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Improving neighbourhoods, improving health?

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CHAPTER

4

The relationship between physical activity and the living environment: a multi-level analyses focusing on changes over time in environmental factors

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ABSTRACT

There is limited evidence on the causality of previously observed associations between neighbourhood characteristics and physical activity (PA). We aimed to assess whether individual-level PA was associated with changes in fear of crime, social cohesion, green spaces, parking facilities, social disorder, and physical disorder that occurred over the past 3 years. In general, in neighbourhoods where residents had more favourable perceptions of the environment in 2006, residents were more likely to be physically active in 2009. In addition, improvements between 2006 and 2009 with respect to perceived social cohesion, green spaces, social disorder, and physical disorder were associated with increased odds of being active in 2009. For both the levels in 2006 and trends in the period 2006–2009, the associations were somewhat stronger among women than among men, but associations did not vary by age or length of residence. For several environmental factors, we observed that not only the levels at a certain point in time, but also recent improvements over time were related to PA. These results provide new support for a causal relationship between these environmental factors and PA.

INTRODUCTION

Physical inactivity has been identified as the fourth leading risk factor for global mortality.¹ It has been shown that participation in regular physical activity (PA) reduces the risk of cardiovascular diseases, some types of cancer, and depression.² In the Netherlands, only 44% of the population older than 15 years are sufficient physically active to accrue health benefits.³

Ecological models of health behavior distinguish individual, social, and environmental determinants of behavior, such as physical activity (PA).⁴ The accumulated evidence of studies investigating the impact of environmental factors on PA suggests that different neighbourhood characteristics may be associated with PA.⁵ Of the many studies exploring this association, nearly all had a cross-sectional design. It is generally agreed that, due to the cross-sectional design, such studies do not provide strong evidence on the causality of the observed relationships.^{6,7} Therefore it is still unclear whether changes in the environment will lead to changes in population levels of PA. Stronger evidence on causality may come from intervention studies, which are however challenging to do in environmental studies.⁸ Alternatively, evidence may come from the evaluation of “natural experiments” or from studies that assess the effect of “spontaneous” changes in environmental factors.

The accumulated predominantly cross-sectional evidence on the association between environmental factors and PA addresses, among others, perceived safety, green spaces, social cohesion, physical and social disorder, and parking:

- Perceived safety from crime is an often explored environmental variable in this type of study. Some cross-sectional studies found a positive association of perceived safety from crime with PA or walking among adults,⁹⁻¹⁷ while other cross-sectional studies found no statistically significant association.^{11,14,18-22}
- For green spaces, the evidence on the association with PA or walking among adults is cross-sectional and inconsistent as well. Whilst some studies suggested that objectively measured green spaces can facilitate PA or walking,^{23,24,25} other studies reported no association.^{24,26-29} Results from studies that measured green spaces subjectively, are inconsistent as well. Some studies found positive association of green spaces with PA,^{9,30,31} while other studies found no association.^{16,22,32} Reviews reported mixed results.^{33,34}
- Several cross-sectional studies among adults suggested that perceived social cohesion in the neighbourhood was associated with higher levels of PA or walking.^{11,13,17,35,36}

Two cross-sectional studies found no association.^{11,37} In an experimental intervention study, increase in social cohesion did not lead to an increase in brisk walking in the intervention group.⁸

- Cross-sectional studies on physical disorder and PA among either adults or children showed inconsistent results. Some studies found that more physical disorder was associated with lower levels of PA or walking,^{16,37-39} other studies reported associations with higher levels of PA,^{9,20,40} while four studies found no association.^{19,20,41,42}
- The few cross-sectional studies that have explored the association of social disorder with PA have been performed among children and do not show consistent results.⁴¹⁻⁴³
- Almost no studies have explored parking facilities and their relationship with PA. A Dutch cross-sectional study⁴⁴ found that fewer parking spaces around the house were associated with more PA. A New Zealand cross-sectional study⁴⁵ suggested that fewer car parks and higher costs of parking would constitute an important incentive to cycle to work instead of car driving.

The present study aimed to explore the extent to which levels of environmental factors and changes over time in levels of environmental factors were associated with PA among adults. We used two large-scale nationwide surveys in the Netherlands from 2006 to 2009 with data on environmental factors at the postal code level and participation in physical activity and sports at the individual-level. Environmental factors measured were perceived safety, green spaces, social cohesion, physical and social disorder, and parking. These data were analysed with three specific aims.

- First, we determined whether the levels of environmental factors measured in 2006 were related to the odds of being active in 2009.
- Second, we determined whether changes in the levels of environmental factors between 2006 and 2009 were related to the odds of being active in 2009.
- Finally, we examined whether these associations varied according to gender, age, and duration of residence.

Previous studies suggested the impact of perceived safety to be gender specific, with a stronger effect among women than men.^{14,16,21,46} However, little is known about gender differences in the impact of other environmental factors.^{16,30,39} To our knowledge, few studies have assessed whether environmental correlates of PA are age-specific. One study⁴⁷ reported that poor neighbourhood safety was associated with inactivity among people aged older than 65, but not among younger people. Based on this previous research we hypothesise associations between environmental

change and PA to be stronger for women and older people. Furthermore, we expected the effect to be stronger for residents who have lived longer at the current address, because they have been influenced by the current neighbourhood environment for a longer period of time.

METHODS

Population

Data were accessed from the cross-sectional Netherlands Housing Survey 2006 and 2009 (WoON06 and WoON09),^{48,49} conducted by The Ministry of Housing, Spatial Planning, and the Environment and Statistics Netherlands. The WoON is a large 3-yearly nationwide survey among people aged 18 and over. This survey focuses on housing quality and people's housing needs, but also includes data on PA and environmental factors. The samples were drawn using the continuous municipal population registries. The samples drawn within municipalities were random. Some municipalities were oversampled. Questionnaires were administered by means of telephone interviews, face to face interviews, and by internet.

A neighbourhood was defined by its 4-digit postal code. In the Netherlands, these areas are 8.3 km² large and include about 4000 residents, on average. To accurately assess changes in environmental factors between 2006 and 2009 we included only neighbourhoods that had a minimum of 30 respondents in both surveys. As a result, we included 320 neighbourhoods, with in total 25,309 (WoON06) and 31,783 (WoON09) respondents. We included only respondents aged 18–84 years. Respondents older than 84 years were excluded because a large proportion of these individuals have physical impairments that can prevent them from being physically active, independently of the living environment. Moreover, a substantial proportion of these respondents may not be included in the WoON surveys, such as the institutionalized population. For all ages together WoON06 and WoON09 had response rates of 70.9% and 62.6% respectively.

Outcome variable

Our outcome variable was PA as reported by the respondents to the 2009 survey. PA was measured in the single question "How many hours a week do you spend on physical activity or sports?" A disproportionately large proportion of persons were found to be active for 0 h per week. In addition, preliminary analyses showed that the environmental factors studied here were not related to mean hours of PA among those who had reported at least 1 h of PA. For these reasons, we decided to dichotomize the PA measure. The dichotomous variable measured whether respondents were engaging in PA at least 1 h per week, whom we labeled "active" (76.6% of all respondents) versus "inactive" (23.4%).

Predictor variables

Neighbourhood-level

Table 1 provides information on the measurement of the variables measured at neighbourhood-level. Three variables, social cohesion, physical disorder, and social disorder, were composed using nine, three, and five survey items respectively. Items were chosen based on measurements used for these constructs in previous research.^{15,19,30,38,39,41,50} For each of these variables, composite scores were created by averaging all items. Chronbach's alpha at the individual-level in the WoON06/WoON09 data was 0.83/0.84 (social cohesion), 0.59/0.66 (physical disorder), and 0.64/0.65 (social disorder). The resulting variables on social cohesion, physical disorder, and social disorder were measured on a continuous scale ranging from 1–5, 1–3, and 1–3 respectively.

The variables fear of crime, satisfaction with green spaces, and satisfaction with parking facilities were measured using one survey question each. We measured the percentage of the neighbourhood population who replied positively to that question. Higher scores reflect more favourable residents' perceptions of that environmental factor.

All environmental factors were measured per neighbourhood for the years 2006 and 2009 separately. The mean of all individual-level scores within a postal code area formed the aggregated neighbourhood-level scores. For each neighbourhood, we in addition measured the change in the levels of environmental factors between 2006 and 2009, by subtracting each neighbourhood's score in 2006 from that in 2009.

Individual-level covariates

A range of individual-level socio-demographic variables were used to control for possible confounding: gender (male versus female), age (a continuous measure), employment status (gainfully employed versus not gainfully employed), highest educational level achieved (up to elementary, lower secondary, upper secondary, and tertiary education), and disposable equivalent household income (a continuous measure, calculated by dividing the disposable household income by the square root of the number of household members⁵¹). In addition to these individual-level variables, we measured the degree of urbanisation of the municipality in which respondents lived, using five standard categories ranging from rural to high density urban.

Table 1: Summary of the scales, environmental items, means, standard deviations (*SD*), and the relations with the total score for social cohesion, absence of physical- and social disorder on the individual level

Scale (composition)	Item	Response category	Mean	SD	Correlation
Environmental factors					
Fear of crime (one item)	I am afraid to be assaulted or robbed in this neighbourhood (Reversed)	5-Point scale ^{ac}	3.90	0.89	-
Satisfaction with green spaces (one item)	How satisfied are you with the amount of green areas in your neighbourhood	5-Point scale ^{ad}	3.80	0.97	-
Social cohesion (mean score of nine items)	It is unpleasant to live in this neighbourhood (Reversed)	5-Point scale ^a	4.06	0.79	0.58
	I feel attached to my neighbourhood		3.47	1.10	0.69
	I feel at home in my neighbourhood		3.91	0.84	0.71
	I talk a lot to my next-door neighbours		3.33	1.08	0.64
	I talk a lot to neighbours other than my next-door neighbours		2.99	1.04	0.64
	In this neighbourhood people treat each other with respect		3.82	0.77	0.72
	I live in a neighbourhood with a high level of solidarity		3.23	0.99	0.77
	People hardly know each other in this neighbourhood (Reversed)		3.30	1.02	0.64
	I'm satisfied with the population composition of this neighbourhood		3.74	0.87	0.59
Physical disorder (mean score of five items)	Graffiti on walls and buildings	3-Point scale ^b	2.64	0.60	0.65
	Vandalism of phone booths and bus or tram shelters		2.54	0.67	0.67
	Garbage on the street		2.08	0.80	0.76
	Dog shit on the street		1.99	0.79	0.64
	Smell, dust, and/or waste		2.58	0.66	0.59
Social disorder (mean score of three items)	To what extent do you experience nuisance from your direct neighbours	3-Point scale ^b	2.67	0.61	0.74
	To what extent do you experience nuisance from other neighbourhood residents		2.67	0.58	0.82
	To what extent do you experience nuisance from youth in this neighbourhood		2.54	0.66	0.75
Satisfaction with parking facilities (one item)	How satisfied are you with the parking facilities in your neighbourhood	5-Point scale ^{ad}	3.40	1.17	-

^a Five-point scale from 1 (totally disagree/totally unsatisfied) to 5 (totally agree/totally satisfied).

^b Three-point scale: (1) often, (2) sometimes, and (3) (almost) never.

^c Respondents were characterized as 'do not fear being a victim of crime in their neighbourhood' if they answered totally disagree or disagree, and 'fear being a victim of crime in their neighbourhood' if they answered not agree, but also not disagree, agree, or totally agree.

^d Respondents were characterized as being satisfied with green- and parking facilities if they answered totally satisfied and satisfied, and unsatisfied if they answered not satisfied, but also not unsatisfied, unsatisfied, or totally unsatisfied.

Data analyses

First, we used scatter plots to illustrate the association of PA with environmental factors in 2006 and changes therein between 2006 and 2009. PA was measured as the proportion of respondents in a neighbourhood who reported being physically active for at least 1 h per week. This measure was presented as odds by plotting it on the logit scale.

Multi-level multivariable logistic regression models were used to investigate whether the odds of being active among the 2009 survey respondents were related to the levels of neighbourhood environmental factors in 2006 and changes therein between 2006 and 2009. We were primarily interested in the relationship with environmental changes between 2006 and 2009. For this, we had to control for levels of environmental factors in 2006 because (a) changes between 2006 and 2009 may depend on initial levels in 2006 and (b) initial levels in 2006 may have independent, lagged effects on physical activity in 2009.

To account for possible dependencies between observations within a neighbourhood, we included random intercepts in the model. Level 1 corresponded to the individual, and level 2 to the neighbourhood-level. Separate models were fitted for each of the environmental factors under study. Results were presented as odds ratios (ORs) with corresponding 95% confidence intervals (CIs). All models were adjusted for gender, age, employment status, education, household income, and degree of urbanisation of municipality. All variables were included simultaneously in the models.

In the first step, we fitted the models for the entire population. Secondly, we applied stratified analyses to assess whether associations varied according to gender, age (18–34 years, 35–59 years, 60–84 years), and duration of residence (living at current address <5 years, 5–9 years, ≥10 years).

Data were analysed using the statistical packages R (version 2.11.1) and SAS (version 9.2).

RESULTS

Table 2 shows that, on average, there were small differences between the survey participants in 2006 and 2009 with regard to gender, age, educational level, and household income. Larger variations were observed with regard to employment status, duration of residence, and the two highest urbanisation categories. Gender and age were weakly related to the PA variable, while employment status, educational level, and household income were strongly positively related to PA. Urbanisation and duration of residence showed no association with PA.

Table 3 shows the distribution, at the level of neighbourhoods, in the level of environmental factors in 2006 and in changes therein between 2006 and 2009. The environmental factors in 2006 and 2009 were highly correlated (correlation coefficients between 0.67 and 0.83). For all six environmental factors, the 2009 levels were on average below the 2006 levels, suggesting a slight deterioration. Yet, many neighbourhoods deviated from this general trend, and experienced either an improvement or a major deterioration in reported levels of environmental factors (see Fig. 1 for the green space variable).

Table 2: Descriptive statistics of the study sample for 2006 ($N=25,309$) and 2009 ($N=31,783$) respectively

	Respondents in 2006 (%)	Respondents in 2009 (%)	Active in 2009 (%)
Gender*			
Female	53.42	55.61	77.36
Male	46.58	44.39	75.92
Age in 3 groups*			
18-34	29.27	28.74	79.74
35-59	43.74	42.94	76.03
60-84	26.99	28.32	74.14
Employment status*			
Not gainfully employed	42.38	32.92	71.88
Gainfully employed	57.62	67.08	78.86
Education level*			
No education/Elementary	12.32	8.72	55.39
Lower secondary	30.78	28.13	69.64
Upper secondary	32.16	35.40	79.20
Tertiary education	24.73	27.74	86.90
Disposable equivalent household income			
Low	25.74	26.25	67.70
Medium low	25.03	25.29	74.82
Medium high	24.88	25.03	79.76
High	24.35	23.42	84.94
Urbanisation of municipality			
Not urban	7.12	5.39	77.65
Slightly urban	2.30	2.47	78.98
Moderately urban	21.93	18.11	80.99
Strongly urban	30.27	22.85	77.92
Very strongly urban	38.37	51.18	74.15
Number of years living at current address*			
< 5 years	32.35	47.82	75.85
5-9 years	23.24	15.86	76.55
≥10 years	44.41	36.33	76.44

* The distribution in 2009 is different from the distribution in 2006 with $P \leq 0.05$, two-sided. Generalised linear mixed models, corrected for neighbourhood-level clustering effects.

Table 3: Mean, standard deviation (SD), and percentile distribution for environmental factors in 2006 and change in environmental factors between 2006-2009, and correlation between environmental factors in 2006 and 2009, for 2009 respondents

Predictor	Environmental factor					
	No fear of crime ^a	Satisfaction green ^a	Social cohesion ^b	Absence of physical disorder ^b	Absence of social disorder ^b	Satisfaction parking facilities ^a
In 2006						
Mean	83.87	77.18	3.55	2.55	2.68	63.72
SD	10.19	11.97	0.19	0.15	0.12	15.06
Percentiles ^c						
10	68.30	60.50	3.26	2.36	2.51	42.49
25	78.83	70.59	3.43	2.45	2.60	55.48
50	86.81	80.53	3.57	2.56	2.69	67.31
75	92.59	86.95	3.71	2.69	2.77	76.69
90	95.66	91.43	3.82	2.76	2.83	82.37
Change between 2006-2009						
Mean	-3.20	-2.87	-0.01	-0.15	-0.05	-3.90
SD	6.79	8.05	0.11	0.09	0.09	8.96
Percentiles ^c						
10	-10.93	-13.79	-0.15	-0.27	-0.17	-15.98
25	-7.28	-8.27	-0.09	-0.20	-0.10	-10.00
50	-2.80	-2.98	0.00	-0.13	-0.04	-3.52
75	1.98	2.37	0.08	-0.08	0.02	3.26
90	6.38	8.59	0.14	-0.03	0.09	8.73
Correlation ^d	0.77	0.76	0.82	0.83	0.67	0.81

^a Numbers are % for the environmental factors: no fear of crime, satisfaction green spaces, and satisfaction parking facilities.

^b Numbers are composite scores between 1 and 5 for social cohesion, and composite scores between 1 and 3 for absence of physical and social disorder.

^c Percentiles of neighbourhoods.

^d Correlation between environmental factors in 2006 and 2009. Measured at the neighbourhood-level.

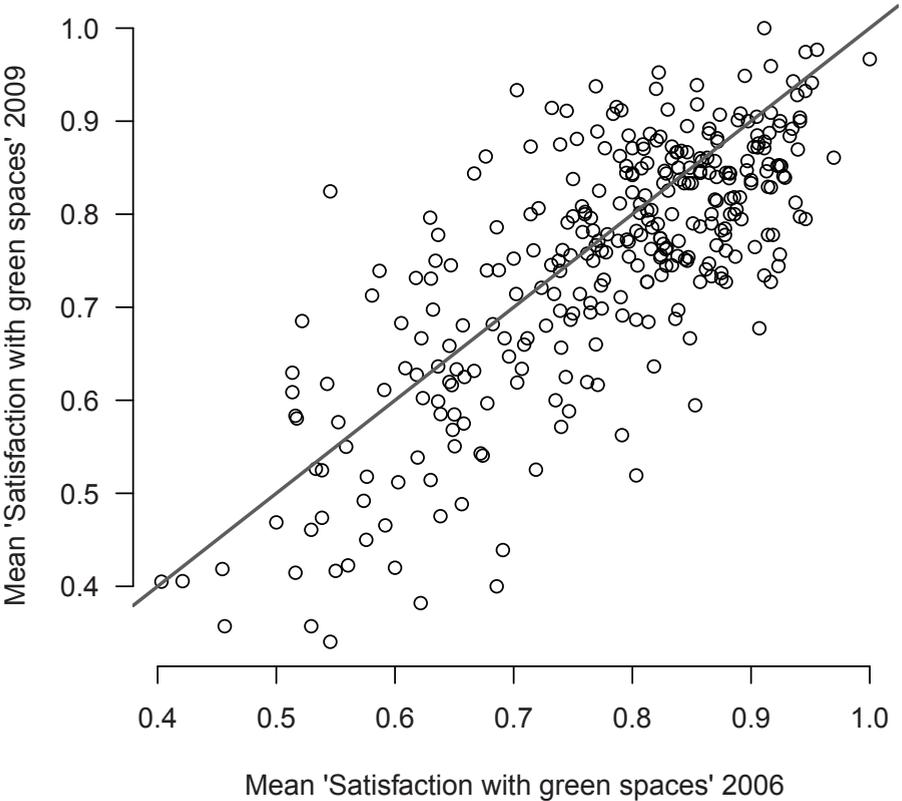
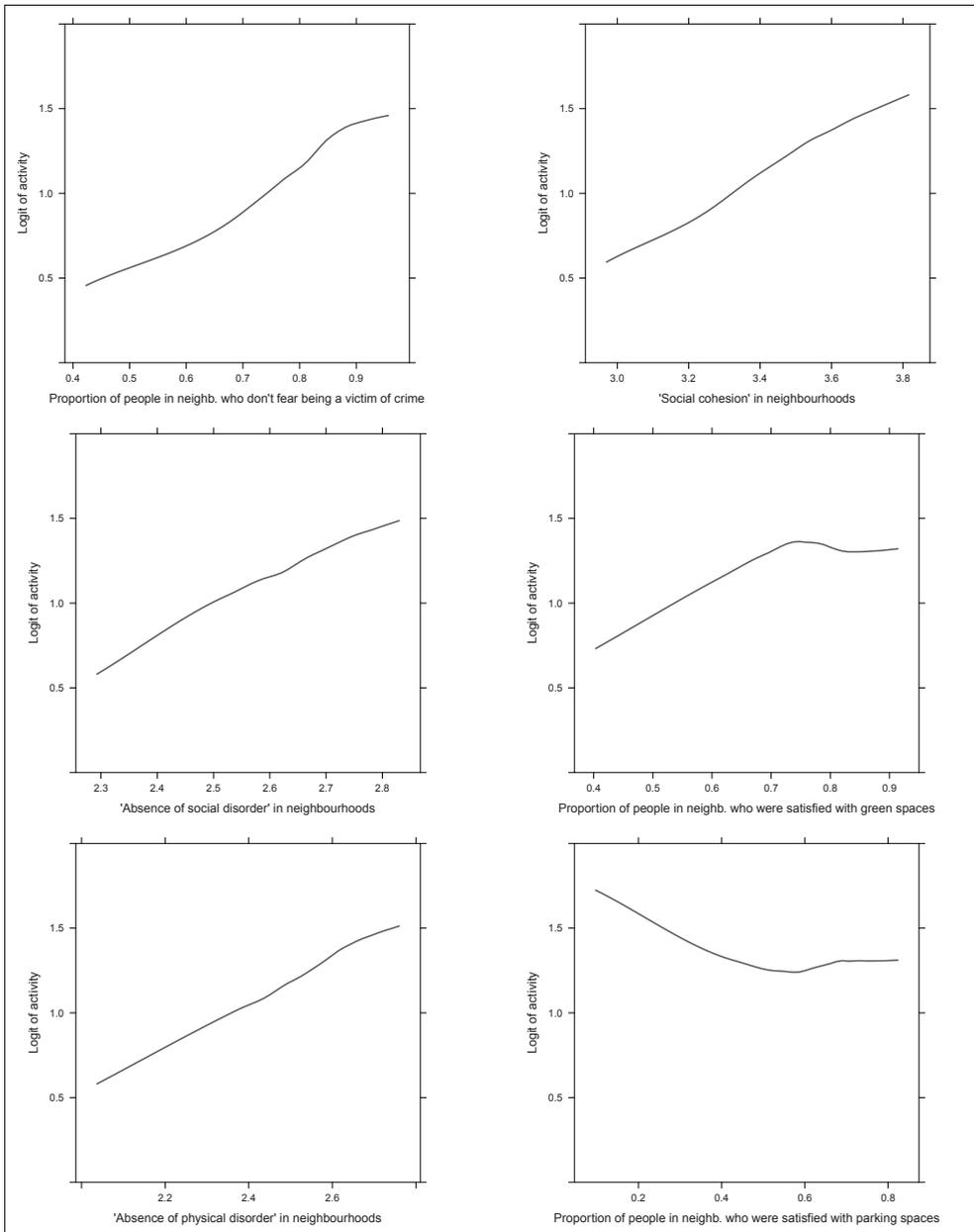


Figure 1: Satisfaction with green spaces in neighbourhoods: 2009 levels plotted against 2006 levels (both measured at neighbourhood level). Correlation coefficient is 0.76.

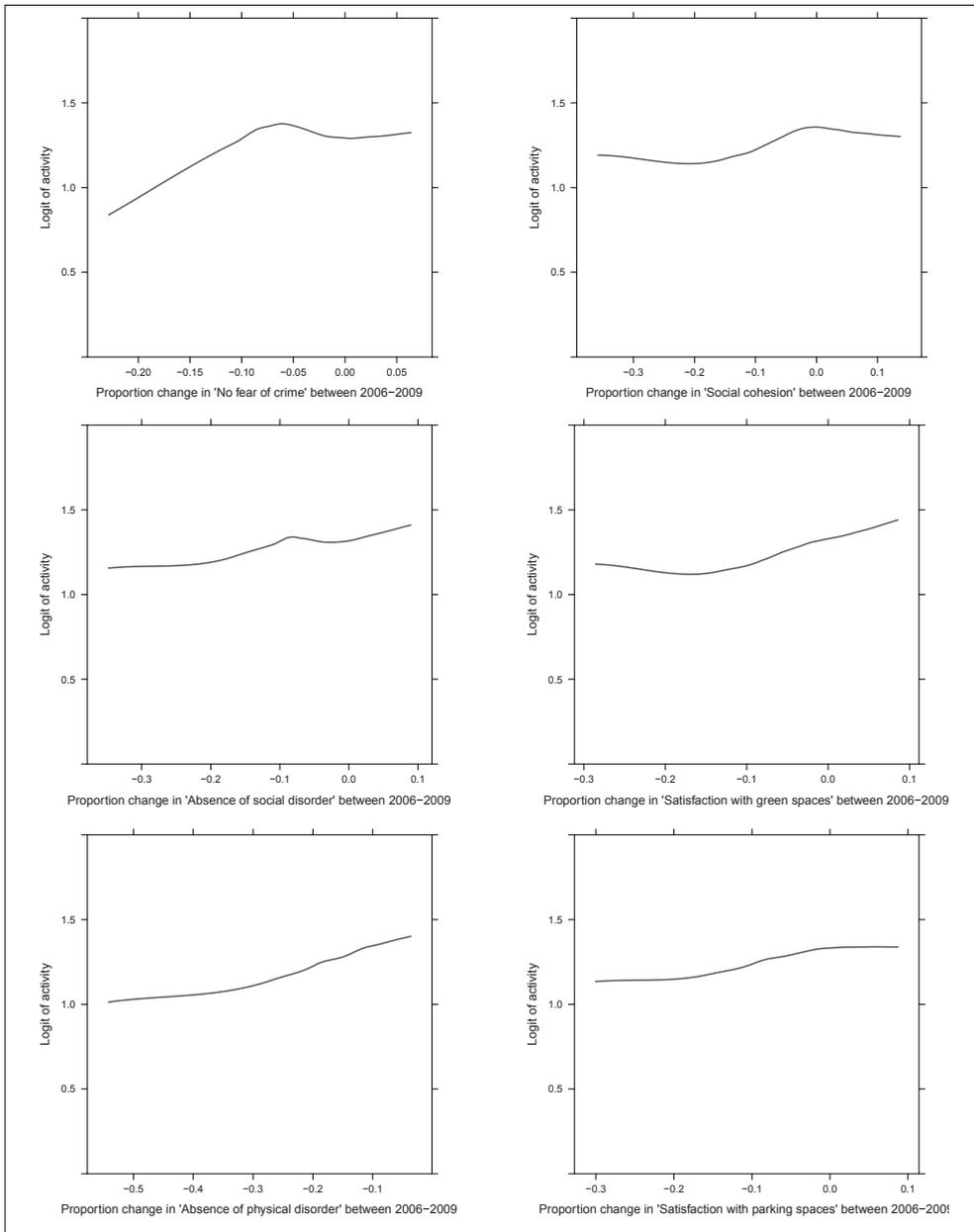
Figs. 2 and 3 present the crude associations of PA with environmental factors, both their levels in 2006 and changes between 2006 and 2009. For most environmental factors, the proportion of people being active in 2009 was statistically significantly positively associated with both the levels in 2006 and with changes between 2006 and 2009. No linear associations were observed between PA and levels of green spaces and (both levels and changes in) satisfaction with parking facilities.

Figure 2: Associations of physical activity in 2009 with levels of desirable neighbourhood environmental factors in 2006^a



^a Prevalence of PA in 2009 (measured as crude logit) in relation to levels of no fear of crime, social cohesion, absence of social disorder, satisfaction green spaces, absence of physical disorder, and satisfaction parking facilities respectively. Relationship depicted by a Loess curve based on 1 degrees of freedom.

Figure 3: Associations of physical activity in 2009 with changes in levels of desirable neighbourhood environmental factors between 2006-2009^a



^a Prevalence of PA in 2009 (measured as crude logit) in relation to changes in no fear of crime, social cohesion, absence of social disorder, satisfaction green spaces, absence of physical disorder, and satisfaction parking facilities respectively. Relationship depicted by a Loess curve based on 1 degrees of freedom.

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Table 4: Associations of physical activity in 2009 with levels of neighbourhood environmental factors in 2006 and changes in levels of neighbourhood environmental factors between 2006-2009, and stratified by gender and age, for 2009 respondents

Predictor ^b	Prevalence of being physically active in 2009 (zero ^c versus at least 1 hour per week)					
	All respondents		Women		Men	
	Odds ratios (95% CI)	Odds ratios (95% CI)	Odds ratios (95% CI)	Odds ratios (95% CI)	Odds ratios (95% CI)	Odds ratios (95% CI)
No fear of crime						
In 2006 ^c	1.38 (1.28-1.51)*	1.30 (1.17-1.44)*	1.45 (1.28-1.46)*	1.35 (1.20-1.50)*	1.41 (1.27-1.57)*	1.37 (1.16-1.50)*
Change between 2006-2009 ^d	1.10 (0.99-1.22)	1.03 (0.90-1.17)	1.12 (1.00-1.27)	1.16 (1.01-1.34)*	1.02 (0.89-1.17)	1.02 (0.87-1.20)
Satisfaction green spaces						
In 2006 ^c	1.05 (0.98-1.12)	1.04 (0.96-1.12)	1.03 (0.95-1.11)	0.98 (0.90-1.07)	1.09 (1.00-1.19)	0.97 (0.89-1.07)
Change between 2006-2009 ^d	1.12 (1.03-1.23)*	1.09 (0.98-1.22)	1.12 (1.01-1.24)*	1.07 (0.95-1.21)	1.11 (0.99-1.25)	1.11 (0.97-1.26)
Social cohesion						
In 2006 ^c	1.16 (1.11-1.22)*	1.12 (1.06-1.18)*	1.17 (1.11-1.24)*	1.09 (1.02-1.16)*	1.22 (1.15-1.29)*	1.09 (1.01-1.16)*
Change between 2006-2009 ^e	1.12 (1.05-1.19)*	1.08 (1.00-1.17)	1.14 (1.06-1.23)*	1.05 (0.96-1.14)	1.14 (1.05-1.24)*	1.14 (1.04-1.26)*
Absence of physical disorder						
In 2006 ^c	1.19 (1.12-1.27)*	1.17 (1.08-1.26)*	1.20 (1.11-1.29)*	1.14 (1.04-1.24)*	1.25 (1.15-1.36)*	1.11 (1.01-1.23)*
Change between 2006-2009 ^e	1.09 (1.01-1.17)*	1.06 (0.97-1.16)	1.09 (1.00-1.19)	1.08 (0.97-1.20)	1.09 (0.99-1.20)	1.02 (0.91-1.15)
Absence of social disorder						
In 2006 ^c	1.27 (1.17-1.37)*	1.22 (1.11-1.34)*	1.29 (1.18-1.42)*	1.17 (1.05-1.30)*	1.29 (1.16-1.44)*	1.26 (1.11-1.42)*
Change between 2006-2009 ^e	1.10 (1.01-1.19)*	1.04 (0.94-1.15)	1.13 (1.03-1.25)*	1.04 (0.93-1.17)	1.11 (0.99-1.24)	1.06 (0.94-1.21)
Satisfaction parking facilities						
In 2006 ^c	0.99 (0.94-1.04)	0.99 (0.93-1.06)	0.99 (0.93-1.05)	0.94 (0.88-1.01)	1.04 (0.97-1.11)	0.98 (0.91-1.06)
Change between 2006-2009 ^d	1.05 (0.97-1.15)	1.03 (0.93-1.14)	1.07 (0.97-1.18)	1.01 (0.90-1.13)	1.11 (0.99-1.23)	1.02 (0.90-1.15)

*The association is statistically significant by P≤0.05, two-sided.

^a Reference group.

^b Control variables: age (where applicable), gender (where applicable), employment status, education, household income, and urbanisation of municipality.

^c One unit change corresponds to an increase by 100% points in the proportion of residents reporting not to fear crime, satisfaction with green spaces, and satisfaction with parking facilities in their neighbourhood.

^d One unit change corresponds to an increase by 100% points in changes in levels of no fear crime, satisfaction with green spaces, and satisfaction parking facilities between 2006 and 2009.

^e One unit change corresponds to an increase by 1 on a scale from 1-5 for social cohesion and 1 on a scale from 1-3 for absence of physical and social disorder.

Results of regression analyses for the total population are presented in the first column Table 4. In general, living in neighbourhoods characterized by more favourable environmental factors in 2006 was associated with higher odds of being active in 2009. However, the odds of being active were not related to satisfaction with green spaces or with parking facilities in 2006. The odds of being active were positively related to favourable changes in most environmental factors between 2006 and 2009, including an increase in the levels of social cohesion, satisfaction with green spaces, and a decrease in social and physical disorder. However no significant relation was observed for changes in satisfaction with parking facilities or changes with regard to fear of crime.

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Further columns of Table 4 show results stratified by age and gender. Contrary to our hypothesis, the associations observed for the total population were not stronger among older people than among younger people. However, as we expected, they were generally somewhat stronger among women compared to men.

Table 5 shows that the associations observed for the total population did not consistently vary according to duration of residence. Contrary to our hypothesis, associations were not generally stronger among residents who have lived longer in the neighbourhood.

Table 5: Associations of physical activity in 2009 with levels of neighbourhood environmental factors in 2006 and changes in levels of neighbourhood environmental factors between 2006-2009, stratified by duration of residence at current address, for 2009 respondents

Predictor ^b	Prevalence of being physically active in 2009 (zero ^a versus at least 1 hour per week)		
	Living at current address < 5 years	Living at current address 5-9 years	Living at current address ≥10 years
	N=9,954	N=5,702	N=12,765
	Odds ratios (95% CI)	Odds ratios (95% CI)	Odds ratios (95% CI)
No fear of crime			
In 2006 ^c	1.39 (1.23-1.57)*	1.45 (1.25-1.68)*	1.32 (1.19-1.47)*
Change between 2006-2009 ^d	1.14 (0.98-1.33)	1.06 (0.87-1.29)	1.06 (0.93-1.21)
Satisfaction green spaces			
In 2006 ^c	0.95 (0.87-1.05)	0.97 (0.86-1.08)	1.09 (1.00-1.18)*
Change between 2006-2009 ^d	1.03 (0.90-1.16)	1.15 (0.98-1.34)	1.14 (1.02-1.27)*
Social cohesion			
In 2006 ^c	1.10 (1.02-1.18)*	1.18 (1.08-1.29)*	1.14 (1.08-1.21)*
Change between 2006-2009 ^d	1.12 (1.01-1.23)*	1.15 (1.02-1.29)*	1.12 (1.03-1.22)*
Absence of physical disorder			
In 2006 ^c	1.17 (1.06-1.29)*	1.25 (1.11-1.40)*	1.15 (1.06-1.25)*
Change between 2006-2009 ^d	1.12 (1.00-1.25)*	1.16 (1.01-1.33)*	1.03 (0.93-0.13)
Absence of social disorder			
In 2006 ^c	1.20 (1.06-1.35)*	1.26 (1.09-1.46)*	1.27 (1.14-1.40)*
Change between 2006-2009 ^d	1.09 (0.97-1.24)	1.05 (0.90-1.23)	1.13 (1.02-1.26)*
Satisfaction parking facilities			
In 2006 ^c	0.94 (0.87-1.01)	0.99 (0.91-1.09)	1.01 (0.95-1.08)
Change between 2006- 2009 ^d	1.06 (0.94-1.20)	1.02 (0.87-1.18)	1.10 (1.00-1.22)

*The association is statistically significant by $P \leq 0.05$, two-sided.

^a Reference group.

^b Control variables: age, gender, employment status, education, household income, and urbanisation of municipality.

^c One unit change corresponds to an increase by 100% points in the proportion of residents reporting not to fear crime, satisfaction with green spaces, and satisfaction with parking facilities in their neighbourhood.

^d One unit change corresponds to an increase by 100% points in changes in levels of no fear crime, satisfaction with green spaces, and satisfaction parking facilities between 2006 and 2009.

^e One unit change corresponds to an increase by 1 on a scale from 1-5 for social cohesion and 1 on a scale from 1-3 for absence of physical and social disorder.

DISCUSSION

Key findings

This study explores whether PA is associated not only with recent levels of environmental characteristics, but also with changes over time in these environmental characteristics. We found that, for the environmental factors perceived fear of crime, social cohesion, and physical and social disorder, living in neighbourhoods with more favourable environmental characteristics in 2006 was associated with higher odds of being active in 2009. Furthermore, we found that, for the environmental characteristics green spaces, social cohesion, and physical and social disorder, improvements in environmental conditions between 2006 and 2009 were related to higher odds of being active in 2009. These positive associations tended to be stronger among women than among men, but not among older people or among residents who have lived longer in the neighbourhood.

Evaluation of potential data problems

The response rates were 70.9% and 62.6% for WoON06 and WoON09 respectively.^{48,49} The non-response consisted of people that refused to participate. If non-response would be strongly related to both neighbourhood environmental factors and PA, this would have biased our results. The non-response rates of WoON06 and WoON09 varied little with region of residence, which may indicate a weak relationship to place of residence in general.^{48,49} Nonetheless, non-response might be related to some specific environmental characteristics, such as degree of social cohesion, which implies that response bias cannot be excluded.

Currently, there is no consensus on which measure should be used to assess neighbourhood attributes,⁵² making comparisons among studies difficult. The indicators of the environment that we used were generally guided by factors used in previous research.^{15,19,30,38,39,41} However, because of data restrictions, some major differences could not be avoided and are discussed below.

- For social cohesion, our measure is a selection of items in line with the definition of Kawachi and Berkman (2000)⁵³ who define social cohesion as the “extent of connectedness and solidarity among groups in society”. The measurement of social cohesion used in most studies on PA, on the other hand, emphasized shared values of neighbors, mutual trust, and the willingness to help each other,^{8,11,13,17,35,36} which is more support-related. Despite these measurement differences, our results were similar to those of most previous studies.^{11,13,17,35,36}

- Many studies that assessed safety from crime asked respondents if the crime rate in their neighbourhood makes it unsafe to walk during the day and at night (e.g.^{9,10}). We instead used a survey question that asked about fear of crime, without a reference to walking outside. This lack of specificity might perhaps have incurred the lack of association between PA and recent changes in safety, although our result is consistent with several studies that report no associations.^{11,14,18-22}
- Social disorder has been measured in previous studies by a scale that consisted of several items.⁴¹ However, all items of this scale showed low frequency except for the item “Adults loitering or congregating”.⁵⁴ This scale may therefore have been dominated by this single item, which corresponds to the questions that we used. This study, which is to our knowledge, the first to assess the effect of social disorder on PA among adults, gives reason to conclude that there is an association between PA and recent changes in social disorder.
- We measured satisfaction with the amount of green spaces using one survey question. Ideally, we would have preferred to distinguish several dimensions, including the amount, type, quality, and proximity of green spaces. An USA study²⁴ reported that PA was not associated with number of parks, while it was strongly associated with residential proximity to parks. Further research on the effects of changes in green spaces should measure changes along different dimensions as well.

To conclude, for some but not all environmental factors, there are grounds to expect that our results might have been influenced by the use of available measures other than those used in previous studies.

Only one single question was used to assess PA, as this was the only one available in the population surveys used in this study. We would have preferred to measure PA in more detail by measuring different types of PA, their intensity, and their duration in minutes instead of hours of PA per week. Additionally, we would have included an objective assessment of PA because self-reports of PA have shown to overestimate levels of PA⁵⁵ due to social desirability and/or the cognitive difficulty to remember the frequency and duration of different types of PA.⁵⁶ Future studies should try to replicate the findings from this study using detailed self-reports of PA as well as objective measurements such as pedometers and accelerometers.

By dichotomizing the measurement of PA, we did not use all survey information on PA. However, in preliminary analyses, we also analysed the mean hours of PA among those who had reported at least 1 hour of PA per week. We found that this additional measure on the amount of PA was not related to any of the environmental factors studied in this paper.

This study only measured PA in terms of ‘hours’ per week, as duration of PA in minutes per week was not measured. Consequently, we were not able to determine the effect of environmental factors on people doing some activity, but which is less than an hour, as less than an hour is assumed in the analysis to be none. However, being physically active more than 0 min per week but less than an hour per week is far beneath the recommended PA guideline for health benefit.

In this paper we regarded people who reported to be physically active 1 h or more per week as “active”. In additional analyses on the total population, we evaluated whether we would have obtained other results by using a cutoff point that is closer to the recommended PA guideline for health benefit. In these analyses, respondents were labeled “active” only if they were physically active at least 3 h a week (instead of 1 h). The results of this analysis were very similar to the associations reported above (see Appendix Table). However, most associations were generally weaker and no statistically significant relationships were observed with improvements between 2006 and 2009 in social disorder and physical disorder.

In this study, we only had data on people’s levels of PA, without references to the place of activity. This implies that we also measured PA of respondents while outside their neighbourhood. However, in the Netherlands, much of PA comprises walking and bicycling, which to a large extent are performed inside of one’s neighbourhood. Nevertheless, if the associations observed in our study would be truly causal, then these associations presumably would be stronger if neighbourhood-related PA had been measured.

We used data from two subsequent cross-sectional surveys in 2006 and 2009. Differences in the perceived neighbourhood environment might be the result of changes in the demographic makeup of the neighbourhood and therefore not reflect real changes in the neighbourhood. Accordingly, this would have led to a spurious association between changes in environmental factors and PA. We have no information on whether the 2006 and 2009 survey samples per neighbourhood differed with regard to socio-demographic factors. We do know that for all neighbourhoods together the two survey samples were quite similar with regard to some socio-demographic factors, but for other factors there were larger differences. To avoid this potential bias, future research on changes in environment should use longitudinal designs or objective measures of the environment.

Almost all environmental factors studied were related to PA. One might question whether this result is due to a common underlying factor that is not controlled for in the analyses, despite extensive controls for socio-demographic factors. For example, respondents from some neighbourhoods

may tend to reflect negatively on their environment, whereas those in other neighbourhoods may be inclined to present positive views. Such a generalised effect would be reflected in a high correlation amongst environmental variables reported for the same neighbourhood. However, we observed moderate relationships between environmental factors in 2006 (average correlation coefficient was 0.50) and weak relationships between trends in different environmental factors (average correlation coefficient was 0.20). This suggests that common underlying factors have had little effect on the changes observed for specific environmental factors.

Explanations

Possible mechanisms

The plausibility of a causal link between PA and social cohesion, social disorder, physical disorder, and green spaces depends on the existence of plausible mechanisms through which these environmental factors could affect PA. However, very little research has been conducted on the mechanisms that link the environment to PA.

Social cohesion has been reported before to be related to more healthy behavior of neighbourhood residents in general, such as less smoking and more PA or walking for exercise.^{11,13,17,35,36,57} We know that frequently observing others exercising is associated with higher levels of PA.⁵⁸ People who are more closely connected to their neighbourhood might even be more likely to adopt healthy norms of behavior such as PA than those living in less cohesive neighbourhoods.⁵³

Social disorder is reflecting nuisance from neighbors or harassment by youngsters resulting in conflicts in the neighbourhood. Conflicts are very stressful and stress is known to be associated with lower levels of PA.⁵⁹

People are inclined to be physically active in esthetically appealing environments.^{18,21,60} Analogously, we expect that a clean and intact neighbourhood (absence of physical disorder) stimulates more time being spent outdoors and hence PA.

Green spaces in one's neighbourhood may invite people to spend a larger part of their spare time outdoors and be more physically active.⁶¹ Research has shown that exposure to green spaces may affect stress levels in a positive way.⁶²⁻⁶⁴ Stress reduction is known to be associated with higher levels of PA.⁵⁹

Why were stronger effects not found for older and for long-time residents?

Older people might perhaps be more sensitive to their neighbourhood environment because they spend more time there. One previous study suggested that safer neighbourhoods were associated with PA only for people aged older than 65 years.⁴⁷ We did, however, not observe stronger effects among older compared to younger people. One explanation may be that PA levels of older people might be determined more often by individual factors such as physical limitations. Future research on the association between environmental factors and PA should distinguish between older people with and without disabilities.

4

We expected to observe larger effects among residents with long duration of residence in the neighbourhood. However, no such effect modification was observed. Possibly, most of the short-term residents of deprived areas might have come from neighbourhoods with similar levels of deprivation⁶⁵ and thus already experienced similar environmental problems such as crime, social control, and social cohesion.^{66,67}

Implications

Cross-sectional research in which PA and environmental conditions are measured at the same point in time, cannot provide strong evidence on causality. Because we measured changes over time in environmental factors over time, and studied associations with PA at the end of the observation period, we provided new evidence on the causality of the relationship between neighbourhood environmental factors and PA. Future research should aim to replicate these findings using similar or longitudinal study designs, including objective as well as subjective assessments of changes in neighbourhood conditions, and detailed self-reports as well as objective measurements of PA.

Our results suggest that improving social cohesion, tackling physical and social disorder, and improving green spaces might lead to an increase in the number of residents who are physically active. We stress that although, the effect of improving environmental conditions on individual-level PA may seem weak, such improvements have the potential to bring benefit to much larger populations, and for a much longer period of time than most individual-level interventions.

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Appendix Table: Associations of physical activity in 2009 with levels of neighbourhood environmental factors in 2006 and changes in levels of neighbourhood environmental factors between 2006-2009, for 2009 respondents

Predictor ^b	Prevalence of being physically active in 2009 (less than 3 hours per week ^a versus at least 3 hour per week)
	All respondents
	Odds ratios (95% CI)
No fear of crime	
In 2006 ^c	1.27 (1.17-1.38)*
Change between 2006-2009 ^d	1.02 (0.92-1.13)
Satisfaction green spaces	
In 2006 ^c	1.05 (0.99-1.13)
Change between 2006-2009 ^d	1.09 (1.00-1.19)*
Social cohesion	
In 2006 ^c	1.13 (1.08-1.18)*
Change between 2006-2009 ^e	1.10 (1.03-1.18)*
Absence of physical disorder	
In 2006 ^c	1.14 (1.07-1.22)*
Change between 2006-2009 ^e	1.04 (0.96-1.12)
Absence of social disorder	
In 2006 ^c	1.22 (1.13-1.33)*
Change between 2006-2009 ^e	1.07 (0.98-1.16)
Satisfaction parking facilities	
In 2006 ^c	1.01 (0.96-1.07)
Change between 2006-2009 ^d	1.04 (0.95-1.13)

*The association is statistically significant by $P \leq 0.05$, two-sided.

^a Reference group.

^b Control variables: age (where applicable), gender (where applicable), employment status, education, household income, and urbanisation of municipality.

^c One unit change corresponds to an increase by 100% points in the proportion of residents reporting not to fear crime, satisfaction with green spaces, and satisfaction with parking facilities in their neighbourhood.

^d One unit change corresponds to an increase by 100% points in changes in levels of no fear crime, satisfaction with green spaces, and satisfaction parking facilities between 2006 and 2009.

^e One unit change corresponds to an increase by 1 on a scale from 1-5 for social cohesion and 1 on a scale from 1-3 for absence of physical and social disorder.