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Healthy aging in a green living environment: a systematic review of the literature

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Samenvatting

Gezond ouder worden in een groene leefomgeving: een systematische review van de literatuur

Aanleiding en doelstelling
Het aandeel ouderen in de bevolking wordt de komende decennia steeds groter. Dit zorgt voor vele uitdagingen, waaronder de vraag hoe we de leefomgeving zo kunnen inrichten dat ouderen zo lang mogelijk prettig en in goede gezondheid zelfstandig kunnen blijven wonen. Groen in de directe leefomgeving zou een positieve bijdrage kunnen leveren aan de gezondheid van ouderen. Deze studie geeft een overzicht van de literatuur naar het verband tussen een groene leefomgeving en de psychosociale status, het beweeggedrag en de gezondheid bij mensen van 60 jaar en ouder.

Aanpak
Door middel van een gestructureerde zoekstrategie is naar relevante publicaties gezocht binnen de databases PubMed, PsycInfo en EMBASE. Kenmerken van de studies en gerapporteerde associaties, alsmede de methodologische kwaliteit op een 11-puntschaal, werden samengevat door twee onafhankelijke onderzoekers.

Resultaten
In totaal zijn 16 publicaties over 11 studies geselecteerd met een methodologische kwaliteit van 5,5 tot 10,5 punten op een 11-puntsschaal. Zeven van de acht studies over beweeggedrag rapporteerden een significante positieve associatie tussen een groene leefomgeving en beweeggedrag. Ervaren (on)veiligheid lijkt hierbij de grootste barrière voor bewegen in een groene leefomgeving. Ook de studies over ervaren gezondheid (n=2), deelname aan sociale activiteiten en een fitness programma (n=1) en de studies over morbiditeit, mortaliteit en overleving (n=3) lieten een significant positieve bijdrage van groen zien. De relatie tussen een groene leefomgeving en de body mass index bleek niet significant (n=1).

Conclusies en aanbevelingen voor vervolgonderzoek
De resultaten van deze studie laten een positief verband zien tussen een groene leefomgeving en beweeggedrag, ervaren gezondheid en morbiditeit, mortaliteit en overleving bij ouderen. Verdere identificatie van barrières voor een optimaal gebruik van de groene leefomgeving door ouderen is gewenst. Op deze wijze kunnen handvatten geboden worden aan stedenbouwkundigen, beleidsmakers en gezondheidsbevorderaars ter stimulering van een actieve leefstijl bij ouderen en voor het creëren van een veilige en groene leefomgeving.

Deze publicatie is mede tot stand gekomen met financiële ondersteuning van de Ministeries van Volksgezondheid, Welzijn en Sport (VWS) en Economische Zaken, (EZ).

Summary

Healthy aging in a green living environment: a systematic review of the literature

Background and objective
The proportion of older people is increasing. Therefore, it is important to know how we can create environments conducive to their psychological and physical wellbeing; environments that support independent living until old age. A green living environment might have a beneficial effect on the health of elderly. This study provides an overview of the literature on the association between a green living environment and psychosocial status, physical activity and (perceived) health in people aged 60 years and over.

Methods
A computerized search was performed within the databases PubMed, PsychInfo, and EMBASE to identify relevant studies. Study characteristics, the reported associations and the methodological quality of the studies were summarized by two independent researchers.

Results
Finally, 16 publications based on 11 studies were selected. The methodological quality of the studies ranged from 5.0 to 10.5 points on an 11-point scale. Seven of the eight studies on physical activity reported a significant positive association between a green living environment and physical activity. Safety is the biggest concern for everyday walking of older people in a green environment, specifically the safety of traffic streets. The studies on perceived health (n=2), participation in social activities and a fitness program (n=1) and the studies on morbidity, mortality and survival (n=3) also showed significant beneficial effects of a green living environment. The relationship between a green living environment and body mass index was not significant (n=1).

Conclusions and recommendations for future research
The results of this study showed a significant positive association between a green living environment and physical activity, and between a green living environment and (perceived) health, including morbidity, mortality and survival among older adults. Further identification of barriers to the accessibility of green areas among elderly is needed. Urban planners, policy makers, and health promotion workers should take these barriers into account when creating safe and healthy living environments that support an active lifestyle.

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1 Introduction

With the increasing urbanization in the Western world, combined with spatial planning policy of densification, the number of people facing the prospect of living in residential environments with fewer green resources is rising (United Nations Population Fund, 2007; Latten, 2009). The consequences for public health are considered substantial, as increasing empirical evidence indicates that a green living environment has a beneficial effect on people's subjective and objective psychological and physiological health (Ulrich, 1991; Hartig, 1991; Hartig, 1996; De Ridder, 2003; Mitchell, 2007; Van den Berg, 2007). Recent reviews have indicated a relationship between a green environment and obesity (Papas, 2007; Feng, 2010; Kirk, 2010; Lachowycz, 2011), total physical activity (Wendel-Vos, 2007; Kacynski 2007; Lee, 2011), walking (Owen, 2004; Kaczinky, 2008), and psychosocial well-being (Bowler, Lee, Pretty 2005). However, these reviews also reported several conceptual and methodological constraints, such as heterogeneity regarding the definition of a green living environment and the type of assessment method. In addition, associations were often weak. Strong evidence for the relationship between a green environment and health has therefore not yet been brought up.

Moreover, it is still unclear what types of green environment are most effective and through which mechanisms a green living environment might lead to a beneficial effect on health. Maas (2006) introduced a conceptual model for the relationship between a green living environment and (perceived) health, and the potential working mechanisms. Three working mechanisms are suggested in the model: exposure, behavior, and selection. Firstly, living in an environment with limited 'exposure' to green space or limited access to green resources may increase the vulnerability to the impact of stressful life events on mental and physical health, as is supposed in the dynamic stress-vulnerability model (Heady and Wearing, 1989; Ormel and Neeleman, 2000). Second, the amount of green space in the living environment could stimulate physical activity and social contacts, that both can influence a variety of health-related outcomes (Berkman, 2000; Mozzafarian, 2008 ; Kawachi and Berkman, 2003). The third mechanism that might explain the relationship between a green living environment and (perceived) health is selection, as people's health also influences the chance of living in a favorable environment (Mytton, 2012). It is known that among young adults, living in good health is often associated with living in a healthy environment (Van Hooijdonk, 2007). For example, people with higher income can afford to live in a favorable environment (Verheij, 1999).

In addition to the conceptual and methodological constraints of previous studies on the effects of green space, most of the reviews that summarized them focused on either children or adults in general. Until now, no such attempt has been performed specifically for elderly, while there is an urgent need for more insight into the specific benefits of a green living environment for elderly for several reasons. Firstly, in an aging society, insight is needed in the manner in which the older generation interacts with their physical environment to know how we can create environments conducive to their psychological and physical wellbeing; environments that support independent living until old age. The elderly will become the major demographic the next decades (World Health Organization, 2006). In the Netherlands, the amount of people aged 65 years and over will rise from 2.6 to 4.6

million in the coming 25 years (Sanderse, 2011). Consequently, the amount of people with chronic diseases and the public spending related to the associated social and medical burden will also rise (Blokstra, 2010). Since a sedentary lifestyle is a key risk factor of premature morbidity and mortality of reducing physical function in the elderly (Blair, 1989; McGuire, 2001), the promotion of a healthy lifestyle of older people thus is a prime concern in the Netherlands and worldwide. Several reviews have been written on the relationship between the physical environment and physical activity, health and functioning in older adults (Cunningham & Michael, 2004; Yen, 2009; Van Cauwenberg, 2011), but no specific effects of the exposure to green spaces have been reported in these reviews. A second reason for reviewing the effects of a green living environment specifically in the elderly, is their dependency on the immediate living environment. For older people, the combination of declines in physical and cognitive functioning and a decrease of the social network could result in a smaller radius of action and a greater dependence on the immediate living environment (Borst, 2004; Forsyth, 2009). Therefore, a stronger effect of a green living environment is expected, since they likely spend more time in the immediate surroundings of their homes resulting in a higher exposure to green space. Also, people reaching retirement will have access to more leisure-time and a greater opportunity to engage in healthy or unhealthy behaviors (Evenson, 2002; Nooyens, 2005).

In this review, emphasis will be put on the effects of a green living environment on (perceived) health through recovery from stress and mental fatigue (i.e., psychosocial status) and physical activity. Accordingly, in this review, we aim to summarize the latest evidence on the association between a green living environment and psychosocial status, physical activity and (perceived) health in people aged 60 years and over. In addition, we aim to indicate what are the working mechanisms behind these associations and to show in what subgroups effects are most pronounced.

2 Methods

2.1 Search strategy and data sources

Studies published from January 2000 to September 2012 were identified through a structured computerized search of PubMed, PsychInfo, and EMBASE. The following search terms were used: ((Green AND ((environment OR space OR border OR neighborhood OR area OR city OR cities) OR (park OR garden)) AND ((Psychosocial OR Stress OR Depression OR Mental fatigue) OR (Behavior OR behavior OR Physical activity OR Exercise OR behav* OR Walking OR Cycling OR bicycle OR Fitness OR Fit OR Hiking) OR (Health OR Quality of life OR well-being). In addition to these terms, related and most recent thesaurus terms of the search engines were added. No limitations for age or study design were added. Based on the title, the search results were checked for relevance and duplicates.

2.2 Selection of studies

Based on the title and the abstract, further study selection was performed. Studies had to examine the association between a green living environment and physical activity, psychosocial status and/or (perceived) health. A green living environment was defined as either green space in general, a park, forest, garden or walking trail near the residence of people. Studies on healing environments, such as hospital gardens, or studies solely focusing on playgrounds were not included. Studies had to be conducted in a sample aged over 60 years or – if a sample with a broader age range was studied with a mean age of at least 60 years. Studies conducted in adult samples were included only if results on the association were reported specifically for a subsample aged 60 years or older, or with a mean age of at least 60 years. Further, studies were included if published in a peer reviewed scientific journal and published in English.

In addition, grey literature from January 2000 to September 2012 was identified through the Educational Resources Information Centre (ERIC), the Dutch database ‘Grey Literature in the Netherlands’ (GLIN), and the National Institute for Public Health and Environment (RIVM), and Netherlands Environment Assessment Agency (in Dutch: Planbureau voor de Leefomgeving) using the search term ‘green’. Grey literature formed a contextual background for the interpretation of the topic and results. Data from grey literature was not further extracted.

2.3 Data extraction

Based on the full-texts of the studies, data was extracted by two independent researchers (i.e., KB and SIdV). In case of disagreement, this was discussed until consensus was reached. Detailed information was extracted from studies that met the aforementioned inclusion criteria. The following study characteristics were extracted: design of the study, aim of the study, size and source of the study sample, country in which the study was performed, age range and/or mean age of the sample, socio-economic status of the sample, type of green living environment, type of outcomes, measurement instruments of green living environment and outcomes, and effects per outcome. If available, additional working mechanisms or results per subgroup (e.g., according to gender) were extracted.

2.4 Methodological quality

Methodological quality (0-11) was assessed by two independent researchers (i.e., KB and SIdV) based on the full-text publications of the studies. The scoring list contained 5 items that indicated internal validity (i.e., reported validity and reliability of measurement instruments of the green living environment and outcomes, and report of statistical analytical procedure) and 6 items that indicated external validity (i.e., representativeness of the study sample, specification of the age range of the study sample, specification of in- and exclusion criteria, response rate or specification of non-response, specification of the study period, and specification of the sample characteristics). Items were derived from scoring lists of Prins et al. (2002) and De Vries et al. (2006). Each item was scored with 'present' (1), 'partly present' (0.5), or 'absent' (0). A total score was computed by summing all unweighted scores. Each study was then assigned a methodological quality rating: high if 8.5 points or more were assigned, moderate if 5.5 – 8.0 points were assigned, and low if 5.0 or less points were assigned. In case of disagreement, this was discussed until consensus was reached.

3 Results

3.1 Selection of studies

The initial cross-database search in PubMed, PsychInfo, and EMBASE resulted in 1470 publications. After eliminating duplicates, 1344 publications remained. Titles and abstracts were reviewed for eligibility criteria, except for the age restrictions, resulting in 201 publications that were fully considered. Based on the full-texts, 12 of them were based on studies conducted in a sample aged over 60 years, with a mean age of at least 60 years, or in an adult sample with subgroup analyses for a subsample aged 60 years or older, or with a mean age of at least 60 years. A backward search of the reference lists of these publications yielded another four publications. Thus, 16 publications were finally included.

3.2 Study characteristics

The 16 included publications were based on 11 studies, since some publications were based on the same study sample. This was true for the three publications of Maas and colleagues, in which the study sample and the investigated independent variable (green space) were similar, but the outcomes were different, i.e., perceived health, physical activity, and morbidity (Maas 2006; 2008; 2009). Further, studies of Li et al. (2005), Nagel et al. (2008) and Fisher et al. (2004) were based on samples recruited from 56 neighborhoods in Portland. In addition, Li et al. (2008) used a larger but comparable sample from 120 neighborhoods in Portland. In these four studies, effects of different independent variables on neighborhood walking were studied: total green/open spaces, distance to a park, and facilities for walking. In addition to the effects on neighborhood walking, Li et al. (2008) also studied the relationship between green/open spaces and body weight/height and physical activity. Lastly, two studies recruited participants from the same neighborhoods in Bogóta and examined the relationship between park density and active park use and walking patterns respectively (Parra, 2010; Gomez, 2010).

The study characteristics of the 11 studies are presented in Table 1. The majority of the studies was conducted in the United States. All studies had a cross-sectional study design and were either surveys (nine studies) or cohort studies (two studies). Sample sizes ranged from 422 to 88,540 participants. Participants were mainly recruited from the general population, with the exception of two studies that contained samples recruited from clinical centers (Michael, 2010) and from a multi-center osteoarthritis trial (White, 2010) respectively. The last-mentioned sample contained participants that were functionally disabled. Study samples all contained participants of 60 or 65 years and older, except for one cohort study that contained birth cohorts of participants of over at least 84 years of age (Takano, 2002).

With the exception of four studies that assessed the green living environment with self-reported measures (Takano, 2002; Booth, 2000; Corseuil, 2011; White, 2010), all other studies used geographical data to define green space. A green living environment mostly entailed parks or ‘green areas’ within a one eight of a mile to three kilometer radius of the participant’s home address. Some studies also included playgrounds, gardens, and recreational facilities in their analyses. With regard to the outcome measures, eight of the 11 studies reported on the association

between a green living environment and physical activity, three studies focused on morbidity, mortality or survival, one study on perceived health, and two studies reported on other outcomes (body mass index (BMI) and disability in daily activities). All studies on physical activity, perceived health, and disability in daily activities used self-reported measures. Studies on morbidity, mortality, survival, and BMI used objective data retrieved from governmental and/or medical records.

Table 1: Study characteristics and effects

Study Country	Study population (age range/mean age)	Study type	Green space (unit) [measurement]	Outcome (unit) [measurement]	Results[1]	Meth quality
PHYSICAL ACTIVITY						
Booth, 2000 Australia	449 randomly selected people (60+) from population survey monitor	Survey	Access to parks (yes/no) [self-report]	Physical activity (% active/inactive, active=expending >800 kcals/kg/week) [self-report]	Having access to a park was significantly associated with physical activity (χ^2 p>0.05).	6.5
Corseuil, 2011 Brazil	1705 non-institutionalized people (60+) recruited from the general population	Survey	Green areas (good-regular-poor-absent) [NEWS[2]] Parks, athletic courts (yes-no) [NEWS]	Commuting physical activity (inactive-low-active-active) [IPAQ[3]]	Green areas and commuting physical activity are not associated (χ^2 p<0.05). The absence of parks/athletic courts is associated with lower levels of commuting physical activity (OR=1.75; 95% CI= 1.22 to 2.51).	7.0
Fisher, 2004 United States	582 residents (65+) randomly sampled from 56 neighborhoods in Portland	Survey	Facilities for walking (trails, paths, parks) [www.parks.ci.portaldn.or.us) Social cohesion [self-report]	Neighborhood walking activity score [self-report]	Neighborhoods having more facilities for walking (trails, paths, parks; range=-0.003 to 0.03) per acre were associated with higher levels of neighborhood walking activity (range=3 to 15; (unstandardized coefficient =16.930, p<0.001). Neighborhood social cohesion (range=5 to 25) was significantly associated with increased levels of neighborhood physical activity (range=3 to 15; unstandardized coefficient=0.034, p<0.05).	6.0
Gomez, 2010 Colombia	1966 people (60+) randomly sampled from 50 neighborhoods in Bogóta	Survey	Park density (total area of public parks/total area* 100%) [GIS[4]]	Walking pattern (% walking ≥60/≥150 min/week) [short IPAQ]	Those who resided in areas within the middle tertile of public park density were more likely to walk for at least 60 minutes than those who lived in areas within the lowest tertile (POR 1.42; 95% CI 1.02 to 1.98).	5.0

Hanibuchi, 2011 Japan	9414 randomly sampled functionally independent people (65+) from 15 municipalities in Japan	Survey	Accessibility to recreational facilities (presence of parks, green spaces and schools) [GIS]	Leisure-time sports activities (frequency) Total walking time/day [self-report]	No association was seen between the presence of parks or green spaces and total walking time. The presence of parks or green spaces showed a consistent association with sports activity at 250m (OR=1.258; 95% CI=1.082- to 1.463), 500m (OR=1.152; 95%CI=1.021 to 1.300) and 1000m radius (OR=1.162; 95% CI=1.056 to 1.280). The association was mostly pronounced among male respondents, in Southern municipalities and among people who had resided ≥50 years in the municipality.	6.0
Li, 2005 United States	577 residents (65+) randomly sampled from 56 neighborhoods in Portland	Survey	Total green and open spaces for recreation within 0.5 mile radius from residence (acres)[GIS]	Neighborhood walking [self-report]	Total green and open spaces in acres (range=0 to 209.10) was significantly related to neighborhood walking (range=3 to 15; unstandardized β =-0.056; 95% CI=-0.103 to -0.009). Relationship between total green and open spaces and neighborhood walking within 0.5 mile radius was moderated by perceptions of safety from traffic (range=1 to 5) and the number of street connections (range=138 to 1020; unstandardized β =0.019; 95% CI=0.007 to 0.032). No significant moderation was observed for proximity of physical activity facilities (1-5) and areas of green and open space (range=3 to 15; unstandardized β=-0.022; 95% CI=-0.060 to 0.016).	8.5

Li, 2008 United States	1221 residents (mean age=62) from 120 neighborhoods in Portland	Survey	Green and open spaces (total acreage for recreation, including public parks and playgrounds) [GIS]	Neighborhood walking (>=150 min/day versus <150 min/day) Walking for transportation and household errands (>=30 min/day versus <30 min/day) Meeting recommendation of >=30 min/day moderate physical activity for at least 5 days/wk, or vigorous physical activity of >=20 min/day for at least 3 days/wk (yes/no) [Behavioral Risk Factor Surveillance System]	Positive association between green and open spaces and meeting the recommendations for physical activity (β=0.062; 95% CI=1.031 to 1.098) and neighborhood walking (β=0.111; 95% CI=1.010 to 1.238)).	5.0
Maas, 2008 The Netherlands	886 people (65+) randomly sampled from GP registers	Survey	Green space (urban green, agricultural green, forest and nature conservation areas) within 1 and 3 km radius (%) [$LGN4_5$]	Physical activity (total number of minutes of walking, cycling, sport activities and gardening per week, whether people spent time on different activities for 30 minutes on at least 5 days/wk) [$SQUASH_6$]	Negative relationship between green space and whether people walk during leisure-time, as well as the relationship between cycling for commuting purposes and the relationship between gardening and physical activity.[a]	7.5
Michael, 2010 United States	422 community-dwelling men (65+) from 6 US clinical centers	Survey	Availability of proximate parks, trails and recreational facilities [GIS]	Walking activity (minutes/day) [Physical activity Scale for the Elderly]	Positive association between living within one eighth mile of parks and one half mile of trails and maintaining or increasing time spent walking, limited to men living in high-SES neighborhoods: (RR=1.22; 95% CI=1.01 to 1.47) and (RR=1.34; 95% CI=1.16 to 1.55).	6.5
Nagel, 2008 United States	546 residents (65+) randomly sampled from 56 neighborhoods in Portland	Survey	Distance to nearest park (feet) [GIS]	Walking time (weekly walking time) [YALE physical activity scale]	A greater distance from the participants' homes to the nearest park was associated with decreased brisk walking time (adjusted β=0.02; p<0.05). Neighborhood safety was not significantly associated with walking time.	6.5

Parra, 2010 Colombia	1966 people (60+) randomly selected from Bogóta	Survey	Park density (park area/land area) [GIS]	Perceived active park use (never—rarely-sometimes-frequently-very frequently) [self-report]	Higher park density was positively associated with perceived active park use. Older adults residing in areas with the second and third tertile of park density have almost three times the odds of reporting active park use as compared to those living in areas with the lowest density (OR=2.78; 95% CI=1.72 to 4.48, OR=2.98; 95% CI=1.80 to 4.93, and p trend<.001).	6.0
MORBIDITY, MORTALITY AND SURVIVAL						
Maas, 2009 The Netherlands	44178 people (65+) randomly sampled from GP registers*	Survey	Green space (urban green, agricultural green, forest and nature conservation areas) within 1 and 3 km radius (%) [LGN4]	Morbidity (prevalence of disease clusters) [electronic medical records]	Lower prevalence rate for 15 of the 24 disease clusters in living environments with a higher percentage of green space.[a]	9.5
Takano, 2002 Japan	3144 residents born in 1903, 1908, 1913 or 1918 recruited from Tokyo metropolitan area registration records	Cohort study	Space nearby for taking a stroll Parks and tree-lined streets nearby Garden [self-report, interview]	Five-year survival [residence records of local government]	Five-year survival percentages were greater with a space to take a stroll (p<0.01), or parks and tree-lined streets nearby (p<0.05). Walkable green streets and spaces nearby is a significant predictor of five-year survival (OR=1.13; 95% CI=1.03 to 1.24), adjusted for age, marital status, attitude towards one's own community and living expenses. After excluding the influence of baseline functional status, a significant association between walkable green streets and spaces nearby and five-year survival remains (OR=1.14; 95% CI=1.03 to 1.25).	5.5
Villeneuve, 2012 Canada	88540 randomly sampled people (65+) from 10 urban areas and who completed tax returns	Cohort	Exposure to green per 30m grid cell and for 500m buffer around home address [Satellite retrievals]	22-year mortality [mortality database]	Reductions in non-accidental mortality for those who lived in areas with more green space (HR=0.97; 95% CI:0.96 to 0.98).[a]	8.0

PERCEIVED HEALTH						
Maas, 2006 The Netherlands	44178 people (65+) randomly sampled from GP registers	Survey	Green space (urban green, agricultural green, forest and nature conservation areas) within 1 and 3 km radius (%) [LGN4]	Perceived health (very good-good versus neither good nor poor-poor-very poor)[self-report]	Perceived health benefits significantly from green space within 1 and 3 km radius in all urban areas (β=0.004, SE=0.001; β=0.005, SE=0.001). In very strongly urban areas, this relation is stronger for green space within a 1 km radius, compared to within a 3 km radius (β=0.006, SE=0.002; β=0.004 ,SE=0.002).[a]	5.0
Maas, 2008 The Netherlands	886 people (65+) randomly sampled from GP registers	Survey	Green space (urban green, agricultural green, forest and nature conservation areas) within 1 and 3 km radius (%) [LGN4]	Perceived health (excellent-very good-good versus moderate-bad)[self-report] Physical activity (total number of minutes of walking, cycling, sport activities and gardening per week, whether people spent time on different activities for 30 minutes on at least 5 days/wk) [SQUASH]	No association was found between the amount of green space in the living environment within 1 and 3 km radius and whether or not people spent time on different activities for 30 minutes on at least 5 days/wk (β=-0.0004, SE=0.002; β=-0.0001, SE=0.002). The amount of physical activity undertaken in a greener living environment does not explain the relationship between green spaces and health.[a]	7.5
OTHER OUTCOMES						
Li, 2008 United States	1221 residents (mean age=62) from 120 neighborhoods in Portland	Survey	Green and open spaces (total acreage for recreation, including public parks and playgrounds) [GIS]	Body weight and height (BMI)	No relationship between green and open spaces and BMI.	5.0

White, 2009 United States	436 people (65+) with functional limitations from the Multicenter Osteoarthritis Study	Survey	Parks and walking areas [Home and Community Environment survey]	Disability in daily activities (0-100) [Late-Life Disability Instrument]	If neighborhoods did not have parks and walking areas, people less frequently engaged in a regular fitness program (OR=0.4; 95%CI=0.2 to 0.7) and in social activities (OR=0.5; 95%CI=0.3 to 1.0). If adequate handicap parking: 1.5-1.8 higher odds of engagement in social and work role activities. If presence of public transportation: 1.5-2.9 higher odds of not feeling limited in social, leisure and work role activities, and instrumental activities of daily living.	10.5

POR=Population Odds Ratio; OR=Odds Ratio; HR=Hazard Ratio; RR=Relative Risk; SE=Standard Error; UC=unstandardized coefficient; BMI=body mass index; 1) Including results for specific characteristics of green spaces (e.g., proximity), for specific subgroups (e.g., females), or for specific working mechanisms (e.g., perceived safety); 2) Neighborhood Environmental Walkability Scale; 3) International Physical Activity Questionnaire; 4) Geographic Information System; 5) National Land Cover Classification database; 6) Short Questionnaire to ASsess Health-enhancing physical activity; a) Derived from a larger study sample and analysed as a subgroup.

Table 2: Methodological quality of the included studies

	Booth, 2000	Corseuil, 2011	Fisher, 2004	Gomez, 2010	Hanibuchi, 2011	Li, 2008	Li, 2005	Maas, 2009	Maas, 2008	Maas, 2006	Michael, 2010	Nagel, 2008	Parra, 2010	Takano, 2002	Villeneuve, 2012	White, 2010
Internal validity																
Independent variable(s): Reported validity of instrument	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Independent variable(s): Reported reliability of instrument	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1
Dependent variable(s): Reported validity of instrument	0	0	1	0	1	0	1	1	1	1	0	1	0	0	1	1
Dependent variable(s): Reported reliability of instrument	0	0	1	0	0	0	1	0	1	0	0	0	1	0	1	1
Complete report of statistical analysis	0.5	1	1	0.5	0.5	0.5	1	1	0.5	0.5	1	0.5	0.5	0.5	0.5	1
Internal validity score (0-5)	**0.5**	**1**	**3**	**0.5**	**1.5**	**0.5**	**4**	**4**	**2.5**	**1.5**	**1**	**1.5**	**1.5**	**0.5**	**2.5**	**5**
External validity																
Representativeness of study sample	1	1	1	1	1	1	1	0.5	0.5	0.5	0.5	1	1	0.5	0.5	0.5
Specification of age range	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Specification of in- & exclusion criteria	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
Response rate>70% or specification non-response	1	1	0	0	0	0	0	1	1	1	1	0	0	1	1	1
Specification of study period	1	1	0	0.5	0.5	0.5	0.5	1	0.5	0	1	1	0.5	1	1	1
Specification of sample characteristics	1	1	1	1	1	1	1	1	1	0	1	1	1	0.5	1	1
External validity score (0-6)	**6.0**	**6.0**	**3.0**	**4.5**	**4.5**	**4.5**	**4.5**	**5.5**	**5.0**	**3.5**	**5.5**	**5.0**	**4.5**	**5.0**	**5.5**	**5.5**
Methodological quality score (0-11)	**6.5**	**7.0**	**6.0**	**5.0**	**6.0**	**5.0**	**8.5**	**9.5**	**7.5**	**5.0**	**6.5**	**6.5**	**6.0**	**5.5**	**8.0**	**10.5**

3.3 Methodological quality

Based on what was reported in the publications, the methodological quality of the studies ranged from 5.0 to 10.5 points on an 11-point scale (see Table 1 and 2). Thirteen studies met at least 50% of the quality criteria and thus were of moderate to high quality. Three of the 16 publications (19%) were assigned at least 8.5 points (indicating that 77% of the quality criteria were met) and thus had a high methodological quality (Maas 2009; Li 2005; White 2009).

Regarding the internal validity of the studies, scores ranged from 0.5 to 5.0 points on a 5-point scale. The majority of the items regarding the internal validity were scored negative (i.e., 0 points). In few publications, the validity and reliability of the methods to assess the green living environment and the outcomes were reported. It must be acknowledged that, in contrast to the measurement of the outcomes, assessments of the green living environment were mainly based on geographical data, instead of on self-report. Nearly all publications provided a complete report of the statistical analyses. However, four publications failed to report what software package was used, and therefore received a lower score (i.e., 0.5 points).

Regarding the external validity, studies were assigned 3.0 to 6.0 points on a 6-points scale. All studies reported adequate information on the study characteristics, the in- and exclusion criteria, and the age range of the study sample. Nearly all studies scored high on representativeness. However, publications that presented the results of post-hoc subgroup analyses based on a subsample within a larger sample (Maas 2006; 2008; 2009; Villeneuve, 2012) received fewer points. Also, samples with only men (Michael, 2010), participants with functional disabilities (White, 2010) or participants aged over 84 years (Takano, 2002) were scored as less representative and received fewer points.

3.4 Effects of a green living environment

The results of the 11 studies on the association between a green living environment and physical activity, morbidity, mortality or survival, (perceived) health, BMI, and disability in daily activities are listed per study in Table 1. Seven out of the eight studies on physical activity showed a significant positive association between a green living environment and physical activity. One of these studies had a high methodological quality (Li, 2005). Positive associations were most pronounced for neighborhood walking. The study of Maas et al. (2008) was the only study that found no positive association between green space and walking, cycling, sport activities, and gardening. Further, three studies reported mixed results. Hanibuchi et al. (2011) found a positive association between a green living environment and sport activities, but no association with neighborhood walking. Further, Li et al. (2008) found a positive association between green areas and neighborhood walking and between green areas and total physical activity, but failed to show this for commuting physical activity. Corseuil et al. (2011) showed a significant association between the absence of parks and athletic courts and commuting physical activity, but failed to show this for the relation between green areas and physical activity for transportation and household errands.
As is shown in Table 1, all three studies on morbidity, mortality and survival showed significant beneficial effects of a green living environment: prevalence rates of

different disease clusters decreased, 22-year mortality reduced and 5-year survival increased when people lived in environments with higher percentages of green space. One of the three studies was of high methodological quality (Maas, 2009). Out of the studies regarding perceived health, Maas et al. (2006) showed that perceived health significantly improved when living close to green space (within 1 or 3 kilometer from the participant's home address). Further, Li et al. (2008) showed no significant association between green and open spaces and BMI. Lastly, based on a study with a methodological quality of 10.5 out of 11 points, White et al. (2009) concluded that the absence of a park nearby the participant's home address was significantly associated with less social activities and lower engagement in a regular fitness program.

3.5 Working mechanisms

Three out of the 11 studies investigated the role of potential working mechanisms behind the association between a green living environment and physical activity (Li, 2005; White 2009) or perceived health (Maas, 2008). Li and colleagues (2005) showed moderation of the relationship between total green and open spaces and neighborhood walking by perceptions of safety and the number of street connections. According to their results, the proximity of physical activity facilities and green areas was no moderator. In contrast to the conceptual model introduced by Maas she could not confirm the role of physical activity as a working mechanism behind a green living environment and perceived health in an experimental study (2008). Further, White et al. (2009) found higher odds of engagement in activities among functionally disabled people if adequate handicap parking places were available nearby parks. In the same study, the presence of public transportation nearby parks also resulted in higher odds of people not feeling limited to engage in activities.

3.6 Subgroups

Four out of the 11 studies reported the effects of a green living environment for specific subgroups. Firstly, Hanibuchi et al. (2011) showed that the positive association between a green living environment and sport activities was most pronounced among men, among people who lived in a municipality for over 50 years, and in Southern municipalities. Further, Michael et al. (2010) found that the positive association between living nearby parks or trails and neighborhood walking specifically accounted for men in neighborhoods with a high socio-economic status. In contrast, Fisher et al. (2004) showed that neighborhoods having greater proportions of low-income households and higher proportions of white residents were associated with higher levels of neighborhood walking. Lastly, Maas et al. (2006) found that the association between green space within a radius of 1 kilometer of the participant's home address and perceived health was more pronounced in areas with very strong urbanity, in contrast to non-urban areas or areas with slight to strong urbanity.

4 Discussion

In this study the latest evidence on the health effects of living in a green environment for elderly was summarized. The results of this systematic review suggest a significant positive association between a green living environment and physical activity, and between a green living environment and (perceived) health, including morbidity, mortality, and survival in people aged 60 years and over. No studies were found on the psychosocial consequences of living nearby green spaces among this age group.

The results of this review are mainly in accordance with those of reviews that focused on adults (e.g., Lee, 2011; Kaczynski, 2007; 2008; Lachowycz, 2011). However, in contrast to the results reported in adults, the beneficial effects of green spaces in elderly are more often significant and are more consistent. This supports our hypothesis that the beneficial effects of a green living environment are larger in the elderly compared to in adults, due to their greater dependence on the immediate living environment and therefore their higher exposure to green space. It is not surprising that the consistent beneficial effects of a green living environment in the elderly also account for children and/or adolescents, as they may be more likely to be influenced by their environment as well (Roemmich, 2006; Ding, 2011).

From the conceptual model of Maas (2009), recovery from stress and mental fatigue (i.e., exposure), behavior (e.g., physical activity), and selection are suggested as potential working mechanisms underneath the association between a green living environment and (perceived) health in adults. In this review, we aimed to summarize the evidence on the specific role of recovery from stress and mental fatigue (i.e., psychosocial status) and physical activity in the model. Although considerable evidence was found for the benefits of a green living environment on physical activity as well as on (perceived) health, Maas et al. (2008) reported no evidence for physical activity as an underlying mechanism for this relationship. One study in our review showed that the perception of safety is a potential mechanism underneath the pathway between green environment and behavior among elderly (Li, 2005). This is in line with a qualitative study of Michael (2006) that revealed that among older people, safety is the biggest concern for everyday walking in a green environment, specifically the safety of traffic streets. Results from that study also indicated that older people often relocate to neighborhoods where they previously lived because of the walkability. Thus, selection might also be a working mechanism behind the relationship between green space and heath for elderly. Although studies of Nagel (2008) and Fisher (2004) have not analyzed neighborhood safety as a moderator of the association between green spaces and neighborhood walking, they showed no significant association between neighborhood safety and walking. Moreover, based on the significant association between social cohesion and neighborhood walking, Fisher et al. (2004) suggest that social cohesion might be a working mechanism. Furthermore, other studies showed that - besides merely the exposure to green areas - the distance to green areas, the presence of walking facilities in parks, the park density, and the accessibility to parks significantly stimulate physical activity in older people (Nagel, 2008; Fisher, 2004; Parra, 210; Gomez, 2010; Booth, 2010; Hanibuchi, 2011). Also, the number of street connections (Li, 2005), adequate handicap parking places and the presence of public transportation nearby parks were associated with more

engagement in activities in a sample of functionally disabled seniors (White, 2009). Based on our findings, a new conceptual model for elderly is illustrated in Figure 1.

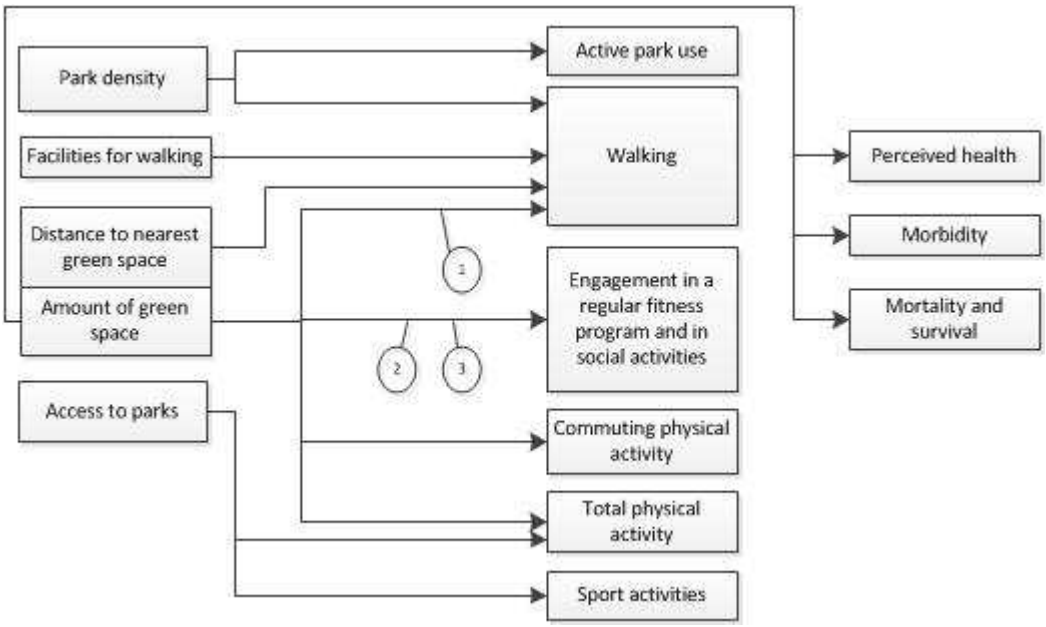

Figure 1: Conceptual model of the association between a green living environment and (perceived) health in the elderly: adjusted from Maas (2009) based on evidence from this review

Arrows represent a significant positive association; circles 1-3 represent moderators of the association: 1) Perceptions of safety and number of street connections, 2) Adequate handicap parking places, 3) Presence of public transportation

When comparing our model for elderly to the model for adults presented by Maas (2009) and when comparing the evidence on the effect of green space on adults' and children's health (Kaczynski and Henderson, 2007; Roemmich, 2006; Cohen, 2006), the barriers related to green areas seem to be more important in the elderly. Evidence from this review indicates that older people may benefit from a nearby green environment *if they feel safe in that environment*. This is confirmed by recently published evidence from Van Cauwenberg and colleagues (2012), who found that feelings of unsafety were negatively associated with walking and cycling in the elderly. Accordingly, merely the presence of a nearby green area might be insufficient, and additional effort should be put in removing safety barriers. Also, increasing social cohesion poses additional challenges for both urban planners and local governments. From a qualitative evaluation of the perception of the environment by older people and influences on walking for transportation, Van Cauwenberg (2012) concluded that access to places for social interaction and places that evoke feelings of safety and familiarity is needed to promote walking for transportation in the elderly. This can be realized by e.g. offering incentives for neighbors to collaboratively undertake activities such as planting trees of keeping public gardens. Research to convincingly identify these barriers as well as other underlying working mechanisms is encouraged. Furthermore, in a society with an increasing trend of densification and a decrease of green areas, urban planners are challenged to reassure the accessibility of green areas.

Strengths and limitations

There are several limitations of this review that should be kept in mind when interpreting the results. Firstly, all studies were cross-sectional, which prevents us to draw conclusions about the causality from the observed associations. Overall, the methodological quality of the studies was reasonable. However, the internal validity of the studies was not always completely reported. For example, studies in which physical activity was assessed used self-reported measures, of which most were not reported to be previously validated. As a result, there is a level of uncertainty about the actual effects of a green living environment on physical activity, since an association between a low internal validity and effect size is plausible (Van Tulder, 2009). Also, similar to what was reported in previous reviews on the effects of green areas, there is a considerable variability in operational definitions and measurements of a green environment. The use of a methodological quality sum-score has drawbacks; it conceals variations in methods and methodological shortcomings, since a positive score on one criterion might compensate a negative score on the other. On the other hand, by linking the sum-scores to the results of the included studies, we were able to add value to the evidence. Although the majority of the studies met at least 50% of the quality criteria, just three studies that showed significant beneficial effects of a green living environment scored 8.5 points or more on their methodological quality. As a result, the conclusion of this review should be drawn with some caution.

Nevertheless, this review is the first to provide a comprehensive overview of the benefits of a green living environment in an understudied and relevant population: the elderly. The comprehensive cross-database search strategy improved the likelihood of identifying all relevant studies. The presented evidence for a beneficial effect of a green living environment in the elderly is robust, as it accounts for the majority of the studies and studies were conducted in a variety of countries.

5 Conclusion

It can be concluded that there is a significant positive association between a green living environment and physical activity, and between a green living environment and (perceived) health, including morbidity, mortality and survival in people aged 60 years and over. Perceived unsafety seems to be the biggest concern for everyday walking of older people in a green environment. Researchers are encouraged to identify barriers to the accessibility of green areas among elderly. Urban planners, policy makers, and health promotion workers should take these barriers into account when creating safe and healthy living environments that support an active lifestyle.

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