low	935			1.00
High	960			1.33 (1.10 to 1.61)**
Social coherence score				
Low	891			1.00
High	1004			1.39 (1.14 to 1.71)**
Local social interaction				
Low	950			1.00
High	945			1.02 (0.84 to 1.25)

*p<0.05, **p<0.01, ***p<0.001
†Adjusted for age, education, work status, household income and marital status.
‡Adjusted for age, education, work status, household income, marital status, walking for recreation, social coherence score and local social interaction.
§Low: 8.6 minutes/day or less; High: more than 8.6 minutes/day.

ranged from 0.01 to 0.41 (between social coherence and local social interaction), which suggests that collinearity is not a critical issue in the regression models.

Table 4 presents the odds ratios of having a higher mental health score (MCS). The unadjusted results (model 1) show that those who reported the highest degree of greenness had almost twice the odds of being in the better mental health category, compared with those who perceived little greenness in their neighbourhood. After adjusting for the sociodemographic variables, the strength of the association of the highest degree of greenness with mental health was attenuated but nonetheless remained significant (model 2). This relationship remained significant in model 3, in which recreational walking, social coherence and local social interaction were added. This final model also shows that the amount of recreational walking undertaken and social coherence were significant predictors of the mental health score.

DISCUSSION

This study adds further evidence to findings of previous studies showing that the availability of green or natural environments is associated with adults' perceptions of better health.[1–4] Although previous research on this topic has used a single measure of general health status, the present study used validated, more specific, measures of SF-12 physical and mental health scores. Our findings suggest differences in the degree of associations of the perceived greenness with physical health and with mental health. The comparison of the relevant odds ratios suggests that the availability of green environments is likely to contribute more to mental health than it does to physical health.

We examined potential mechanisms of health benefits of green environments by examining the relationships between greenness, walking, social factors and health indices concurrently. We found that the greenness category was associated with walking for recreation, social cohesion and local social interaction, suggesting that these behaviours or phenomena are likely to occur more often in areas where people perceive more natural elements. Of these variables, walking for recreation was associated with physical health scores and the association between greenness and physical health became non-significant after recreational walking was added to the regression model. This suggests that the relationship between greenness and physical health may be mediated by recreational walking. Such a mechanism was postulated, although not demonstrated, in past studies suggesting the link between the availability of green open spaces and walking[10 11] and those showing the effects of walking on health outcomes.[14–16] The present study provides some empirical support for the potential mediating role of walking in this relationship.

For the relationship between greenness and mental health, the findings suggest a different pathway. The final regression model showed that recreational walking and social coherence were associated with mental health scores and perceived greenness remained an independent, significant predictor of mental health. This suggests that the relationship between perceived greenness and mental health is not totally attributable to walking or to social cohesion. One potential factor explaining this ''unaccounted'' path is the restorative effects of green or natural environments. Early work by the Kaplans[7 34] postulated that contact with nature reduces attention fatigue, which accumulates as the mental effort to maintain attentional focus is sustained. These restorative effects are likely to occur both during activity in natural environments[8] and from ''static'' contact with nature, such as viewing natural landscapes and contact with natural elements.[35 36] Considering that the benefits resulting from walking have already been accounted for, the residual association between perceived greenness and mental health may involve restorative effects from static experiences of nature.

Previous studies have reported mixed findings on the relationship between natural environments in neighbourhoods and walking.[10–13] The present study contributes new evidence supporting the relevance of neighbourhood green environments to people's walking, based on a relatively large sample of Australian adults.

Our findings are strongly suggestive of the importance of ''walkable'' green environments for better health and support findings from a previous study on older people's health and walkable green environments.[18] The finding suggests that neighbourhood green spaces are conducive to better health, in so far as they are walkable, especially in the case of physical health. Research has produced some green environmental attributes that may induce participation in physical activity.

What this paper adds

Several studies have shown that the availability of neighbourhood green features is associated with residents' perceived health status. This study found that perceived greenness of neighbourhoods contributes to perceived physical and mental health in different degrees and in different ways. Neighbourhood greenness was more associated with mental health than with physical health. Walking for recreation seemed to explain the association between greenness and physical health, whereas the relationship between greenness and mental health was partly accounted for by walking for recreation and social coherence. The restorative effects of natural environments may be involved in the residual association of the latter relationship.

Policy implications

This study found that neighbourhood green environments where people can walk are likely to contribute to residents' physical and mental health. In order to promote community health through enhancement of the environment, the planning and design of neighbourhood open spaces need to place emphasis on the importance of "walkable" green spaces.

Neighbourhood aesthetics has been found to play a role in encouraging physical activity.[37 38] Shade provided by trees may also encourage being outdoors in hotter climates. There are, however, other green environmental attributes that may act to deter walking, such as vegetation obstructing a line of vision, which may decrease the sense of safety.[39] It is important to identify more specific green environmental attributes that facilitate or encourage physical activity.

The findings showed that walking for transport was associated neither with physical nor mental health scores, whereas walking for recreation was associated with both (table 2). If walking contributes to health simply by energy expenditure, the purpose of walking (transport or recreation) should not matter. It is not possible to determine why walking for transport was not related to health from this study alone. There are, however, some potential reasons for the results. First, it is possible that healthier people tend to walk more for recreation than do less healthy people. Second, walking for transport and walking for recreation may be different in the continuous duration of walking at one time. Walking for transport tends to involve a series of relatively short bouts, whereas recreational walking may be more continuous.[40] The updated recommendation for physical activity specifies bouts of at least 10 minutes of activity for health benefits.[41] Continuous longer walking has also been found to have some additional health benefits over walking done in multiple short bouts.[42 43] Third, the settings in which walking takes place may be a factor. As shown in the results, recreational walking was associated with neighbourhood greenness, suggesting that this type of walking is more likely to happen in natural environments, which may provide restorative benefits. On the other hand, walking for transport normally occurs along streets, where there may be fumes, noise and heat. Finally, it is possible that recreational walking is associated with other behaviours conducive to health, such as exercise and healthy eating. Recreational walking may be associated with health because it is a marker of healthy lifestyles.

The greenness score used in the study included an item on the pleasantness of natural features. This means that our operationalisation of the greenness construct was not simply a measure of access or the amount of natural areas in neighbourhoods but also included the aesthetic aspects of such environments. The relevance of such aspects to people's activity patterns has been shown in previous studies.[37 38] The findings of the study suggest the importance of the quality of natural environments, as well as the quantity and access, for promoting walking and health.

Ratings reflective of local social interaction with neighbours were not associated with mental health in this study after adjustment. As we found that social cohesion was associated with mental health, a similar relationship involving local social interactions might have been expected. Our measure of local social interaction was the number of days on which participants informally engaged with neighbours (waved, said hello and chatted). It is possible that closer interaction may be necessary to generate health benefits.

The limitations of this study include its cross-sectional nature, which precludes any causal inferences on the basis of the significant associations that we have reported. The lower response rate could introduce selection bias. Our sample underrepresented men, younger people and people with lower levels of education and this needs to be considered in generalising from the findings of the study. Another limitation of our study is the reliance of self-report measures for greenness and for walking. Future studies could utilise objective measures of greenness obtained from remote sensing data.[44] A recent study has, however, reported that perceptions of the natural environment have stronger associations with physical activity than do objective measures.[45] The importance of how people perceive their environment should thus not be underestimated.

Future research may explore further the mechanisms of the health benefits of natural spaces. As discussed, the current study has shown that recreational walking is likely to be one of the factors linking the availability of green spaces and health but it was not clear whether it was walking to green spaces or walking within green spaces that contributed to health. Furthermore, it is not known to what extent the active and passive use of green space is beneficial to health. Longitudinal studies are also required, ideally examining the effects of environmental interventions (eg, the construction of a new park, the substantial upgrade of current parks) on health outcomes to examine the causal relationship between natural environments and health.

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