

Do Physical Activity, Social Cohesion, and Loneliness Mediate the Association Between Time Spent Visiting Green Space and Mental Health?

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Abstract

This cross-sectional study investigated whether physical activity, social cohesion, and loneliness mediate the association between time spent visiting green spaces and perceived mental health and vitality. Questionnaire data

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were collected from 3,948 residents from 124 neighborhoods across four European cities. Multilevel linear regression analysis revealed positive, but weak, associations between time spent visiting green space and Medical Outcome Study Short Form (SF-36) mental health and vitality score, which suggest small mental health benefits. Single mediation analyses showed that different indicators of physical activity (total, during leisure time, and walking during leisure time), social cohesion, and loneliness were mediators. Multiple mediation analyses showed that physical activity during leisure time and loneliness may explain about 25% of the relationship. The unmediated part of the association suggests that other mediators may explain the association.

Keywords

time spent visiting green space, mental health, vitality, mediation analysis, social cohesion, loneliness, cross-sectional study, physical activity

Introduction

Evidence is mounting that the amount of green space near the residence is positively associated with mental health (Gascon et al., 2015; M. van den Berg et al., 2015). Commonly proposed mechanisms include the provision of suitable and attractive places for leisure time physical and social activities and for restoration from stress and mental fatigue (de Vries, van Dillen, Groenewegen, & Spreeuwenberg, 2013; Hartig, Mitchell, de Vries, & Frumkin, 2014; Health Council of the Netherlands and Dutch Advisory Council for Research on Spatial Planning, 2004).

The number of studies that investigate the mechanism underlying the relations between green space and mental health is growing. Many experimental studies have indicated that contact with green space can help people to recover from stress and mental fatigue (Health Council of the Netherlands and Dutch Advisory Council for Research on Spatial Planning, 2004; A. E. van den Berg, Hartig, & Staats, 2007). Several epidemiological studies have shown that the amount of residential green space was associated with lower stress levels (Fan, Das, & Chen, 2011; Gidlof-Gunnarsson & Ohrstrom, 2007; Grahn & Stigsdotter, 2003; Nielsen & Hansen, 2007; Stigsdotter et al., 2010). Furthermore, several studies that have explored the role of intermediate factors (mediators) in the association between green space and mental health have provided support for the stress mechanism (Dadvand et al., 2016; de Vries et al., 2013)

However, while the evidence for the stress mechanism is relatively strong and consistent, the evidence for the behavioral mechanisms is still weak and

inconsistent. There is mixed evidence that the amount of green spaces is positively associated with physical activity (Bancroft et al., 2015). Concerning social contacts, several studies have shown that the amount of neighborhood green space facilitates social contacts and strengthens social ties or social cohesion (Arnberger & Eder, 2012; Kazmierczak, 2013; Kuo, Sullivan, & Wiley, 1998; Kweon, Sullivan, & Wiley, 1998). Few studies have explored mediation in the associations between the amount of green space and mental health outcomes. These studies have provided support for mediation by several indicators of physical activity (Maas, Verheij, Spreeuwenberg, & Groenewegen, 2008; Richardson, Pearce, Mitchell, & Kingham, 2013; Sugiyama, Leslie, Giles-Corti, & Owen, 2008) and of social contacts (de Vries et al., 2013; Maas, van Dillen, Verheij, & Groenewegen, 2009; Sugiyama et al., 2008). Maas et al. (2009) found that loneliness and perceived shortage of social support mediated the association, but not social cohesion or social contacts with neighbors and friends. Sugiyama et al. (2008) found that recreational walking and social coherence together partly explained the association between perceived greenness of the neighborhood and mental health. De Vries et al. (2013) showed that approximately 60% of the total association between quantity and quality of streetscape greenery and mental health was explained by adding three potential mediators in the model: stress, social cohesion, and physical activity during leisure time and for transport.

While several studies have adequately assessed the meditating roles of the behavioral mechanisms in the association between the amount of residential greenness and mental health (de Vries et al., 2013; Maas et al., 2009; Maas et al., 2008; Richardson et al., 2013; Sugiyama et al., 2008), there are no studies that have investigated these mediating roles in the association between use of green space and mental health. For people who have sufficient independent mobility, use of green space, in terms of visits to green space on purpose, is proposed to be a better proxy of exposure than the amount of green space, especially when exploring those behavioral mechanisms that are related to specific leisure time activities. However, for people with limited mobility, (visual) exposure to green space near home by looking out the window might be more important than visiting green space. In this study, the total time spent visiting green space near home as well as further away is assessed to take account of possible trade-offs, that is, people who have little or no green space near home might visit green space further away more often or for a longer duration.

This study was part of the Positive Health Effects of the Natural Outdoor environment in Typical Populations in different regions in Europe (PHENOTYPE) project. A previous study, conducted with the same

PHENOTYPE data, showed small but significant positive associations between visiting green spaces and mental health in a large population of residents across four European cities (M. van den Berg et al., 2016). The present study was a follow-up to that study. In that study, vitality was used as an outcome next to the mental health outcome, which is often used in epidemiological research. Both outcomes are subscales of the Medical Outcome Study Short Form (SF-36). While the mental health scale measures psychological distress (e.g., depression), the vitality scale was designed to assess subjective general well-being and measures positive health states (e.g., energy) as well as physical and psychological distress (e.g., fatigue) (McHorney et al., 1993). Therefore, vitality may be particularly sensitive to exposure to green space because it is associated with resilience to stress and with psychological and physical well-being (Ryan & Deci, 2008). For both outcomes, robust associations were found with total time spent on visiting green space in the previous study conducted with the PHENOTYPE data in the four European cities, which were somewhat stronger for the vitality outcome (M. van den Berg et al., 2016).

Objective

The objective of the current study was to investigate whether and to what extent physical activity (total physical activity, leisure time physical activity, and walking during leisure time), social cohesion, and loneliness, separately and combined, mediate the association between total time spent visiting green spaces and mental health in a European population using the SF-36 mental health components: (a) perceived mental health and (b) perceived vitality. This study tested the hypotheses that total time spent visiting green spaces exerts its effect on mental health and vitality indirectly through the following mediators: total physical activity, physical activity during leisure time, walking during leisure time, social cohesion, and loneliness.

Method

Study Background

Data for this study were derived from a questionnaire administered as part of the PHENOTYPE project. Data were collected from adult residents of four European cities: Barcelona (Spain), Kaunas (Lithuania), Doetinchem (the Netherlands), and Stoke-on-Trent (the United Kingdom). An overview of the project and its protocols have been described elsewhere (Nieuwenhuijsen et al., 2014). All procedures were approved by ethical committees of the respective research institutes.

Study Population and Data Collection

In each of the four cities, approximately 30 spatial units (or neighborhoods) were selected in such a way to ensure variation in access to green space and in socioeconomic status (SES; total 124 neighborhoods). To ensure variability in access to green space, for each spatial unit, the averaged (Euclidean) distance was calculated from all residential addresses to green spaces of more than one hectare using data from the Urban Atlas land use database (Barcelona, Stoke-on-Trent, and Kaunas) and the TopNL databases (Doetinchem). These averaged distances were placed into quintiles to define five categories. To ensure variability in SES, the tertiles of the distribution of SES, based on country-specific data, were used to define three categories of SES for each city. For each city, each spatial unit was fit into one of the 15 (i.e., 3×5) combinations of green space and SES categories. In the next step, from each combination, two neighborhoods (with sufficient adult population) were selected that varied in types of green spaces and that were not adjacent to each other.

A random sample of 30 to 35 nonhospitalized adults, aged 18 to 75 years, was selected in each neighborhood. A total sample of 1,000 respondents per city was aimed for using similar procedures for population selection in the four cities. Due to specific privacy rules, data in Kaunas were collected by postal questionnaire instead of face-to-face interviews (see Supplemental Table S1 that presents the number of residents who were approached and the response rates).

Questionnaire

Most questions were derived from existing and validated measures. Where new questions were developed, they were drafted in English and translated (and back translated) into Dutch, Spanish, Catalan, and Lithuanian. Green spaces were defined as all public and private open spaces that contain “green” and “blue” natural elements such as street trees, forests, city parks, and natural parks/reserves, including all types of water bodies, further referred to as “green spaces.”

The following subset of questions was used for this study:

- a. Mental health and vitality subscales from SF-36 were used (Ware, 2000; Ware & Sherbourne, 1992). The five-item mental health subscale, also known as the five-question Mental Health Inventory, assessed nervousness and feelings of depression in the past month (Cronbach's $\alpha = .73$), whereas the vitality subscale, including four items, assessed the

perceived level of energy and fatigue (Cronbach's $\alpha = .76$). All items were scored on a 6-point scale and sum scores were transformed into a scale from 0 to 100 according to the guidelines by Ware (2000). Higher scores reflect better mental health and higher vitality.

- b. Frequency and duration of visits to green space were reported for three categories of green space: (i) "close to your home (less than 15 min by foot or bike)," (ii) "in your city or town (more than 15 min by foot or bike)," and (iii) "close to your city or town." Visit frequency was measured by asking "how often did you visit in the last 4 weeks on purpose the following green spaces." All items were scored on a 5-point scale with categories: *never, 1 time or less in past month, 2-3 times in past month, 1-4 times weekly, (almost) daily*. Visit duration was assessed by asking, "how much time did you spent in each of the following green spaces in the last four weeks *per visit*?" scored on a 4-point scale (<1 hr, 1-2 hr, 3-5 hr, 6-10 hr). To calculate the total time spent visiting green spaces, the frequency and duration questions were combined. For each green space category (i.e., close to home, in your city/town, close to your city), a fixed value in the middle of the range of each of the four answer categories from the visit frequency items was chosen (respectively, 0.5, 2.5, 8, and 20 times). The values were multiplied with a fixed value in the middle of the range of values of each of the four answer categories of the visit duration items (respectively, 0.5, 1.5, 4, and 8 hr) and then summed. "Never" and "not applicable" for visit frequency were both set on null hours per month.
- c. Sociodemographic characteristics were obtained by using standardized questions about gender, age (in years), household composition (with children younger than 12 years/with older children or without children), level of education—(a) low, that is, primary school or no education; (b) medium, that is, secondary school/further education; (c) high, that is, university degree or higher—subjective income situation (three categories: "cannot make ends meet," "just have enough to get along," and "being comfortable"), and work status (employed/unemployed).
- d. Physical activity was assessed by the Short Questionnaire to Assess Health-Enhancing Physical Activity (SQUASH; Wendel-Vos et al., 2004). Potential mediators were total physical activity, as well as specific physical activity categories more likely to be conducted in green spaces: physical activity during leisure time (minutes per week) and walking during leisure time (minutes per week), each obtained by multiplying frequency (number of days per week) and duration (average

time in minutes per day). For total physical activity and physical activity during leisure time, the time spent on all types of activities, ranging from light to heavy intensity, were summed. All three activity variables were logarithmically transformed to derive close-to-normal distributed variables, thereby excluding respondents with zero values ($n = 173$ for total physical activity, $n = 469$ for physical activity during leisure time, $n = 1,107$ for walking during leisure time).

- e. Social cohesion and loneliness were explored as a potential mediators, following de Vries et al. (2013) and Maas et al. (2009). To measure social cohesion, the social cohesion and trust scale developed by Sampson et al. (1997) was used. It consists of five items, for example, "people are willing to help their neighbors" and "people in this neighborhood can be trusted," to be scored on a 5-point scale (*strongly agree* to *strongly disagree*). A sum score was calculated such that a higher score represents a higher degree of social cohesion (Cronbach's $\alpha = .85$). Loneliness was assessed using six items based on the UCLA (University of California Los Angeles) Loneliness Scale (Russell, 1996), for example, "there are people I get along with" and "I feel part of a group friends." Each item was scored on a 5-point scale and a sum score was calculated with a higher score reflecting a higher degree of loneliness (Cronbach's $\alpha = .81$).

Statistical Analysis

Multilevel linear regression analyses were conducted to investigate the associations between total hours visiting green spaces per month and mental health/vitality and, to assess mediation (or indirect effects). Two levels were included: individual and neighborhood. A random intercept was included in the models, because a likelihood ratio test showed that this significantly improved the regression models; a random slope did not and, therefore, was not included. The same set of the following potential confounders was used in all models: gender, age, level of education, perceived income, employment status, household composition with/without children younger than 12 years, and city. Only complete cases were included in the mediation analyses ($n = 2,972$ for the multiple mediation analysis with mental health as outcome; $n = 2,960$ for the multiple mediation analysis with vitality as outcome).

Mediation analysis consists of testing hypotheses about the two pathways of influence through which an independent variable exerts its effect on the outcome; that is, directly from independent variable to the outcome variable and indirectly through an intervening variable or mediator (Hayes,

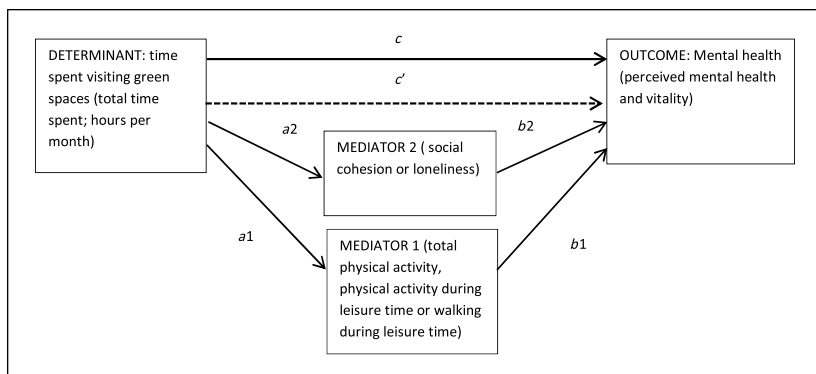


Figure 1. Multiple mediation model of this study.

Note. The a path is the association between determinant and mediator; the b path is the association between mediator and outcome; the c path is the overall association between determinant and outcome; the c' path is the direct (unmediated) association between determinant and outcome.

2013; MacKinnon, 2008). The single mediation analysis consisted of the following three regression steps analyzing the association between visits to green spaces and (a) mental health/vitality as outcomes, to estimate unstandardized regression coefficient c (the total effect); (b) potential mediator as outcome, to estimate the unstandardized regression coefficient a ; (c) mental health/vitality as outcomes, while including the potential mediator, to estimate the independent effect of the mediator on the outcomes and the direct effect on the outcomes (respectively, the unstandardized regression coefficients b and c'). The size of the indirect or mediated effect was represented by the product of the coefficients a and b (MacKinnon, 2008). To test whether an intervening variable was a significant mediator, the Sobel test was used (MacKinnon, 2008; Sobel, 1982). Significance was set at $p \leq .05$ level. The indicators of physical activity and social contacts with the largest significant mediation effect were included in the multiple mediation model. Figure 1 presents the multiple mediator model of this study (two mediators). The total mediated effect was calculated as the sum of the individual mediated effects ($a_1 \times b_1 + a_2 \times b_2$). To test the total mediated effect, the SE was derived using the formula according to MacKinnon (2008). All analyses were performed with SPSS 20.0.

A sensitivity analysis was conducted to explore differences in single mediation effects of physical activity analyzed as continuous variables versus dichotomized (around median values) variables. In a second sensitivity

analysis, the Monte Carlo method was used as an alternative to the Sobel test of significance of the mediation effects (Field, 2013).

Results

Study Population

The characteristics of the study population included in the analyses ($N = 3,748$) are shown in Table 1. Table 2 shows descriptive statistics of time spent visiting green space close to home, in the city, and near the city in the past month. The total number of hours of time spent visiting green space was used in the analyses. Almost half of the time was spent in green space close to home. Table 3 shows the descriptive statistics of the variables tested as mediators.

Associations Between Time Spent Visiting Green Spaces and Mental Health and Vitality (c Coefficients)

Statistically significant positive associations were found between time spent visiting green spaces and mental health and vitality (Tables 4 and 5). The regression coefficients (c) indicate that an additional hour per month of visiting green spaces was associated with a significant but small increase on the mental health (0.021-0.029 points) and vitality (0.037-0.042 points) 0 to 100 scales.

Associations Between Time Spent Visiting Green Space and Mediators (a Coefficients)

Time spent visiting green spaces was significantly associated with all three physical activity variables (Tables 4 and 5; $p < .001$). However, the regression coefficients (a) were small, ranging from 0.001 for total physical activity to 0.003 for physical activity during leisure time (Table 4). A regression coefficient of 0.001 indicates that each additional 1 hr time spent visiting per month was associated with an additional 1 min physical activity per week ($e^{0.001}$) or 4 min per month. Furthermore, both loneliness and social cohesion were significantly associated with time spent visiting green spaces, respectively, $a = -0.006$ (single model; Table 4) and -0.005 (multiple model; Table 5), and $a = 0.004$ ($p < .001$; Table 4). This indicates that each additional 1 hr time spent visiting green space per month was associated with a decrease in feelings of loneliness and an increase in social cohesion.

Table 1. Characteristics of the Study Population Included in the Analyses (Pooled Data for All Four Cities).

Total <i>n</i> (%)	3,748 (100)
Age (18-75 years), <i>M</i> (<i>SD</i>)	51.3 (16.0)
Missing, <i>n</i>	53
Age groups, <i>n</i> (%)	
18-25	310 (8.4)
26-45	1,013 (27.4)
46-65	1,542 (42.7)
66-75	830 (22.5)
Male (= 1), <i>n</i> (%)	1,674 (44.7)
Missing, <i>n</i>	0
Highest qualification, <i>n</i> (%)	
Low	264 (7.0)
Medium	1,653 (44.4)
High	1,807 (48.2)
Missing, <i>n</i>	24
Employed (vs. not), <i>n</i> (%)	2,304 (61.5)
Missing, <i>n</i>	0
Subjective income situation, <i>n</i> (%)	
Cannot make ends meet	375 (10.7)
Enough to get along	1,740 (49.9)
Comfortable	1,375 (39.4)
Missing, <i>n</i>	258
Household composition, <i>n</i> (%)	
children <12	567 (15.2)
Other	3,156 (84.8)
Missing, <i>n</i>	25
Transformed mental health (sum score scale 0-100, higher is better), <i>M</i> (<i>SD</i>)	73.6 (16.1)
Missing, <i>n</i>	22
Transformed vitality (sum score scale 0-100, higher is more), <i>M</i> (<i>SD</i>)	61.8 (18.7)
Missing, <i>n</i>	24

Associations Between Mediators and Mental Health and Vitality, Controlling for Time Spent Visiting Green Spaces (b Coefficients)

Table 4 shows that, when controlling for time spent visiting green spaces, total physical activity was only significantly associated with vitality

Table 2. Descriptive Statistics of Visits to Green Spaces (Hours Per Month) Close to Home, in City/Town, and Near City (Pooled Data of All Four Cities).

Total <i>n</i> (%)	3,748 (100)
Number of hours spent close to home (<15 min on foot/bike) in green spaces, median [IQR]*	4.0 [0.3-12.0]
Number of hours spent in your city/town (>15 min on foot/bike) in green spaces, median [IQR]*	0.8 [0.0-10.0]
Number of hours spent near city in green spaces, median [IQR]*	0.8 [0.0-10.0]
Total number of hours spent in green spaces, median [IQR]*	11.5 [1.5-32.0]
<i>M</i> total (<i>SD</i>)	27.5 (26.7)

Note. Due to the skewness of the distributions, the medians do not sum up.

*IQR= InterQuartile Range.

($b = 1.494, p \leq .001$) and not with mental health, whereas physical activity during leisure time was significantly associated with both mental health ($b = 0.938, p \leq .01$) and vitality ($b = 2.067, p \leq .001$). In the multiple mediator model, the association remained significant ($b = 0.764, p \leq .05$), after adding the second mediator loneliness to the model (Table 5). In addition, Table 2 shows that walking during leisure time was not associated with the outcomes, but loneliness and social cohesion were. The association between loneliness and both outcomes decreased somewhat but remained significant, after adding the second mediator physical activity during leisure time in the multiple mediation model (mental health: single model $b = -1.116$, multiple model $b = -0.999, p \leq .001$; vitality single model $b = -0.006$, multiple model $b = -0.636, p \leq .001$; see Tables 4 and 5).

Single and Multiple Mediation (Product of *a* and *b* Coefficients)

For mental health and vitality outcomes, all tested variables, except for walking during leisure time, were significant mediators ($p \leq .05$; indirect effect assessed as the product of the *a* and *b* coefficients; Table 4). In the associations with mental health as well as vitality, the physical activity and social variables accounting for the largest proportions mediated were loneliness (respectively, 23% and 10%) and physical activity during leisure time (respectively, 10% and 16%; Table 4). In the multiple mediation models, significant mediation was found when both mediators were combined, accounting for 30% of the association with mental health and 25% of the association with vitality (Table 5).

Table 3. Descriptive Statistics of the Potential Mediators (Pooled Data of All Four Cities).

Total <i>n</i> (%)	3,748 (100)
<hr/>	
Total physical activity, minutes per week, <i>M</i> (<i>SD</i>)	1,649 (1,264)
Missing, <i>n</i>	0
Total physical activity log transformed (2-9), <i>M</i> (<i>SD</i>)	7.11 (0.96)
Missing, <i>n</i>	173
Physical activity during leisure time, minutes per week, <i>M</i> (<i>SD</i>)	494 (491)
Missing, <i>n</i>	0
Physical activity during leisure time log transformed (2-8), <i>M</i> (<i>SD</i>)	5.94 (0.99)
Missing, <i>n</i>	469
Walking during leisure time, minutes per week, <i>M</i> (<i>SD</i>)	206 (272)
Missing, <i>n</i>	0
Walking during leisure time log transformed (2-8), <i>M</i> (<i>SD</i>)	5.24 (0.99)
Missing, <i>n</i>	1,107
Loneliness (6-27, higher is more), <i>M</i> (<i>SD</i>)	12.31 (3.74)
Missing, <i>n</i>	50
Social cohesion (5-25, higher is more), <i>M</i> (<i>SD</i>)	17.11 (3.44)
Missing, <i>n</i>	189

*Direct Associations Between Time Spent Visiting Green Spaces and Outcomes (*c'* Coefficients)*

After adjustment for each of the significant mediators, the direct associations with both outcomes were somewhat weaker than the overall associations (*c'* coefficients vs. *c* coefficients; Figure 1), but remained significant (Table 4). This indicates that the association is partly mediated by each of the mediators. The same holds for the small decrease in the regression coefficient of the direct association (*c'* coefficient) compared with that of the overall association (*c* coefficient) in the multiple mediation models (Table 5).

Single Mediation Sensitivity Analysis

The mediation analysis with the physical activity variables dichotomized around the mean values showed comparable results, except for walking during leisure time (Table 5). This variable was a significant mediator in the association between time spent visiting green space and vitality, but not in the association with mental health.

Table 4. Mediation Effects of Separate Potential Mediators on the Association Between Time Spent Visiting Green Space and Mental Health/Vitality (Data of All Cities Pooled).

Mediator (M)	Comp c (SE) ^a	Comp a (SE) ^b	Comp b (SE) ^c	Comp a x comp b (SE) ^d	95% CI of comp a x comp b	Comp c' (SE) ^e	% mediate effect ^f
Single-mediator model for the association between time spent visiting green space (X) and mental health (Y)							
Total physical activity n = 3,401	0.591 (0.122)	0.076 (0.025)	0.367 (0.120)	0.028 (0.013)*	[0.002, 0.053]	0.528 (0.113)	5
Physical activity during leisure time n = 3,401	0.591 (0.122)	0.174 (0.025)	0.312 (0.118)	0.054 (0.022)*	[0.011, 0.097]	0.519 (0.115)	10
Walking during leisure time n = 3,166	0.604 (0.121)	0.150 (0.025)	0.177 (0.120)	0.027 (0.018)	[-0.010, 0.063]	0.573 (0.119)	4 ns
Single-mediator model for the association between time spent visiting green space (X) and vitality (Y)							
Total physical activity n = 3,398	0.113 (0.121)	0.076 (0.025)	0.418 (0.116)	0.032 (0.014)*	[0.005, 0.058]	0.630 (0.110)	5
Physical activity during leisure time n = 3,398	0.113 (0.121)	0.174 (0.025)	0.609 (0.096)	0.106 (0.023)*	[0.062, 0.150]	0.490 (0.095)	18
Walking during leisure time n = 3,162	0.113 (0.115)	0.150 (0.025)	0.409 (0.104)	0.061 (0.019)*	[0.025, 0.098]	0.641 (0.104)	9

Note. All models were adjusted for gender, age, level of education, perceived income, employment status, household with/without children <12 years and city; a random intercept was included to account for neighborhood clustering; Sobel test of significance of mediation ($p \leq .05$); physical activity variables tested as potential mediating variables dichotomized around the media. Unstandardized comparable (comp) regression coefficients and standard errors (see for calculations, Mackinnon & Dwyer, 1993). CI = confidence interval.

^aThe comparable c coefficient refers to the total association between time spent visiting green space (X) and mental health/vitality (Y).

^bThe comparable a coefficient refers to the association between time spent visiting green space (X) and the mediator (M).

^cThe comparable b coefficient refers to the association between the mediator (M) on the outcome mental health/vitality (Y) when adjusted for visits to green space (X).

^dThe product of comp a and comp b estimates the indirect effect or mediation.

^eThe comparable c' coefficient refers to the direct association between time spent visiting green space (X) and the outcome (Y), adjusted for the mediator.

^fThe percentage of the mediated effect is estimated by $\text{comp a} \times \text{comp b} / (\text{comp a} \times \text{comp b} + \text{comp c}') \times 100\%$.

* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 5. Mediation Effect of Two Mediators Simultaneously on the Association Between Time Spent Visiting Green Space and Mental Health/Vitality (Data of All Cities Pooled).

Mediator (M)	a (SE) ^a	b (SE) ^b	ab (SE) % mediated	SUMab ^c	95% CI of SUMab	c (SE) ^d	c' (SE) ^e	% mediated effect ^f
Multiple mediation time spent visiting green space (X) and mental health (Y) (n = 2,972)								
Physical activity during leisure time, M1	0.003 (0.0004)***	0.764 (0.298)*	0.002 (0.001)* 7%	0.0075 (0.0016)*	[0.004, 0.010]	0.026 (0.006)***	0.018 (0.006)**	30
Loneliness, M2	-0.005 (0.001)***	-0.999 (0.083)***	0.005 (0.001)* 21%					
Multiple mediation time spent visiting green space (X) and vitality (Y) (n = 2,960)								
Physical activity during leisure time, M1	0.003 (0.000)***	2.032 (0.354)***	0.006 (0.001)* 16%	0.009 (0.002)*	[0.006, 0.012]	0.037 (0.007)***	0.028 (0.007)***	25
Loneliness, M2	-0.005 (0.001)***	-0.636 (0.099)***	0.003 (0.001)* 9%					

Note. All models were adjusted for gender, age, level of education, perceived income, employment status, household with/without children <12 years, and city; a random intercept was included to account for neighborhood clustering; Sobel test of significance of mediations ($p < .05$); unstandardized regression coefficients and standard error. CI = confidence interval.

^aThe a coefficient refers to the association between time spent visiting green space (X) and the mediator (M1, M2).

^bThe b coefficient refers to the association between the mediator (M1, M2) and the outcome (Y), adjusted for visits to green space (X).

^cThe sum of the products of a and b coefficients estimates the indirect effect or mediation via the mediators M1 and M2 simultaneously (for calculation of SE, see MacKinnon (2008)).

^dThe c coefficient refers to the total association between time spent visiting green space (X) and the outcome (Y).

^eThe c' coefficient refers to the direct association between time spent visiting green space (X) and the outcome (Y), adjusted for both mediators M1 and M2.

^fThe percentage of the multiple mediated effect is estimated by $SUMab / (SUMab + c) \times 100\%$.

* $p < .05$. ** $p < .01$. *** $p < .001$.

Discussion

Main Findings

The current study tested the hypotheses that physical activity (total and leisure time), walking during leisure time, and social cohesion and loneliness individually mediate the small associations between time spent visiting green spaces and mental health and vitality. Physical activity during leisure time and loneliness were the strongest mediators, providing evidence for the hypothesized mechanisms underlying the associations. Combining these two mediators in multiple mediation models explained about one quarter to one third of the total proportion of the overall associations. This suggests that visiting green spaces promotes physical activity, especially during leisure time, and mitigates feelings of loneliness, and that both mediators seem to play a role in the association between time spent visiting green spaces and mental health. However, the associations between time spent visiting a green space and both mental health indices were small, which suggests that a large increase in time spent visiting a green space (e.g., an extra 5 hr a day on 5 days a week that adds up to 100 hr a month) is needed for a small increase of 3 points on the mental health scale and 4 points on the vitality scale. That a large part of the association could not be explained by physical activity during leisure time and loneliness suggests that other mediators may be involved, such as mediators related to stress and mental fatigue (i.e., the restoration mechanism), environmental quality (e.g., noise), or other, yet unknown, mechanisms. More research is needed to gain insight into which other mechanisms play a role.

The finding of weak associations between time spent visiting green space and physical activity variables suggests that visits to green space only marginally contribute to total physical activity and even to physical activity during leisure time. An explanation could be that people may choose other places or possibilities for physical activity and also may not be physically active most of the time when visiting green space. Despite these weak associations, total physical activity and, to a greater extent, physical activity during leisure time were significant mediators of the associations concerning mental health and vitality. These findings are in line with those of a Dutch study that found that physical activity during leisure time combined with physical activity for transport was a weak mediator, but overall physical activity was not a mediator (de Vries et al., 2013). However, that study differs in its focus on quantity and quality of streetscape greenery. Whereas several other studies found evidence that physical activity acts as a mediator in the relationship between amount of green space and mental health (Paquet et al., 2013; Richardson et al., 2013; Sugiyama et al., 2008), the current findings provide evidence that

both physical activity during leisure time and total physical activity mediate the association between time spent on visiting green space and mental health.

In the current study, no mediation was found for walking during leisure time on the associations, although for vitality, there was a trend ($p = .057$). This seems to contradict previous findings (de Vries et al., 2013; Sugiyama et al., 2008). The null finding could be due to the smaller number of cases in the analyses due to the exclusion of respondents with zero values as a consequence of log transformation of the variables, and weaker associations with mental health (b path). Concerning the association with vitality, the significant mediation effect for walking during leisure time analyzed as a dichotomized variable supports this assumption (Table 5). This suggests that the exclusion of people with zero values possibly underestimates the mediation effect, particularly for walking for leisure time.

Another finding was that physical activity during leisure time seemed the most dominant mediator in the association with vitality, while it was a less important mediator compared with loneliness in the association with mental health. One explanation could be that vitality also measured components of physical health (Ware, 2000) and, therefore, showed stronger associations with physical activity variables (b path). Overall, the findings provide indications for the proposed underlying mechanism that suggests that people's mental health might benefit from visiting green space for active leisure time purposes, such as walking.

The findings of significant mediation by social cohesion and loneliness were also in line with previous studies that have implicated a number of indicators of social contacts as mediators of the relationship between green space and mental health (de Vries et al., 2013; Maas et al., 2009; Sugiyama et al., 2008). Maas et al. (2009) suggested that green space does not facilitate social contacts per se, but strengthens the sense of community that is comprised of feelings of trust, acceptance, and belonging. Therefore, it seems plausible that green space might also mitigate feelings of loneliness, which was a stronger mediator in the current study than social cohesion. Furthermore, the results of the multiple mediation model for mental health showed that loneliness accounted for the largest part of the combined mediation effect (Table 5), suggesting that the effect of green spaces mitigating feelings of loneliness is more important than promoting physical activity as far as mental health is concerned.

The current study found significant mediation when combining physical activity during leisure time and loneliness in one mediation model, suggesting that both mechanisms work collectively. This confirms previous findings, although those studies explained associations with perceived greenness (Sugiyama et al., 2008) and streetscape greenery quantity and quality (de Vries et al., 2013), instead of time spent visiting green space.

Strengths and Limitations

An important strength of this study is the large study population from different cities across Europe, with residents randomly selected from neighborhoods with sufficient variability in availability of green spaces and SES. Furthermore, this study has some methodological strengths compared with the previous studies that investigated mechanisms underlying health benefits of green space (de Vries et al., 2013; Maas et al., 2009; Richardson et al., 2013; Sugiyama et al., 2008). The product of coefficients approach used in the current study goes beyond the widely used causal steps approach, developed by Baron and Kenny (1986), setting no precondition on significant regression steps. Another strength of the current study is the use of a parallel multiple mediation model to collectively account for two mediators. This enhanced the power of the tests of the indirect effects (Hayes, 2009, 2013). The model hypothesized that the two mechanisms work independently, thereby excluding other more complex pathways of interrelationships as suggested by Fan et al. (2011), who found that physical activity, social support, and stress have recursive relationships between each other.

Limitations of this study are recognized. First, the Sobel test that was used in the current study to test the statistical significance of mediation has been criticized for being conservative and assuming the sampling distribution of indirect effects (ab) as normal, while it tends to be asymmetric, unless large samples are available and the indirect effects are large (Preacher & Hayes, 2008). Moreover, the Sobel test presumes that the a - and b -path coefficients are independent, which might not be the case for multilevel models as used in this study. Although several researchers have recommended bootstrapping or the Monte Carlo method (Hayes, 2009, 2013), the Sobel test was used in this study because of the high statistical power from the large study population and its transparency. Second, the measure of time spent visiting green spaces was not limited to green spaces in the neighborhood, while the social cohesion measure refers to a sense of community of living in the same neighborhood. However, time spent visiting green spaces close to home and total time spent visiting green spaces was highly correlated ($r = .8$, $p < .001$). Third, both social cohesion and loneliness are related to, but not direct measures of social contacts, which is the mechanism under investigation. Using loneliness as a potential mediator could be disputed as a fairly distal mediator, that is, conceptually close to mental health. This raises the issue of reverse causality of mental health causing loneliness (Kenny, 2014). Nevertheless, the consistent findings of the current study, as well as those of Maas et al. (2009), suggest that feelings of loneliness might provide a useful proxy for social contacts.

However, it is not clear whether this can be explained by green spaces facilitating social contacts, or, for example, by providing opportunities for feeling connected with other people and with nature more in general. Fourth, the cross-sectional nature of the data precludes causal inferences about the reported associations, and reverse causal order and directions cannot be ruled out. For example, people with a higher mental health score may be more physically active during leisure time and, thus, spend more time visiting green spaces. Fifth, all data were derived from self-report questionnaires, so same source and method bias are acknowledged. The measures used to assess time spent visiting green spaces were newly developed questionnaires that were not tested for their reliability and validity. Finally, the response rates for the four cities were relatively low, especially for the Dutch city. A nonresponse analysis revealed lower percentages of people with less education in the study population of three of the four cities than in the regional and national population data, while in one city (Stoke-on-Trent), this percentage was somewhat higher in the study sample. Therefore, the results may not be generalizable to cities with high percentages of people with less education.

Conclusion and Recommendations

The associations between time spent visiting green space and both mental health indices were weak, which suggest small mental health benefits. Nevertheless, this study provides support for the hypothesis that time spent visiting green spaces contributes indirectly to mental health and vitality through collectively mitigating feelings of loneliness and promoting physical activities during leisure time, such as walking. It is well known that physical activity and social relationships are important determinants of mental health. Preventing stress levels from becoming chronically elevated decreases the risk of developing mental disorders such as depression and anxiety (World Health Organization, 2001, 2013).

Green spaces should be designed in such way to support both physical and social activities. This study does not provide indications on which green space characteristics or personal motivational factors influence frequency and duration of visits to green space. Therefore, future research on determinants of visits to green space is needed. However, this study has revealed that, next to these indirect behavioral-related pathways, other mediators may play a role in explaining the association between visits to green spaces and mental health and vitality. Further research should investigate whether and to what extent indicators of stress and mental fatigue, and indicators of personal motivation to visit green space, such as connectedness (i.e., feeling in

community with nature; Mayer & Frantz, 2004) mediate the association between time spent on visiting green spaces and mental health. Other study designs, such as longitudinal studies and natural experiments, are needed to provide evidence for causal relationships.

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Supplemental Material

The supplemental material for this article is available online.

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