Mental health benefits of green spaces

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Chapter 2

Health Benefits of Green Spaces in the Living Environment: A Systematic Review of Epidemiological Studies

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ABSTRACT

Objectives

The objective was to systematically review the literature examining the relationship between quantity and quality of green spaces in the living environment and three health outcomes: perceived general health, perceived mental health, and (all-cause) mortality.

Methods

An online search was followed by a selection process applying eligibility criteria. Three levels of evidence were defined based on the number and quality of the studies, and the consistency of the findings. Fourteen studies on perceived general health, 19 on mental health and seven on all-cause mortality were included in the review.

Results

The evidence synthesis showed strong evidence for significant positive associations between the quantity of green space (objectively measured around the residence) and perceived mental health and all-cause mortality, and moderate evidence for an association with perceived general health. There were insufficient studies on the quality of green spaces to conduct an evidence synthesis. A few studies provided indications that associations depend on subgroups such as gender, age groups and groups with different social economic status, but the findings were mixed.

Conclusions

Further research should focus on exploring relationships between more detailed characteristics of green space and more specific health outcomes in different population subgroups and in different countries. To strengthen the evidence-base, studies with more sophisticated designs, e.g. “natural experiments”, are needed.

INTRODUCTION

In the past two decades, conviction has gained ground that in order to be effective in promoting health and healthy behaviour, public health interventions have to address not only individual characteristics but also the physical and social environment (Brug, et al., 2006; Egger and Swinburn, 1997; Macintyre et al., 2002). The WHO has advocated this socio-ecological approach, recognizing the large worldwide increase of people living in urban environments, and stated that healthy cities offer "a physical and built environment that encourages, enables and supports health, recreation and well-being [..] (WHO Europe, 2009). In recent years, a large body of research has focused on the health effects of the built environment, including the direct physical impacts of, for example, environmental pollution and the indirect effects on social safety and physical activity (Barton, 2009; Ding and Gebel, 2012; Frumkin H, 2003).

The physical or built environment is often described in terms of a "man-made environment". Cities and urban areas are made up of buildings and "grey spaces" (e.g. open space between buildings such as hard infrastructure), and of "green spaces": open spaces with natural elements such as parks, playgrounds and recreation areas (Swanwick et al., 2003). Availability of these green spaces, providing opportunities for outdoor physical activities, social contacts and relaxation, might be an important environmental determinant of the health of urban residents. In the past decade, a growing number of reviews have shown relationships between green spaces and several determinants of health, such as physical activity, overweight or obesity, and stress (Bowler et al., 2010; Croucher et al., 2007; Di Nardo et al., 2012; Health Council of the Netherlands and Dutch Advisory Council for Research on Spatial Planning, 2004; Lachowycz and Jones, 2011; Lee and Maheswaran, 2011). However, what is lacking is a systematic review that focuses on the direct evidence for the relation between green space and health outcomes, such as perceived general health , perceived mental health, and mortality. In the past decade, the number of studies investigating these direct relationships has increased rapidly. Furthermore, it is important to know for whom and under what conditions green spaces in the living environment may contribute to health. Some researchers have hypothesized that people who spend more time in the vicinity of their home (children, youth, elderly and housewives), may benefit more from green space in their living environment (de Vries et al., 2003; Maas et al., 2006). Other researchers have explored whether social economic status influences the relationship between green spaces and health (Mitchell and Popham, 2007; Mitchell and Popham, 2008).

This paper presents the results of the first systematic review of epidemiological studies that have examined relationships between green spaces in the living environment and health. It contributes to a more robust evidence base for public health professionals and urban planners, and identifies knowledge gaps. The objectives of this review were to: (i) conduct a systematic literature search on studies investigating the relationships between the quantity and quality of green spaces in the living environment (both objectively and subjectively measured), and perceived general and mental health, and all-cause mortality; (ii) assess the methodological

quality of the studies; (iii) synthesize the results of the selected studies to assess the strength of the evidence for these relationships; (iv) assess whether the results differ for population subgroups.

METHODS

Search strategy and eligibility

Online literature searches were conducted in MEDLINE, PubMed (non-Medline), EMBASE, PsycINFO, and Web of Science, combining the following keywords: 'health' with 'natural environment', 'natural space', 'natural infrastructure', 'greenspace' and 'greenery'; and additionally 'health' with combinations of 'green', 'greener', 'greening' and 'greenness with 'environment', 'space', ' infrastructure', 'city/cities', 'area', and 'neigbo(u)rhood'. No language and date restrictions were applied. Additional manual searching was done by scanning reference lists of articles. The literature search was developed and conducted by a search specialist and completed in October 2014.

In order to be included in the review, a study had to meet the following criteria: (i) the study had to be observational with either a cross-sectional or longitudinal design; (ii) the study had to use an objective or subjective (i.e. self-reported or perceived) measure for quantity or quality of green space in the living or home environment (the home environment was defined as the geographical area surrounding the place of residence); (iii) the green space measure was included in the analysis for the relationship with a health outcome measure as a separate variable (not as a variable in a composite environmental score); (iv) the outcome measure of the study had to be one of the following health measures: perceived general health, perceived mental health or mortality due to all (or non-accidental) causes (both types of mortality rates are assumed to be comparable); (v) study participants had to be a sample of the *adult* population of non-institutionalized people who might be exposed to green space in their daily living environment at or close to their home; studies conducted in specific settings such as work or school environments and hospital or nursing settings were excluded; (vi) studies that measured the same health outcome and green space measures had to use an independent (not overlapping) sample if the same study population was investigated; (vii) only original or primary studies published in English in peer-reviewed journals were included; editorials, reviews, dissertations and conference abstracts were excluded from the review.

Selection of studies

All articles which were identified through the search process were blinded and were screened for potential relevance based on the title and abstract by two independent reviewers (MB and

JM). Disagreements were discussed and resolved. After this initial screening step, full text articles were assessed independently by two reviewers (MB and WW) and studies were excluded with specific reference to the eligibility criteria. Disagreements were resolved by consulting a third reviewer (JM). The PRISMA flow diagram was used to summarize the selection process (Liberati et al., 2009).

Data extraction

The first reviewer (MB) extracted data from the included studies, and a second reviewer (JM) checked these data. The following data were described in the data-extraction sheets separately for each type of outcome: the study design, country and setting or scale (country-level, city, neighbourhood), study population (age range and response rate), green space and health outcome measures used in the statistical analyses, and main findings (significance of statistical associations after adjustment for potential confounders; effect estimates – highest value if multiple categories of green space levels exist – with confidence intervals or other measures of association such as regression parameters with standard error and p-values; statistical models used).

Quality assessment

A quality assessment of all included studies was conducted using a methodological quality criteria list. This list was adapted from two existing lists developed for the quality assessment of observational studies (Ariëns et al., 2000; National Institute for Health and Clinical Excellence, 2006). The list included nine criteria: four referring to the study population, one to the validity and reliability of the outcome measures, and four to the statistical analyses and adjustment for confounding (see Supplementary Table 5). A criterion was rated as 'positive' if it was met, 'negative' if the criterion was not met, 'not reported' (NR) if no or not enough information was available to reach either a positive or negative conclusion, 'not applicable' (NA) if the criterion could not be applied (criterion D was only applicable to studies with a longitudinal design). An overall quality score was calculated by adding up the positive scores. This sum score was presented as a percentage of the total items that were applicable. Studies were rated as high quality (HQ) if they had 100 percent positive scores; studies with 75 to 100 percent positive scores were rated as medium quality (MQ), and studies with less than 75 percent positive scores as low quality (LQ). The methods measuring the quantity or quality of green space were not incorporated in the quality assessment of the individual studies. Since there is currently limited knowledge about the reliability and validity of these measures, they are described separately without a quality assessment.

Two reviewers (MB and HK) scored all studies independently. The results were discussed and disagreements were solved. If the reviewers could not agree, a third reviewer (MP) was consulted to decide.

Level of scientific evidence

A meta-analytical approach was not applicable because of the heterogeneity of the green space measures. Therefore, a "best evidence synthesis" was used for synthesizing the strength of the evidence evidence (Ariëns et al., 2000; Singh et al., 2012; Wendel-Vos et al., 2007). This method combines a systematic search process with a detailed critical analysis of study characteristics and a qualitative synthesis of the evidence. In this review, three levels of evidence were defined to draw conclusions on the relationship between the quantity or quality of green space in the living environment and general health. Each level takes into account the number and methodological quality of the studies, and the consistency of findings as follows:

1. strong evidence: consistent findings in multiple ($\geq$ 3) high-quality studies;
2. moderate evidence: consistent findings in at least one high-quality study and two or more medium-quality studies;
3. inconclusive evidence: consistent findings in multiple ($\geq$ 3) medium-quality studies or inconsistent findings in multiple ($\geq$ 3) studies.

Studies of low-quality were excluded from the evidence synthesis. The evidence from high-quality studies is assumed to be strong if studies meet all the quality criteria; hence, the risk of bias will be low. Consistency was defined if more than 50% of the studies have significant findings in the expected direction (in this review, for example, more green space or higher quality of green space is associated with better health or lower mortality) (Wendel-Vos et al., 2007). An evidence synthesis was conducted for studies that examined associations in general (adult) population samples. Studies that explored associations for specific subgroups were not included in the evidence synthesis but were described separately.

The heterogeneity between studies with regard to different measures for quantity and quality of green spaces complicates the combining of the results to assess the evidence level. The following aggregation step was applied to partly overcome this heterogeneity. Studies that used the following two types of objective measures of the *quantity* of green spaces were combined: (i) the percentage of green space within a certain distance or radius around the residence; and (ii) the percentage of green space in a certain geographically defined area. It is assumed that the differences between these measures and the methods used to assess them only marginally influence the results. Studies that used other objective and subjective measures of quantity and quality of green space were kept separately because an earlier study had shown a lack of agreement between self-reported or perceived measures and objective measures of quantity of green space (Leslie et al., 2010). It is not known whether the same holds true for objective and subjective measures of the *quality* of green space.

RESULTS

Study selection

Figure 2.1 shows the flow diagram of the selection of studies. After removing duplicate records, 5160 articles remained. Out of these 5160 articles, 5072 were excluded, mostly because they did not investigate the relationship between green space and one of the three selected health outcomes, or were "not reporting an original or primary study". In the next selection step, the full texts of the remaining 85 articles were retrieved for a detailed assessment of eligibility. Another 51 articles were excluded in this step (see flow chart, Figure 2.1). A total of 34 articles were included, of which 19 focused on perceived general health; 21 on perceived mental health and seven studies on all-cause mortality (some articles described two health outcomes). In the last step, studies that used overlapping but smaller, samples of the same study population and the same measures of green spaces were excluded: two studies on perceived mental health, and five studies on perceived general health (de Vries et al., 2013; Maas et al., 2008; Mitchell et al., 2011; van den Berg et al., 2010). From Maas et al. (2009), only the study on mental health was included. Björk et al. (2008) and de Jong et al. (2012) investigated the same study population but used samples from different years. Three other – longitudinal – studies with overlapping samples were all included because they used different time frames and methods to pool and analyse the cohort data (Alcock et al., 2014; Astell-Burt et al., 2014; White et al., 2013). Finally, 40 studies described in 32 articles were included in the systematic review (14 studies on perceived general health, 19 on mental health and seven on all-cause mortality).

Description of selected studies

Table 2.1 shows an overview of the number of included studies by type of health outcome and study country. Supplementary Table S2.1 to S2.3 provide more detailed descriptions of the characteristics of these studies. More than half of the fourteen studies that examined the relationship with perceived general health, were conducted in the Netherlands and UK (Table 2.1). All studies on perceived general health used samples from the general population (adults, and in some cases also including youth) and were cross-sectional in their design. The Netherlands, UK and Australia conducted almost 75 percent of the nineteen studies that examined the relationship with perceived mental health

(Table 2.1). Fifteen of the nineteen studies used a cross-sectional, and four a longitudinal design (Alcock et al., 2014; Annerstedt et al., 2012; Astell-Burt et al., 2014; White et al., 2013). All seven included studies on all-cause mortality were conducted in non-European countries (Table 2.1). The Canadian study used a slightly different measure of all-cause mortality, i.e. mortality due to all non-accidental causes. All these studies were cross-sectional in their design, except that used a longitudinal design (Villeneuve et al., 2012).

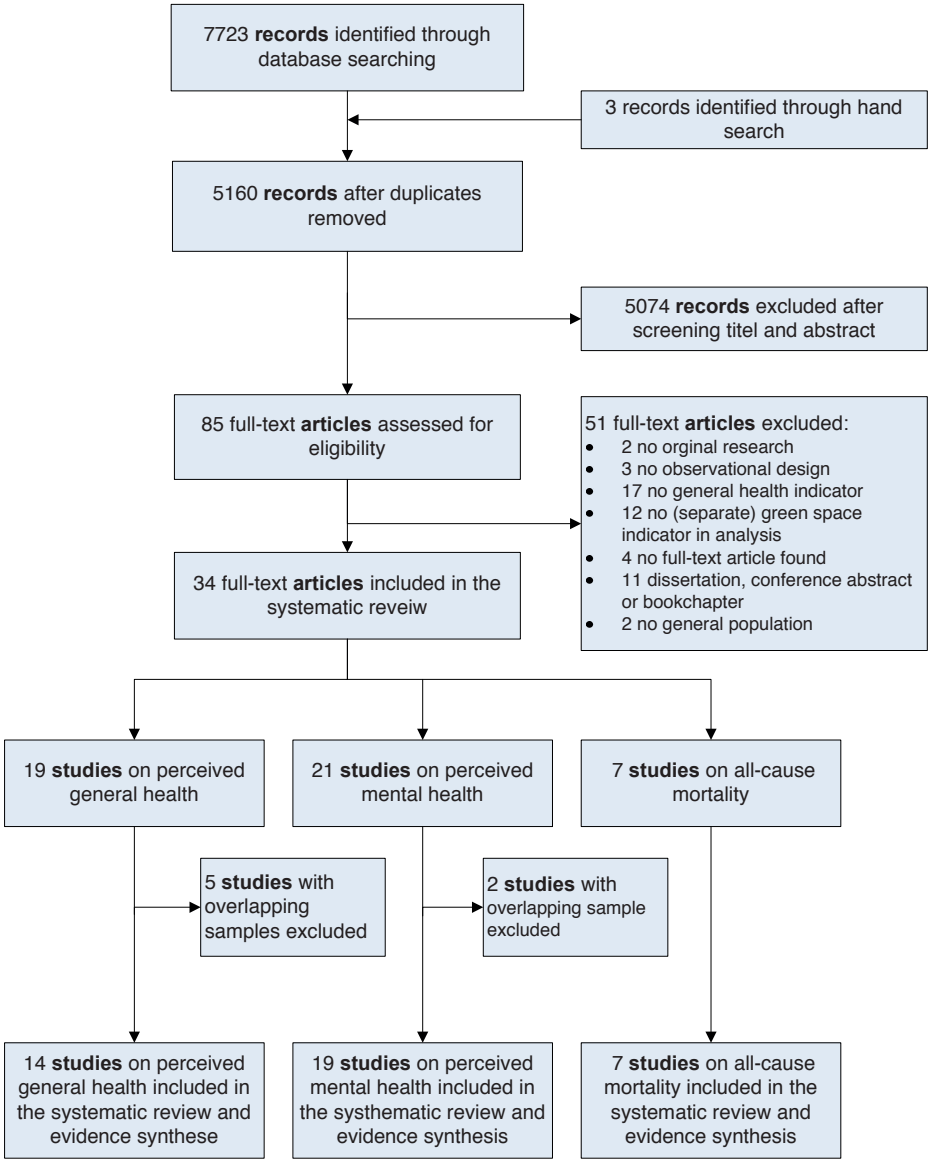

Figure 2.1: Flow diagram of the literature search.

Measures of quantity and quality of green space

Almost 60 percent of the selected studies used objective measures of the *quantity* of green space. Four studies performed in the Netherlands objectively assessed the quantity of green space through measuring the percentage of green space within a certain distance or radius (500 m, 1 km, 3 km, 1 to 3 km) around the residence (de Vries et al., 2003; Maas et al., 2009;

Table 2.1: Summary of the included studies

	Number of studies	References
Perceived general health (n = 14)		
Netherlands	5	Agyemang et al., 2007; de Vries et al., 2003; Maas et al., 2006; van Dillen et al., 2011; Putrik et al. 2014
UK	3	Dunstan et al., 2013; Mitchell and Popham, 2007; Richardson and Mitchell, 2010
Belgium	1	van Herzele and de Vries, 2011
Sweden	2	Björk et al., 2008; de Jong et al., 2012
Lithuania	1	Reklaitiene et al. 2014
Australia	1	Carter and Horwitz, 2014
New Zealand	1	Richardson et al, 2013
Percieved mental health (n = 19)		
Netherlands	4	de Vries et al., 2003; Maas et al., 2009; Putrik et al., 2014; van Dillen et al., 2011
UK	5	Alcock et al., 2014; Astell-Burt et al., 2014; Guite et al., 2006; Ward-Thompson et al., 2012; White et al., 2013
Sweden	1	Annerstedt et al., 2012
Lithuania	1	Reklaitiene et al., 2014
Australia	5	Astell-Burt et al., 2013; Carter and Horwitz, 2014; Chong et al., 2013; Paquet et al. 2013; Sugiyama et al., 2008
New Zealand	1	Richardson et al., 2013
USA	2	Beyer et al., 2014; Sturm and Cohen, 2014
All-cause mortality (n = 7)		
UK	2	Mitchell and Popham, 2008; Mitchell et al., 2011
USA	2	Coutts et al., 2010; Richardson et al., 2012
Canada	1	Villeneuve et al., 2012
Japan	2	Takano et al., 2002a,b

Maas et al., 2006; van Dillen et al., 2011). In these studies, the dominant land use type was determined for each 25 x 25 metre grid cell as input in a geographical information system (GIS). Small patches of greenery and private gardens were not included. One study determined the dominant land use type in small geographical units and used GIS to assess the percentage of green space ('parkland') to a buffer of 1 km around the participant's residence (Astell-Burt et al., 2013). Ten studies estimated the percentage of green space for a geographically defined small area (e.g. neighbourhood, Census tract, CAS-ward, Lower level Super Output Area) using a combination of detailed maps and land classification databases (Alcock et al., 2014; Astell-Burt et al., 2014; Chong et al., 2013; Mitchell and Popham, 2007; Mitchell and Popham, 2008; Mitchell et al., 2011; Richardson et al., 2013; Takano et al., 2002a,b; Ward-Thompson et al., 2012; White et al., 2013). In two studies, the green coverage information for small areas was aggregated to estimate a green space percentage at a larger geographically level: the city level (Richardson et al., 2012) and the county level (Coutts et al., 2010). Three studies used satellite remote sensing data to estimate the Normalized Difference Vegetation Index (NDVI) and

assigned this at respectively a 500 m buffer around the residence (Villeneuve et al., 2012), a 1000 m network distance from the respondent's home (Paquet et al., 2013) and averaged for small-scale areas (Beyer et al., 2014). The latter also measured tree canopy coverage.

Other green space measures used were: the distance to the nearest green space (Reklaitiene et al., 2014) or to certain types of green spaces such as parks (Carter and Horwitz, 2014; Sturm and Cohen, 2014); presence or number of different recreational or "green qualities" within a certain distance (either Euclidian or walking) (Annerstedt et al., 2012; Björk et al., 2008; de Jong et al., 2012); the presence of a (private) garden (de Vries et al., 2003). Three studies used field observations of visible green elements in streets to characterise the streetscape greenness of neighbourhoods (Dunstan et al., 2013; van Dillen et al., 2011; van Herzele and de Vries, 2011). One study used a subjective measure of quantity of green space by asking the respondents to assess the "greenness" of their neighbourhood (Sugiyama et al., 2008).

Only five studies focused on *quality* of green space (see Supplementary Tables S2.1 to S2.3). One study used an audit by trained assessors to obtain an objective measure of green areas and streetscape greenery collecting information on quality indicators such as absence of litter, accessibility and colourfulness (van Dillen et al., 2011). In three studies respondents were asked to rate their satisfaction with the quality (and availability) of green space in the neighbourhood (Agyemang et al., 2007; Guite et al., 2006; Putrik et al., 2014). One study assessed quality by asking respondents to rate two green space quality aspects: useability and retention (Carter and Horwitz, 2014).

Methodological quality

The percentage of agreement on the scores for assessing the overall quality of the articles between the two reviewers was 70 percent. Supplementary Table S2.4 presents the final scores per criterion, the number of negative and positive scores, the number of positive scores as a percentage of the total applicable criteria, and the overall ratings.

All articles had a 50 percent or more criteria scored; thus, sufficient information was presented in the articles to rate the methodological quality of the described studies. The overall methodological quality was rated as high for 14 selected articles, as medium for 14 selected articles and as low for four articles. The following four low-quality-rated articles did not meet the criteria on the use of appropriate statistical methods, adjustment for confounding and representativeness for the study population: Carter and Horwitz, 2014; Takano et al., 2002a; Ward-Thompson et al., 2012 and van Herzele and de Vries, 2011. Consequently they were excluded from the evidence synthesis.

Perceived general health

Associations with quantity of green space

Table 2.2 shows five studies that examined the association between the percentage of green space within a certain distance or buffer around a residence or within a small area and perceived general health (see Supplementary Table S2.1): two high-quality studies (de Vries et al., 2003; Maas et al., 2006) and two medium-quality studies (Mitchell and Popham, 2007; van Dillen et al., 2011) reported a positive association; one medium-quality study did not find a significant association (Richardson et al., 2013). The consistent findings of two high-quality studies and two medium-quality studies and only one showing no association provide moderate evidence for a positive association between the percentage of green space in a small area or around a residence and perceived general health in a general population sample.

Four studies used other objective measures of the quantity of green space and were not included in the evidence synthesis (see Table 2.2). Only one found a significant association. This medium-quality study found a significant association with the self-reported presence of recreational green qualities (de Jong et al., 2012). A high-quality study reported that people who had a garden did not feel significantly healthier (de Vries et al., 2003). Two medium-quality studies did not find a significant association with, respectively, the objectively assessed presence of natural elements in neighbourhoods (Dunstan et al., 2013) and the number of 'recreational values' within 300 metres of the residence (Björk et al., 2008).

Associations with quality of green space

The findings of three medium-quality studies consistently showed a positive association between quality of green space and perceived general health (Table 2.2) (Agyemang et al., 2007; Putrik et al., 2014; van Dillen et al., 2011). Two studies showed that the group of people that was more dissatisfied with the quality of the green spaces in their neighbourhood had respectively 64% (Agyemang et al., 2007) and 6 percent % (Putrik et al., 2014) higher odds of reporting poor perceived general health, compared to the group that was less dissatisfied. Another study demonstrated that the objective quality of green space as well as that of the streetscape greenery was positively associated with perceived general health (van Dillen et al., 2011).However, because of the lack of a high-quality study, the evidence is still inconclusive.

Associations for subgroups

Several studies have paid special attention to subgroups of the population (see Table 2.2). These studies conducted subgroup analyses for the association with quantity of green space only. Three studies investigated whether the association depends on the degree of urbanity and the type of population groups (de Vries et al., 2003; Maas et al., 2006; Mitchell and Popham, 2007). One study showed that the association was only significant for people living in moderate urban and nonurban areas (de Vries et al., 2003). The same three studies found that

the associations differed for population subgroups with different level of education or social economic status. De Vries et al.(2003) and Maas et al. (2006) found that people with a low level of education tend to benefit more from green space in their living environment as opposed to people with a high level of education. Mitchell et al. (2007) reported that in their stratified analyses the association depended on the combination of the degree of urbanity and level of income deprivation: a significant association was found in high- and low-income urban areas and low-income rural areas, but not in higher-income suburban areas and higher-income rural areas. In the lower income suburban areas, more green space tended to be associated with even 'higher risk of not good' health (Mitchell and Popham, 2007), although not significantly. The results of studies on other subgroups were less consistent. De Vries et al. (2003) found no differences in associations for children, elderly and housewives, while Maas et al. (2006) found stronger associations for youth and elderly living in the most urbanized areas (within a 1-km buffer) (Maas et al., 2006). One study examined gender differences and found no association for men, and for women the 'rate of reporting not good perceived general health' was even marginally higher in greener wards (Richardson and Mitchell, 2010). Another study found that female park users only had higher odds of poor general health if they lived more than 300 metres but less than 1000 metres away, compared to male and female park users living closer than 300 metres from the nearest green space (no significant association was found for male and female park users living more than 1000 metres away) (Reklaitiene et al., 2014).

Perceived mental health

Associations with quantity of green space

Table 2.3 shows seven studies reporting a significant positive association between quantity of green space in a buffer around the residence or in a small area and perceived mental health: five of them were judged as high-quality (Beyer et al., 2014; de Vries et al., 2003; Maas et al., 2009; Paquet et al., 2013; White et al., 2013), and two as medium-quality (Richardson et al., 2013; van Dillen et al., 2011). One study used a longitudinal design and found that the same individuals had lower mental distress when living in urban areas with a higher percentage of green space (with and without gardens) than when living in urban areas with a lower percentage of green space (White et al., 2013). Only one high-quality study failed to find a significant association (Chong et al., 2013). The green space measure in this study was limited to state forests and national parks, excluding urban green spaces. Therefore, based on five high-quality studies with significant findings and one high-quality with null findings, it is concluded that there is strong evidence for a positive relationship between the quantity of green space in a small area or around the residence and perceived mental health.

Three studies used other green space quantity measures and, therefore, not included in the evidence synthesis (see Table 2.3). One medium-quality study did not find a significant association (Annerstedt et al., 2012). A medium-quality study found that living further away

Table 2.2: Overview of findings and overall quality scores of the selected studies on perceived general health by type of green space measure (HQ = high quality; MQ = medium quality; low quality studies were excluded from the review).

Green space quantity or quality measure	Studies with significant ($p < 0.05$) findings in the expected[a] direction in general populations		Studies with null findings in general populations		Studies with significant findings for subgroups[b]	
	No. of studies	Ref.	No. of studies	Ref.	No of studies	Ref.
Amount of green space around residence (circular buffer)	2 HQ	Maas et al., 2006; de Vries et al., 2003			1 HQ	de Vries et al., 2003 (*only lower educated, moderate/nonurban)*
	1 MQ	van Dillen et al., 2011;			1 HQ	Maas et al., 2006[c]
Amount of green space in small area/ neighbourhood	1 MQ	Mitchell & Popham, 2007	1 MQ	Richardson et al., 2013	2 MQ	Mitchell & Popham, 2007 *(only marginally for women in the opposite direction)* Richardson & Mitchell, 2010[c]
Presence/ number of green spaces within distance or small area	1 MQ	de Jong et al., 2012	1 MQ	Bjørk et al., 2008		
			1 MQ	Dunstan et al., 2013		
Having a garden			1 HQ	de Vries et al., 2003		
Distance to nearest green space (objective or self-reported)					1 MQ	Reklaitiene et al., 2014 *(female park users living close to park)*
Quality of green areas/ streetscape (objective or self-reported)	1 MQ	van Dillen et al., 2011				
Satisfaction with green space quality	2 MQ	Ayemang et al., 2007; Putrik, 2014				

[a] For this systematic review, the "expected" direction corresponded to more green spaces, higher amount of green space, smaller distance to green space, higher perceived greenness, higher quality of green space, higher satisfaction with green space being associated with higher (odds of) mental health. No studies were found with significant interactions in the direction opposite of that expected.

[b] Subgroup analyses were based on age, gender, education level, work status, income deprivation, urbanity and park use or certain combinations e.g. urbanity and income deprivation or gender and park use (see Supplementary Table S2.1)

[c] Findings of subgroup analyses were all significant only differing in strength of the associations.

(but closer than 1.6 km) from a specific park was associated with lower mental health (Sturm et al, 2014). Another medium-quality study used a subjective measure of the quantity of green space and found that the group of people that perceived their living environment as being highly green had 60 percent higher odds for better mental health, compared with the group that perceived it as not very green (Sugiyama et al., 2008).

Associations with quality of green space

Three medium-quality studies investigated the relationship with objective and subjective measures of quality of green space (see Table 2.3). Although the findings these studies are consistent, the evidence is inconclusive because of the lack of a high-quality study. One medium-quality found no significant positive association between mental health and the objectively assessed quality of the green areas, but did find a significant positive association between mental health and the quality of streetscape greenery (van Dillen et al., 2011). The other two studies reported that higher satisfaction with green space in the residence area was significantly associated with lower odds of psychological distress (Putrik et al., 2014) or higher odds of not being in the lowest quartile of mental health (Guite et al., 2006).

Associations for subgroups

There are indications from three high-quality studies and two medium-quality studies that gender, age and level of physical activity of people moderate the associations between quantity of green space and perceived mental health, but the evidence is inconclusive (significant and non-significant findings; see Table 2.3). Two cross-sectional studies reported the same results for subgroups with regard to perceived mental health as to general health: significant positive associations only for lower educated groups (de Vries et al., 2003) and for female park users living close to a park (Reklaitiene et al., 2014). Further, people who had a garden reported better mental health only when they lived in very strong urban environments (de Vries et al., 2003). Another cross-sectional study found in their population sample of 45 years and older a significant interaction with how physically active people were (Astell-Burt et al., 2013). For the most active group, living in the greenest neighbourhood was associated with an 18 percent lower odds of being highly mentally distressed, while for the least active group there was no significant association.

Furthermore, a longitudinal study exploring gender differences across the life course found that the percentage of green space within wards was associated with better mental health among men but not among women (Astell-Burt et al., 2014). Analyses of interactions with age showed gender-specific trajectories across the life course: among women aged 41 and above, mental health increased through older age only when they lived in wards with moderate green space (Astell-Burt et al., 2014). Another longitudinal study followed the mental health change over a 5-year time frame for subgroups of movers. It showed significant improvement in mental health in the three years post-move (compared to two years post-move) for people who

Table 2.3: Overview of findings and quality scores of the selected studies on perceived mental health by type of green space measure, including quality scores (HQ = high quality; MQ = medium quality; low quality studies were excluded from the review; all studies cross-sectional except those indicated with lo = longitudinal design).

	Studies with significant ($p \leq 0.05$) findings in the expected[a] direction in general populations		Studies with null findings In general populations		Studies with significant findings for subgroups[b]	
Green space quantity or quality measure	No. of studies	Ref. (study design)	No. of studies	Ref	No of studies	Ref.
Amount of green space around residence in circular buffer	3 HQ	Maas et al., 2009; Packet et al., 2013; *(lo);* de Vries et al., 2003			1 HQ	Alcock et al., 2014 *(lo: only movers to more green space)* Astell-Burt et al., 2014
	1 MQ	van Dillen, 2011			1 MQ	*(lo:men early adulthood through middle age; women only middle age through old age)*
					2 HQ	de Vries et al., 2003 *(lower educated)* Astell-Burt et al., 2013
Amount of green space in small area/ neighbourhood	2 HQ	Beyer et al., 2014; White et al., 2013	1HQ	Chong et al., 2013		*(middle/old-aged and only most physically active)*
	1 MQ	Richardson, 2013				
Presence/ number of green spaces within distance			1 MQ	Annerstedt et al., 2012 *(lo)*	1 MQ	Annerstedt et al., 2012 *(lo:physically active women)*
Having a garden					1 HQ	de Vries et al., 2003 *(high urban)*
Distance to nearest green space (objective or self-reported)	1 MQ	Sturm & Cohen, 2014			1 MQ	Reklaitiene et al., 2014 (female park users living close to park)
Perceived greenness	1 MQ	Sugyjama et al., 2008				
Amount of streetscape greenery	1 MQ	van Dillen et al., 2011				
Quality of green areas/streetscape(objective or self-reported)	1 MQ	van Dillen et al., 2011				
Satisfaction with green space quality	2 MQ	Putrik et al., 2014 Guite et al., 2006				

[a] For this systematic review, the "expected" direction corresponded to more green spaces, higher amount of green space, smaller distance to green space, higher perceived greenness, higher quality of green space, higher satisfaction with green space being associated with higher/odds of mental health. No studies were found with significant interactions in the direction opposite of that expected.

[b] Subgroup analyses were based on age, gender, education level, work status, urbanity, level of physical activity and park use or certain combinations e.g. gender and level of physical activity or gender and park use (see Supplementary Table S2.2).

moved to greener areas, while for people who moved to less green areas no significant change in mental health was found (Alcock et al., 2014). A third longitudinal study that explored gender differences found no significant association for men, while for women who had access to two recreation qualities, only those who were physically active had 70 to 80 percent lower odds for poor mental health at follow-up (Annerstedt et al., 2012).

Mortality due to all causes

Associations with quantity of green space

Five high-quality studies examined the association between the objectively assessed quantity of green space around the residence and all-cause mortality (see Table 2.4). Four studies found that population groups living in areas with more green space had a lower mortality rate, compared to groups living in areas with less green space (Mitchell and Popham et al.,2008; Mitchell et al. 2011; Villeneuve et al., 2012; Coutts et al.; 2010). One high-quality study contradicts the findings reported above. This study performed by Richardson et al. (2012) in 49 cities in the USA showed that the greenest city had 133 more male deaths and 94 more female deaths per 100,000 residents compared to the least green city. Contrary to the other studies, the quantity of green space in this study was measured on the small-scale Census tracts and then summed on the much larger scale of whole cities. Based on the findings of five high-quality studies of which only one with conflicting results (association pointing in the opposite direction), it is concluded that there is strong evidence for a negative association between the amount of green space around the residence and all-cause mortality. The quantity of green space was measured in these studies as percentage green coverage based on land use data, but also as an NDVI based on remote sensing data.

Associations for subgroups

One high-quality study found that the quantity of green space in the living environment affected most strongly the mortality rates for population groups that were most deprived (Mitchell and Popham, 2008). Another study explored the association between a subjective measure of the quantity of green space and mortality for a specific age group. This medium-quality study examined the five-year survival rate of a cohort of elderly living in a highly urbanized area of Tokyo (Takano, et al., 2002b). The study showed a significant association with the self-reported amount of “walkable” green streets and spaces near the residence measured at the start of the study. The group of older people who perceived their neighbourhood as greener and easier to walk in had a 13 percent higher odds for survival compared to the group that perceived it as less green and less easier to walk in. None of the found studies investigated the relation with quality of green space.

Table 2.4: Overview of findings and overall quality scores of the selected studies on all-cause mortality by type of green space measure, including quality scores (HQ = high quality; MQ = medium quality; low quality studies were excluded from the review; all studies cross-sectional except those indicated with lo = longitudinal design).

Green space quantity or quality measure	Studies with significant ($p < 0.1$) findings in the expected[a] direction in general populations		Studies with significant findings ($p \leq 0.05$) in the direction opposite of expected[a]		Studies with null findings		Studies with significant findings for subgroups	
	No. of studies	Ref.	No. of studies	Ref.	No. of studies	Ref.	No. of studies	Ref.
Amount of green space in circular buffer	1 HQ	Villeneuve et al., 2012 *(lo)*	1 HQ	Richardson et al., 2012			1 HQ	Mitchell and Popham, 2008 *(stronger for more deprived groups)*
Amount of green space in small area/ neighbourhood	3 HQ	Coutts et al., 2012 Mitchell and Popham, 2008 Mitchell et al., 2011						
Distance to nearest green space (objective or self-reported)					1 HQ	Coutts et al., 2012		
Perceived greenness							1MQ	Takano et al, 2002b *(elderly)*

[a] For this systematic review, the "expected" direction corresponded to more green spaces, higher amount of green space, smaller distance to green space being associated with lower mortality rate.

DISCUSSION

Principal findings: evidence for associations

The aims of this review were: to systematically search for and select studies on the associations between the quantity and quality of green spaces and perceived general health, mental health, and all-cause mortality; to assess the methodological quality; if possible, to conduct an evidence synthesis for each health outcome; and to identify different results for subgroups . The search revealed more than 5000 records, from which 34 articles were selected for inclusion in the review. Nineteen articles (53 percent) were published in the past two years, underlining the rapid growth of epidemiological studies in this relatively young field of research. The 34 articles describe 14 studies on perceived general health, 19 on perceived mental health and seven on all-cause mortality. Only five articles described studies on the relationships with objective or perceived quality of green space.

The evidence synthesis showed there is strong evidence for an association between the *quantity* of green space in people's living environment and perceived mental health and mortality due to all causes in general adult populations. This suggests that adults who live in green neighbourhoods report better mental health and have a lower risk of dying than adults who live in less green neighbourhoods. Additionally, the systematic review showed that there is moderate evidence for an association between perceived general health and the *quantity* of green space objectively measured as the percentage of green space within a small geographically defined area or buffer around the residence. The number of studies that focused on other measures of quantity of green space (presence or number of green spaces) was too small to conduct separate evidence syntheses. Concerning the *quality* of green spaces, only three medium-quality studies on perceived general health and another three on perceived mental health and no studies on all-cause mortality were identified. Although the findings consistently showed significant positive associations, this review could not provide convincing evidence due to the lack of high-quality studies.

Specific subgroups

Another aim of the review was to examine whether the associations differ depending on the type of population subgroups. Some researchers have hypothesized that people who spend more time in the vicinity of their home (children, youth, elderly and housewives) may benefit more from green space in their living environment (de Vries et al., 2003; Maas et al., 2006). However, their studies showed conflicting findings. Some other studies showed a dependency of the association on the level of income deprivation or educational level: people with lower social economic status seem to benefit more from green space in the living environment than people with high social economic status (de Vries et al., 2003; Maas et al., 2006; Mitchell and

Popham, 2007). Additionally, the review identified one study that found that the association between the quantity of green space and all-cause mortality differed for gender: men seem to benefit more from green space in their living environment than women (Richardson and Mitchell, 2010). Richardson et al. (2010) argue that men and women perceive and use green space in different ways, where women's use of green space is more influenced by the quality and perceived social safety of green spaces than men's use. Findings from other studies support this hypothesis (Astell-Burt et al., 2014; Maas et al., 2009). Furthermore, there are some indications that associations seem to vary across life course (Astell-Burt et al., 2014) and that the level of physical activity moderates the associations (Annerstedt et al., 2012; Astell-Burt et al., 2013). It is well known that physical activity patterns differ between men and women and across the life course (Koeneman et al., 2011), which could also explain the gender-specific variations in associations with green space across the life course. The review did not identify studies that analysed the associations for different ethnic minority groups. In most studies these groups were underrepresented as a result of selective non-response.

Strengths and limitations of this review

This review is the first in this relatively young field of epidemiological research that meets the criteria of a systematic transparent selection method of studies and evidence synthesis. The review has several strengths. Firstly, the restriction in the search strategy to articles published in peer-reviewed journals ensured a selection of articles of relatively better quality. Secondly, a pilot search was conducted to develop a coherent set of keywords and a search strategy that would limit the number of retrieved records without compromising coverage. Only two potentially relevant studies were found through manual searching. This indicates that the database search was comprehensive. A limitation of the review is that the possibility of publication bias cannot be ruled out: it is generally known that articles presenting positive findings are more likely to be published (Egger and Swinburn, 1997). Another limitation is that to enable an evidence synthesis, two types of green space quantity measures were combined. When more studies become available, it will be possible to investigate whether relationships with health outcomes differ for different green space quantity measures. Furthermore, because formal guidelines to judge the quality of observational studies are lacking, the chosen criteria and the cut-off points might seem a bit arbitrary. For instance, in calculating the overall quality ratings, all criteria were assumed to be equally important and no distinction was made for different study designs, while for example experimental studies might provide more convincing evidence. To make sure that the quality assessment was conservative, the cut-off points used in the review were very strict: 100 percent of the scored criteria had to be scored positively for a study to be ranked as high quality. For future systematic reviews on observational studies specific guidelines the development of specific guidelines is recommended.

Knowledge gaps and implications for future research

Most of the selected studies used a cross-sectional design. In cross-sectional studies the temporal relationship between exposure and outcome cannot be established and, therefore, it is not possible to draw conclusions on the causality of the relationships. Another weakness of the cross-sectional design is that selection bias cannot be excluded as a consequence of residual confounding. Most studies adjusted their models for socio-economic and demographic factors that may confound the results. However, the choice of these factors varied, especially in the mortality studies, and there is no consensus on which set of factors is required. Furthermore, the results may be influenced by selective migration, since healthy people chose to live in greener environments. However, longitudinal studies on health-related migration in the Netherlands suggest that direct selection cannot be held responsible for geographical differences that remain if socio-economic and demographic factors are taken into account. People who moved from the countryside to the city were as healthy as people who moved from the city to the countryside (van Lenthe, Martikainen and Mackenbach, 2007; Verheij, Van de Mheen, de Bakker, Groenewegen and Mackenbach, 1998). More observational studies with a longitudinal design are needed that analyse whether changes in the quantity or quality of green space are associated with changes in health outcomes, adjusting for other variables that influence health outcomes such as lifestyle and air quality. However, even observational longitudinal studies cannot control for all potential confounding and selection processes. Thus, causality can still not be assumed. Well-controlled interventions or quasi-experimental studies ("natural experiments") are needed to provide evidence for the causality of the relationships and to rule out selection effects. For instance, an intervention with before and after measurement in case of improvement of neighbourhood's green spaces could be set up. Or a study could focus on selecting groups of people who move to new neighbourhoods with different green space levels. A time-series approach could address trajectories over time, before and after changes in green space exposure, and explore adaption processes.

Although the review revealed a lack of studies on perceived general health, future research should not only focus on general health outcomes, but also on mediating factors. There are indications from several studies that exposure to green space can stimulate recovery from stress and mental fatigue (Hartig, Mitchell, de Vries and Frumkin, 2014; Health Council of the Netherlands and Dutch Advisory Council for Research on Spatial Planning, 2004) , encourage physical activity (Bowler, Buyung-Ali, Knight and Pullin, 2010; Hunter, Christian, Veitch, Astell-Burt, Hipp and Schipperijn, 2015) and facilitate social contacts (Maas, van Dillen, Verheij and Groenewegen, 2009). Thus, further epidemiological research on green space and health should focus on investigating relationships between quantity and quality of green space and level of stress, mental fatigue, physical activity and social contacts. This may provide stronger clues for the mechanisms which can explain the beneficial effects of green spaces.

The review revealed an important knowledge gap regarding the relationship between quality of green space and health. Almost all of the identified studies focused on the quantity of green space in the living environment using a variety of objective green space measures. Van Dillen et al. (2012) examined quality and quantity separately, but also in combination. Their results suggest that both quantity and quality of green space, especially from streetscape greenery, may be important factors regarding health benefits (van Dillen et al. 2012).

With respect to the currently used quantity measures, it should be noted that they usually do not contain information on small natural elements such as street trees and domestic gardens. The finding that people's general mental health seems to benefit from streetscape greenery is interesting, because it suggests that people do not only benefit from green spaces by visiting them, but also through viewing them from their home (van Dillen et al., 2012). With the development of satellite image methods with higher spatial resolution, this small-scale greenness can also be measured, which could provide more detailed information about exposure of greenery of gardens and streets around the house. Detailed audits could capture those quantitative and qualitative characteristics of green spaces that are closely related to the different ways people use them or are exposed to them. In conclusion, sophisticated measures of both quantity and quality of green space should be developed to provide more insight into exposure-effect relationships.

The review revealed that research on this topic was conducted in a limited number of highly developed countries, mainly North-West European countries, Australia and the United States. One study in this review, a mortality study conducted in the United States, showed an even higher risk of dying for people living in greener cities (Richardson et al., 2012). Another study conducted in New Zealand, not included in this review, found no association between the quantity of green space and cardiovascular mortality (Richardson, Pearce, Mitchell, Day and Kingham, 2010) The authors argued that their findings were specific for their country: in the US, urban sprawl and greater car-dependency may lead to unhealthy environmental conditions and lifestyles that cancel out the health benefits of green space and even lead to an inverse relationship with green space; in New Zealand, green space is much more abundant and there is less social and spatial variation in its availability than in other countries. This could explain why no associations were found. To investigate whether the conclusions from this review can be generalized to countries with different urban and land use planning and different lifestyles, it is important to conduct more epidemiological studies across European and non-European countries where rapid urbanization is present.

Conclusion and policy implications

This review suggests that there is strong evidence for a relationship between the quantity of green space in the living environment and general health and mortality due to all causes. Especially the suggestion that the general health of population groups with lower socio-economic

status seems to benefit more from green space in the living environment is interesting, because of the health difference between lower and higher socio-economic status groups (Marmot, 2006). However, due to the cross-sectional design of most of the included studies, the results of this review should be interpreted with caution. As stated above, "natural experiments" are needed to examine the causal nature of relationships between both quantity and quality of green space and specific health outcomes for different population groups. These studies will strengthen the evidence base on the health benefit of green spaces and will support public health professionals to create healthy cities using green space as a promising environmental tool for promoting health.

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Supplementary Table S2.1: Data-extraction from studies reporting on the associations between green space and perceived general health with methodological quality score (HQ = high quality, MQ = medium quality, LQ =low quality). Cr = cross-sectional study; Lo = longitudinal.

Reference (quality score)	Design (Cr or Lo)	Country (setting)	Study sample/number of subjects in analyses (age; response rate %)
Agyemang et al. 2007 (MQ)	Cr	Netherlands Amsterdam	2914 from 75 neighbourhoods (≥ 18 y; response rate ?)
Bjørk et al. 2008 (MQ)	Cr	Sweden Scania region, suburban and rural areas	24,819 (18 – 80 y; response rate 59%, inner city respondents excluded)
Carter et al. 2014 (LQ)	Cr	Australia 4 suburban neighbourhoods in Perth	440 (response rate 22.5%)
de Jong et al. 2012 (MQ)	Cr	Sweden Scania region, suburban and rural areas	22,671 (18 - 80 y; response rate 54%, inner city respondents excluded)
de Vries et al. 2003 (HQ)	Cr	Netherlands country level	10,197 (≥ 11 y, response rate 77%; sample of people registered with 103 general practices DNSGP-1 1987-1988)

Health outcome(s)	Green space quantity/quality measure	Findings after adjustment *(statistical model used)*
Perceived general health (1 item SF-36; 'fair or poor' = 1)	Dissatisfaction with quality of green space (neighbourhood level)	Significant positive association only for the medium level compared to the low level of dissatisfaction: OR 1.64 (95% CI 1.11 - 2.44) *(multilevel logistic regression)*
Perceived general health (1 item SF-36; 1= very poor 7= very good)	1. Number of ' recreational values' within 300 m from the residence (GIS-based)	1. No significant association OR 0.95 (95% CI 0.83 – 1.10)
	2. Number of ' recreational values' within 100 m from the residence (GIS-based)	2. No significant association; no data (p >0.30) *(ordinal regression)*
Perceived general health (subscale of SF-36; above median coded as 1 = better health)	1. Self-reported proximity to play and social spaces 2. Self-reported proximity to larger green spaces and trees 3.self-reported green space useability 4.self-reported retention of green space and bushland	No significant association No significant association Significant positive association: OR 2.08 (p=0.013) only for high compared with low level of useability No significant association *(logistic regression)*
Perceived general health (1 item; score 6/7 is good health)	1. Area-aggregated proportions of perceived presence/absence of five 'green qualities' (i.e. green space types Serene, Wild, Lush, Spacious, Culture) within 5 – 10 minutes walking distance in 1000 m^2 areas 2. Objectively assessed (GIS-based) presence/absence of five ' green qualities' within 300m distance from respondents home at neighbourhood level	1. Significant positive association, OR 1.05 (95% CI 1.03 – 1.08) 2. No significant association, OR 0.99 (95% CI 0.73 – 1.02) *(single-level logistic regression, note: no clustering found in outcome variables)*
Perceived general health (1 item SF-36; 'less than good' = 1)	1. Percentage of green space (urban green, agricultural green, forests, natural areas), 3 km around centre of neighbourhood	1. Significant negative association overall sample b = -0.009 (SE 0.003; p<0.05) Analysis by degree of urbanity: only significant for moderate urban and nonurban; resp. b = -0.027 (SE 0.008) and b = -0.040 (SE 0.010; p<0.05) Analysis subgroups: significant only in lower educated group b = -0.009 (SE 0.004; p <0.05) no significant association for children, housewives and elderly.
	2. Percentage of green space within 1 km buffer around six character postal code.	2. No significant negative association overall sample b = -0.0006 (SE 0.0021)

Supplementary Table S2.1: Data-extraction from studies reporting on the associations between green space and perceived general health with methodological quality score (HQ = high quality, MQ = medium quality, LQ =low quality). Cr = cross-sectional study; Lo = longitudinal. (continued)

Reference (quality score)	Design (Cr or Lo)	Country (setting)	Study sample/number of subjects in analyses (age; response rate %)
Dunstan et al. 2013 (MQ)	Cr	UK urban areas in South Wales	31442 (>18 y; response rate ??)
Maas et al. 2006 (HQ)	Cr	Netherlands country level	250,782 (> 16 y; response 76.5 %; sample of people registered with 104 general practices DNSGP-2;2000 – 2002)
Mitchell and Popham 2007 (MQ)	Cr (ecological)	UK country level	Total UK population 2001 Census in 32.482 LSOAs (Lower level Super Output Area, 4 km^2)
Putrik et al. 2015 (MQ)	Cr	Netherlands Maastricht	9,879 (> 18 y; response rate 25%)

	Health outcome(s)	Green space quantity/quality measure	Findings after adjustment *(statistical model used)*
		3. Percentage of green space between 1 to 3 km buffer around six character postal code.	3 Significant negative association overall sample b = -0.0079 (SE 0.0038; p<0.05)
		4 Presence of garden	4. No significant association b = -0.125 (SE 0.098) *(logistic multiple multilevel regression)*
	Perceived general health (1 item; poor health = 1)	Presence of natural elements (subscale of objective Residential Environment Assessment TooL)	No significant association OR 1.03 (95% CI 0.93 – 1.14) lowest compared with highest (*multilevel logistic regression)*
	Perceived general health (1 item SF-36; 'good/very good' = 1)	1. Percentage of green space within a 1 km radius around x,y coordinates of six character postal code	1. Significant positive association b =0.005 (SE 0.000; p≤ 0.001) at all degrees of urbanity; stronger for elderly, youth and secondary educated people
		2. Percentage of green space within a 3 km radius around x,y coordinates of six character postal code	2. Significant positive association b =0.006 (SE 0.001; p≤ 0.001) at all degrees of urbanity; stronger for elderly, youth and secondary educated people *(multilevel logistic models)*
	Indirect age and sex standardised morbidity rate (SMR) of 'not good' (perceived) health in each LSOA	Percentage of LSOA classified as green space	Significant negative association b = -0.021 (p<0.000) for all areas (association depends on degree of urbanity and level of income deprivation: after stratifying association holds in all urban areas and rural low-income areas; suburban lower income b = +0.032 not sign.) *(linear regression; stratified for urban-rural and income combinations)*
	Perceived general health (1 item SF-36; poor or very poor = 1)	Satisfaction with quality and availability of green space	Significant negative association OR 0.94 (95% CI 0.92 – 0.97) p< 0.05; higher satisfaction associated with 6% lower odds of poor general health (*multilevel logistic regression)*

Supplementary Table S2.1: Data-extraction from studies reporting on the associations between green space and perceived general health with methodological quality score (HQ = high quality, MQ = medium quality, LQ =low quality). Cr = cross-sectional study; Lo = longitudinal. (continued)

Reference (quality score)	Design (Cr or Lo)	Country (setting)	Study sample/number of subjects in analyses (age; response rate %)
Reklaitiene et al. 2014 (MQ)	Cr	Lithuania Kaunas	3,254 men and 3,907 women (45 – 72 y; response rate men 62.3 % for women 66.9%)
Richardson et al. 2010 (MQ)	Cr (ecological)	UK country level	28,600,000 (16 – 64 y) in 6432 urban wards
Richardson et al. 2013 (MQ)	Cr	New Zealand country level	8157 (> 15 y; National Survey of Health Status; response rate?)
van Dillen et al. 2012 (MQ)	Cr	Netherlands 80 neighbourhoods in four cities	1641 (> 15 y; response rate 22%; sample 80 neighbourhoods in 4 cities)
Van Herzele and de Vries 2012 (LQ)	Cr	Belgium two neighbourhoods in Ghent	190 (response rate about 30%)

	Health outcome(s)	Green space quantity/quality measure	Findings after adjustment *(statistical model used)*
	Perceived general health (1 item SF-36; poor or very poor = 1)	Distance to nearest green space (<300m, 300 – 999 m, ≥1 km)	Significant negative association only for female park users (≥ 4 h/week) living 300 – 999 m distance compared to <300 distance to green space, OR 1.89 (95% CI 1.17- 3.07); living further away associated with 89% higher odds of poor or very poor general health No significant associations for female park users living more than 1000 m away, for female non-park users and male non-park/ park users *(multiple logistic regression)*
	Limiting long term illness (LLTI;'not good' perceived general health = 1)	Percentage combined coverage of all green spaces larger than 5 m^2 for each ward (excluding domestic gardens)	No significant association for men (IRR 1.01, 95% CI 1.00 – 1.03); significant positive association for women IRR 1.02 95% CI 1.00 – 1.04 (green space level 75% compared to <25%) *(negative binomial regression)*
	Perceived general health (SF-36; lowest quartile 'poor general health' =1)	Percentage green space within CAUs (Census Area Unit, mean 5 km2); excluded aquatic areas, private gardens, green spaces < 0.02 ha (quartiles)	No significant association OR 1.02 (95% CI 0.84 – 1.24); highest green space quartile compared with lowest)
	Perceived general health (1 item SF-36; higher is healthier)	1. Quantity of green areas (m^2 within 500 m distance of residence)	1. Significant positive association b =0.041 (SE 0.012) p≤0.001
		2. Quantity streetscape greenery	2. Significant positive association b =0.073 (SE 0.023; p≤0.01)
		3. Quality of green areas	3. Significant positive association b =0.189 (SE 0.062; p≤0.01) Significant interaction between quantity and quality for the association with perceived general health (quantity is more important when quality is high and vice versa)
		4. Quality of streetscape greenery	4. Significant positive association b =0.165 (SE 0.044 ; p≤0.001) *(multilevel linear regression)*
	Perceived general health (1 item, % less than good = 1)	Characterisation of overall level greenness based on field observations of visible green elements in streets and accessible green areas at different spatial levels (up to 1600 m away)	No significant difference *(no regression analyses but chi-square for difference in mean health outcome)*

Supplementary Table S2.2: Data-extraction studies reporting on the associations between green space and perceived mental health with methodological quality scores (HQ = high quality, MQ = medium quality, LQ = low quality). Cr = cross-sectional study; Lo = longitudinal.

Reference (quality score)	Design (Cr or Lo)	Country (setting)	Study sample/number of subjects in analyses (age; response rate %)
Alcock et al. 2014 (HQ)	Lo (relocation study)	UK England	594 movers to greener areas; 470 movers to less green areas (response rate 74% of households, follow-up 80%– 90% of initial sample of British Household Panel Survey 1991 - 1996, 2003 - 2008)
Annerstedt et al. 2012 (MQ)	Lo	Sweden Scania Regio, suburban and rural areas	7549 respondents living in inner city areas and who had moved excluded (18 – 80 y; response rate 54,5%; follow-up rate 77%; baseline n = 13,604; follow-up 5 y n = 10,485)
Astell-Burt et al. 2014 (HQ)	Lo	UK England, Scotland, Wales	29626 male, 35781 female living in 2681 urban wards for 9 years (response rate 74% of households, follow-up 80 -90% of initial sample of British Household Panel Survey 1996 - 2004)

	Health outcome(s)	Green space quantity/quality measure	Findings after *adjustment (statistical model used)*
	Self-rated propensity to psychiatric morbidity (GHQ-12; higher is better mental health)	Percentage of green space within LSOAs (Lower-layer Super Output Area) including gardens	Movers to more green space significant better mental health 3 years post-move compared to 2 years pre-move (b=0.431, SE 0.162, p=0.008), movers to less green space no significant change in mental health (b = 0.163, SE 0.175 p = 0.354); Note: differences between two groups at post-move times not tested *(fixed effect regression)*
	Self-rated propensity to psychiatric morbidity/ perceived mental health at follow up (GHQ-12; score 0-2 good health; 3-12 not good)	1. Presence/absence of five 'recreation qualities'(i.e. types of green space; Serene, Wild, Lush, Spacious, Culture) within 300m buffer around residential address	1. No significant associations (Spacious men: OR 1.1 95% CI 0.6 – 1.2; women: 1.1 95% CI 0.8 – 1.6) Note: significant interaction effect for woman: group who is physical active and has access to Serene and Spacious green space has 80% resp. 70% lower odds for poor mental health at follow-up than group with same access but not physical active
		2. Number of 'recreational qualities' (0 to 5)	2. No significant association (men: OR 0.9 95% CI 0.6 – 1.2; women: 0.9 95% CI 0.7 – 1.2) *(single level logistic regression; no-clustering-effect for baseline data)*
	Self-rated propensity to psychiatric morbidity (GHQ-12; higher is less healthy)	Percentage of green space within wards (excluding water and private gardens)	For men: significant negative association for men b = -0.333 (SE 0.124) p< 0.01; significant interaction with age: men living in higher level of green space had higher mental health compared to living in lowest level from early adulthood through middle age (no statistical values reported) For women: no significant for women in general (b = 0.093, SE 0.128) but significant interaction with age: association for women when in their mid-40s and older and living in moderate levels of green space (no statistical values reported**)** *(multilevel linear regression)*

Supplementary Table S2.2: Data-extraction studies reporting on the associations between green space and perceived mental health with methodological quality scores (HQ = high quality, MQ = medium quality, LQ = low quality). Cr = cross-sectional study; Lo = longitudinal. (continued)

Reference (quality score)	Design (Cr or Lo)	Country (setting)	Study sample/number of subjects in analyses (age; response rate %)
Astell_Burt et al. 2013	Cr	Australia region new South Wales	260,061 (45 – 106 y; response rate 18%; sample of Medicare Australia Database)
Beyer et al. 2014 (HQ)	Cr	US Wisconsin	2,479 (21 – 74 y: response rate 63%;sample of Survey of the Health of Wisconsin)
Carter et al. 2014 (LQ)	Cr	Australia 4 suburban neighbourhoods in Perth	440 (35 - 64;response rate 22.5%)

Health outcome(s)	Green space quantity/quality measure	Findings after *adjustment (statistical model used)*
Psychological distress (Kessler-10; score > 22 = high distress)	Percentage of green space within 1 km buffer around participants' residences	Significant negative association, OR 0.91 (95% CL 0.84 – 1.00) p<0.05 Significant interaction with physical activity, no association for least physical active (OR 0.99, 95% Cl 0.85 – 1.15) but significant association for most physical active group living in greenest versus least green neighbourhood, (OR 0.82 (95% Cl 0.67 0 0.99) *(multilevel logistic regression)*
Symptoms of depression (42-item Depression Anxiety and Stress Scales, DASS; higher scores, poorer mental health)	1.Level of greenness measured by NDVI in US Census Blocks (smaller than census tracts)	Significant negative association between 25% more greenness and lower score for symptoms of depression and stress, strongest for depression, b = -1.005 (SE 0.293) p < 0.05 (no association for anxiety)
	2.Level of greenness measured by percentage of tree canopy coverage in US Census Blocks	Significant negative association between 25% more greenness and lower score for symptoms of depression and anxiety, strongest for depression, b = -1.369 SE 0.464) p < 0.05) (no association for stress)
	3. combined measure of NDVI and tree canopy average in US census blocks	Significant negative association between 25% higher greenness and lower scores for symptoms of depression, anxiety and stress, strongest for depression b = -1.379 (SE 0.397) p < 0.05 *(multivariate linear regression)*
Perceived mental health (subscale SF-36; above median coded as 1 = better mental health)	1. Self-reported proximity to play and social spaces	Significant positive association: OR 1.70 (p = 0.079) highest compared to lowest proximity level
	2. Self-reported proximity to larger green spaces and trees	No significant association
	3.self-reported green space useability	No significant association
	4.self-reported retention of green space and bushland	No significant association *(logistic regression)*

Supplementary Table S2.2: Data-extraction studies reporting on the associations between green space and perceived mental health with methodological quality scores (HQ = high quality, MQ = medium quality, LQ = low quality). Cr = cross-sectional study; Lo = longitudinal. (continued)

Reference (quality score)	Design (Cr or Lo)	Country (setting)	Study sample/number of subjects in analyses (age; response rate %)
Chong et al. 2013 (HQ)	Cr	Australia Sydney	10,710 (≥ 16 y; response rate 60%; sample of New South Wales Population Health Survey)
Guite et al. 2006 (MQ)	Cr	London four areas of Greenwich	848 (>18 y; response rate 38%; after missing values effective response rate 31%)
de Vries et al. 2003 (HQ)	Cr	Netherlands country level	10,197 (≥ 11 y; response rate 77%; sample of people registered with 103 general practices DNSGP-1 1987-88)
Maas et al. 2009 (HQ)	Cr	Netherlands country level	10,089 (>11 y; response rate 64.5%; sample of people registered with 104 general practices) Subsample 4842 (data for social contacts)

	Health outcome(s)	Green space quantity/quality measure	Findings after *adjustment (statistical model used)*
	Psychological distress (Kessler-10; score ≥ 22 = high distress)	Percentage of parkland at postcode level (only state forests and national parks)	No significant association, OR 1.35 (95% CI 0.92 – 1.97), p = 0.12 Significant interactions with perception of neighbourhood safety and area disadvantage; most disadvantaged subgroup perceiving neighbourhood as unsafe had 153% higher odds for being high distressed (OR 2.53, 95% CI 1.53 – 4.19, p<0.01) when living in >40% parkland compared to < 20% *(GEE logistic regression)*
	Mental health (SF-36v2; lowest quartile vs. three higher quartiles)	Dissatisfaction with green space (such as parks, gardens within a 15-20 minutes walk or 5-10 minutes drive)	Significant positive association between dissatisfaction with being in the lowest quartile of mental health, OR 2.4 (CI 1.53 – 3.77) *(multivariate logistic regression)*
	Self-rated propensity to psychiatric morbidity/ perceived mental health (GHQ-12; score ≥ 5 = less healthy)	1. Percentage of green space (urban green, agricultural green, forests, natural areas), 3 km around centre of neighbourhood	1. Significant negative association overall sample, b = -0.010 (SE 0.003) p≤ 0.05 Note: more green related to more health. Analyses by degree of urbanity: no significant association Analyses subgroups: significant only in lower educated group, b = -0.011 (SE-0.006) p≤0.05; no significant association for children, housewives and elderly
		2. Percentage of green space within 1 km buffer around six character postal code.	2. No significant association, b = -0.0018 (SE 0.0021)
		3. Percentage of green space between 1 to 3 km buffer around six character postal code	3. Significant negative association, b = -0.0084 (SE 0.0038) p≤0.05
		4. Presence of garden	4. No significant association, b = -0.179; SE 0.0104) *(logistic multiple multilevel regression)*
	Self-rated propensity to psychiatric morbidity (GHQ-12; score high propensity =1)	1.Percentage within a 1 km radius around x,y coordinates of six character postal code	1. Significant negative association, b = -0.005 (SE 0.002) p≤0.01 Subsample: significant negative association, b = -0.004 (SE 0.0021)
		2. Percentage within a 3 km radius around x,y coordinates of six character postal code.	2. Significant negative association, b = -0.004 (SE 0.002) p≤ 0.05 Note: in subsample no association, b = -0.002 (SE 0.003) *(multilevel regression, adjusted also for urbanity)*

Supplementary Table S2.2: Data-extraction studies reporting on the associations between green space and perceived mental health with methodological quality scores (HQ = high quality, MQ = medium quality, LQ = low quality). Cr = cross-sectional study; Lo = longitudinal. (continued)

Reference (quality score)	Design (Cr or Lo)	Country (setting)	Study sample/number of subjects in analyses (age; response rate %)
Paquet et al 2013 (HQ)	Cr	Australia Adelaide	3754 (>18 y; North West Adelaide Health Study; **response rate 49.4%??**)
Putrik et al. 2015 (MQ)	Cr	Netherlands Maastricht	9879 (> 18 y; response rate 25%)
Reklaitiene et al. 2014 (MQ)	Cr	Lithuania Kaunas	6944; 3,254 men and 3,907 women (45 – 72 y; response rate men 62.3 % for women 66.9%)
Richardson et al. 2013 (MQ)	Cr	New Zealand country level	8157 (> 15 y; response rate 67,9%; 2006/07 New Zealand Health Survey; response rate)
Sturm and Cohen, 2014 (LQ)	Cr	US 10 neighbourhoods in Los Angeles	Household survey 838 residents in census tract around parks (> 18 y; response rate 88%)
Sugiyama et al. 2008 (MQ)	Cr	Australia Adelaide	1895 (20- 65 y; response rate 11.5%)

Health outcome(s)	Green space quantity/quality measure	Findings after *adjustment (statistical model used)*
Mental health/ psychological well-being (5 items SF-36 mental health scale; score 0 – 100, higher is healthier)	Median Public Open Space greenness measured by NDVI in 1000 m network buffer	No significant association, b= -0.54 (95% CI -1.1 – 0.01) p= 0.05 *(linear regression models and Generalised Estimating Equations to account for clustering within spatial units)*
Psychological distress (Kessler: high distress vs low or medium)	Satisfaction with quality and availability of green space	Significant negative association OR 0.92 (95% CI 0.88 - 0.97) p<0.05; higher satisfaction was associated with 18% lower odds of high psychological distress *(multilevel logistic regression)*
Depressive sympoms (CES-D10 scale; score > 4.0 having depressive symptoms = 1)	Distance to nearest green space (<300m, 300 – 999 m, ≥1 km)	Significant negative association for female park uses (≥ 4 h/week) living 300 – 999 m and > 1 km compared to < 300 distance from nearest park, resp. OR 1.56 (95% CI 1.09 – 2.23) and OR 1.92 (95% CI 1.11 - 23.3); women living further away associated with 56% and 92 % higher odds of having depressive symptoms No significant associations for men *(multiple logistic regression)*
Perceived mental health (F-36); lowest quartile ' poor mental health'	Percentage green space within CAUs (Census Area Unit, mean 5 km2); excluded aquatic areas, private gardens, green spaces < 0.02 ha (quartiles)	Significant negative association, OR 0.81 (95% CI 0.66 – 1.00) p=0.045; living in highest quartile green space level was associated with 19 % lower odds to have 'poor mental health' *(multilevel logistic regression)*
Mental health (MHI-5 , score 0 – 100, higher is heathier)	Distance from a park (400 m, 400 – 800 m, 800 – 1.6 km, > 1.6 km)	Living more than 400 m but less than 800 m is associated with lower mental health compared to living at less than 400 m distance, b = -2.24 (SE 1.14) p < 0.05;; living at more than 800 m but less than 1 .6 km distance is also associated with less mental health compared to living at distance less than 400 m, b = -4.64 (SE 1.08) p <0.01 No significant association b = -0.33 (SE 1.17) distance >1.6 km *(multilevel multiple regression)*
Perceived mental health (SF-12; component score MCS)	Perceived greenness	Significant positive association, OR 1.60 (95% CI 1.26 – 2.04) Note: group with perceived high greenness had 60% higher odds for better mental health scores compared group with perceived low greenness *(logistic multiple regression)*

Supplementary Table S2.2: Data-extraction studies reporting on the associations between green space and perceived mental health with methodological quality scores (HQ = high quality, MQ = medium quality, LQ = low quality). Cr = cross-sectional study; Lo = longitudinal. (continued)

Reference (quality score)	Design (Cr or Lo)	Country (setting)	Study sample/number of subjects in analyses (age; response rate %)
van Dillen et al. 2012 (MQ)	Cr	Netherlands 80 neighbourhoods in four cities	1641 (>15 y; response rate 22%)
Ward-Thompson et al. 2012 (LQ)	Cr	UK Dundee	25 unemployed men and women (35 – 55 y; response rate 33%)
White et al. 2013 (HQ)	Lo	UK England	87,573 person years from 12,818 adults living in urban areas (adults, response rate 95%; follow-up 80 – 90%; sample from British Household Panel Survey 1991 -2008)

	Health outcome(s)	Green space quantity/quality measure	Findings after *adjustment (statistical model used)*
	Mental health status (MHI-5; score 1 – 100, higher is healthier)	1. Quantity of green areas (m^2 within 500 m distance of residence)	1. Significant positive association, b = 0.683 (SE 0.243) p≤0.01
		2. Quantity streetscape greenery	2. Significant positive association, b = 1.304 (SE 0.455) p ≤0.01
		3. Quality of green areas	3. No significant association
		4 Quality of streetscape greenery	4. Significant positive association, b = 3.071 (SE 0.860) p≤0.001 *(multilevel linear regression)*
	Self-reported mental wellbeing (shortened version of Warwick and Edinburgh Mental Wellbeing Scale; score 7 to 35, low to high wellbeing)	Percentage of green space (postcode level)	No significant association b = 0.370 *(Pearsons bivariate correlations*)
	Mental distress (GHQ-12; higher is less healthier)	Percentage of green space within LSOAs (Lower-layer Super Output Area) including gardens/excluding gardens	Significant negative association b = -0.0043 (SE 0.0013) p<0.001; higher percentage of green space was associated with lower mental distress/higher mental health Note: excluding gardens did not change the results *(fixed-effects analyses??)*

Supplementary Table S2.3: Data-extraction from studies reporting on the association between green space and all-cause mortality with methodological quality score (HQ =high quality, MQ = medium quality, LQ = low quality). Cr = cross-sectional study; Lo = longitudinal

Reference (quality score)	Design (Cr or Lo)	Country (setting)	Study population (response/follow-up rate; number of deaths)
Coutts et al. 2010 (HQ)	Cr	US Florida 67 counties	67 counties total population Florida (167,708 deaths)
Mitchell and Popham 2008 (HQ)	Cr	UK England	40,813,236 working-age population in 32,482 Lower level Super Output Areas (LSOA, 4 km^2) (366,348 deaths)
Mitchell et al. 2011 (HQ)	Cr	UK 4 cities in Britain	1,625,495 (< 65 y) in 286 small areas CAS wards
Richardson et al. 2012 (HQ)	Cr	US city level	49 cities, combined study population 43 million
Takano et al. 2002a (LQ)	Cr	China Shanghai	13,066 in 20 ward units
Takano et al. 2002b (MQ)	Lo	Japan (two cities in Tokyo metropolitan area)	Cohort 3144 follow-up 5 y seniors ≥ 73 (response rate 43%; follow up rate 98,9%)

Health outcome (s)	Green space quantity/quality measure	Findings after *adjustment (statistical model used)*
All-cause mortality (ICD-10 codes A00 –Y89)	1. Amount green space in county	1. No significant association (b = -0.00; SE 0.00; p= 0.22)
	2. Average (Euclidian) distance to nearest green space from all census tracts centroid within county, weighted by population	2. No significant association (b = 0.04; SE 0.04; p = 0.25)
	3. Average amount of green space within 4 defined (Euclidian) distances from all census tracts centroid within county, weighted by population (min. 0,4 km max. 4.8 km)	3. Significant negative association between all four distances (0.04 km: b = -0.01;SE 0.00; p = 0.03; 4.8 km: b = -0.00; SE 0.00; p = 0.02) *(negative binomial regression)*
All-cause mortality	Percentage of LSOAs land area classified as green space	Significant negative association: lower incidence rate ratio for higher groups of exposure to green space (compared to group with least exposure to green space); IRR 0.9436. 95% CI 0.09256 – 0.9620 Significant interaction between income deprivation and exposure to green space *(negative binomial regression)*
All-cause mortality registered at CAS ward level (ICD-10 codes A00-R99 excluding external causes) between 2001 – 2002 Office of National Statistics and GRO Scotland)	Percentage green space at ward CAS level (three methods: 1 hybrid; 2 CORINE; 3 OSMM)	Significant negative association: lower incidence rate ratio for groups in areas with more than 60% green space (compared to less than 20%); method 1 IRR 0.7837 (SE 0.0320); 2 IRR 0.8027 (SE 0.0302); 3 IRR 0.8176 (SE 0.0392) *(negative binomial regression*)
All-cause mortality (Big Cities Health Inventory, 2004)	City-level percentage green space coverage	Significant positive association: higher mortality rate in highest city greenness vs. lowest; greenest cities had 133 more male death and 94 more female death per 100.000 population compared to least green cities male b =132.90 95% CI 18.33-247.46; female b =94.21 95% CI 21.76-166.66 *(linear regression)*
Age-adjusted mortality (1995, 1996, 1997)	Percentage of total land area of parks, gardens and green space Percentage coverage of urban green areas	Significant negative correlation , highest in 1996 r= -0.685 p = 0.000 *(spearman's correlation)*
Five year survival of older people	Self-reported amount of walkable green streets and spaces near the residence at baseline	Significant positive association: OR 1.13 95% CI 1.03 – 1.24 *(multiple logistic regression)*

Supplementary Table S2.3: Data-extraction from studies reporting on the association between green space and all-cause mortality with methodological quality score (HQ =high quality, MQ = medium quality, LQ = low quality). Cr = cross-sectional study; Lo = longitudinal (continued)

Reference (quality score)	Design (Cr or Lo)	Country (setting)	Study population (response/follow-up rate; number of deaths)
Villeneuve et al. 2012 (HQ)	Lo	Canada 10 urban areas in province Ontario	Cohort 575,000 follow-up 22 y; (adults ≥ 35 y; follow-up 95%; 187,000 deaths)

	Health outcome (s)	Green space quantity/quality measure	Findings after *adjustment (statistical model used)*
	Non–accidental mortality (ICD-9 codes <800; ICD-10 codes <V01)	Normalized Difference Vegetation Index (NDVI-value) assigned to place of residence defined at 6-character postal code at time of entry into cohort at 500 m buffer	Significant negative association; increase in green space was associated with reduced mortality rate ratio; RR (for increase in interquartile range of green space)= 0.95 95% CI 0.94-0.96 *(Cox proportional hazards model*)

Supplementary Table S2.4: Methodological quality assessment scores for the studies included in the review.

Study	Criteria[a]	A	B	C	D	E	F	G
	Reference (health outcome)							
1	**Agyemang et al. 2007** (perceived general health)	+	-	NR	NA	+	+	+ OR
2	**Alcock et al. 2014** (perceived mental health)	+	+	+	+	+	+	+ β, SE
3	**Annerstedt et al. 2012** (perceived mental health)	+	+	+	-	+	+	+ OR
4	**Astell-Burt et al. 2014** (perceived mental health)	+	+	+	+	+	+	+ β, SE
5	**Astell-Burt et al. 2013** (perceived mental health)	+	+	-	NA	+	+	+ OR
6	**Beyer et al. 2014** (perceived mental health)	+	+	+	NA	+	+	+ β, SE
7	**Björk et al. 2008** (perceived general health)	+	-	+	NA	+	+	+ OR
8 en 9	**Carter et al. 2014** (perceived general health (perceived mental health)	+	+	-	NA	+	-	+
10	**Chong et al. 2013** (perceived mental health)	+	+	+	NA	+	+	+ OR
11	**Coutts et al. 2012** (all-cause mortality)	+	+	+	NA	+	+	+ β, SE
12	**de Jong et al. 2012** (perceived general health)	+	-	+	NA	+	+	+ OR
13 en 14	**de Vries et al. 2003** (perceived general health) (perceived mental health)	+	+	+	NA	+	+	+ β, SE
15	**Guite et al. 2006** (perceived mental health)	+	+	-	NA	+	+	+ OR
16	**Dunstan et al. 2013** (perceived general health)	+	+	NR	NA	+	+	+
17	**Maas et al. 2006** (perceived general health)	+	+	+	NA	+	+	+ β, SE
18	**Maas et al. 2009** (perceived mental health)	+	+	+	NA	+	+	+ β, SE
19	**Mitchell et al. 2007** (perceived general health)	+	+	NR	NA	+	+	+ β, SE
20	**Mitchell et al. 2008** (all-cause mortality)	+	+	NA	NA	+	+	+ IRR
21	**Mitchell et al. 2011** (all-cause mortality)	+	+	NA	NA	+	+	+ IRR
22	**Paquet et al 2013** (perceived mental health)	+	+	+	NA	+	+	+ β, CI

H	I	Total -	Total +	% + / applicable	Q[b]	Comments
+	+	1	6	75	MQ	Adjustment for income
+	+	0	9	100	HQ	Adjustment for education, household income; area level income, education, employment
+	+	1	8	89	MQ	adjustment for financial stress
+	+	0	9	100	HQ	Adjustment for education, household income, economic activity
+	+	1	8	89	MQ	Adjustment for household income, education level, employment
+	+	0	8	100	HQ	Adjustment for education, household income, occupational status, type of health insurance; area level median household income, education instability, unemployment
+	+	1	7	88	MQ	Adjustment for problems paying bills and smoking
-	+	3	5	63	LQ	Adjustment for education and income only in analysis mental health, no other SES but not tested in regression model
+	+	0	8	100	HQ	Adjusted for education, household income, employment status
+	+	0	8	100	HQ	adjustment for Bachelor's degree or higher, smoking and physical activity
+	+	1	7	88	MQ	Adjusted for education and economic difficulties
+	+	0	8	100	HQ	Adjustment for type of health insurance and urbanity
+	+	1	7	88	MQ	Adjustment for paid employment and for rent arrears
+	+	0	7	88	MQ	
+	+	0	8	100	HQ	Adjustment for type of health insurance and urbanity
+	+	0	8	100	HQ	Adjustment for area-level income-deprivation index and urbanity
+	+	0	7	88	MQ	Adjustment for area-level income-deprivation index and urban/ rural classification
+	+	0	7	100	HQ	Adjustment for area-level income deprivation index, urbanity and air pollution, not for smoking
+	+	0	7	100	HQ	Adjustment for area-level income-deprivation index, air pollution, not for smoking
+	+	0	8	100	HQ	Adjustment for education, income, area level SES

Supplementary Table S2.4: Methodological quality assessment scores for the studies included in the review. (continued)

Study	Criteria[a]	A	B	C	D	E	F	G
	Reference (health outcome)							
23 en 24	**Putrik et al. 2014** (perceived general health) (perceived mental health)	+	+	-	NA	+	+	+ OR
25 en 26	**Reklaitiene et al. 2014** (perceived general health) (perceived mental health)	+	NR	+	NA	+	+	+ OR
27	**Richardson et al. 2010** (perceived general health = Limiting Longterm Illness)	+	+	NR	NA	+	+	+ IRR
28	**Richardson et al. 2012** (all-cause mortality)	+	+	NA	NA	+	+	+ β
29 en 30	**Richardson et al. 2013** (perceived general health) (perceived mental health)	+	-	+	NA	+	+	+ OR
31	**Sugiyama et al. 2008** (perceived mental health)	+	+	-	NA	+	+	+ OR
32	**Sturm et al. 2014** (perceived mental health)	+	NR	+	NA	+	+	+
33	**Takano et al. 2002a** (mortality)	+	+	NA	NA	+	-	+
34	**Takano et al. 2002b**	+	+	-	+	+	+	+ OR
35 en 36	**van Dillen et al. 2011** (perceived general health) (perceived mental health)	+	-	-	NA	+	+	+ β, SE
37	**van Herzele et al. 2011** (perceived general health)	+	-	-	NA	+	-	+
38	**Villeneuve et al. 2012** (non-accidental = all-cause mortality)	+	+	NA	+	+	+	+ IRR
39	**Ward-Thompson et al. 2012** (perceived mental health)	+	-	-	NA	+	-	+
40	**White et al. 2013** (perceived mental health)	+	+	+	`+	+	+	+ β, SE

[a] See Supplementary Table S2.5 for the criteria which were used to assess the methodological quality.

[b] Quality score if cut off points 100% = HQ; 75 – 100% = MQ; < 75% = LQ

H	I	Total -	Total +	% + / applicable	Q[b]	Comments
+	+	1	8	88	MQ	Adjusted for education and income
+	+	0	7	88	MQ	Adjusted for education
+	+	0	7	88	MQ	Adjustment for air pollution, not for smoking
+	+	0	7	100	HQ	Adjustment median household income and air pollution, not for smoking
+	+	1	8	88	MQ	Adjusted for individual SES index
+	+	1	7	88	MQ	Adjustment for household income
+	-	1	6	75	MQ	
+	-	2	5	71	LQ	Note: no regression, only spearman's correlation
+	+	1	8	89	MQ	
+	+	2	6	75	MQ	Adjustment for household income
+	-	4	4	50	LQ	Note: no regression, only chi-square test
+	+	0	8	100	HQ	Adjustment for indirect smoking index and air pollution
+	-	4	4	50	LQ	Note: no regression, only Pearsons correlation
+	+	0	9	100	HQ	Adjusted for education, income,

Supplementary Table S2.5: Criteria used for the methodological quality assessment of the studies included in the review.

Criteria: yes = +; no = - ; NR = not reported; NA = not applicable

A. Is the setting (source population/area) adequately described?[a]
B. Is the eligible population or area representative of the source population or area (were important groups underrepresented)?[a]
C. Was the response rate 50% or higher?[a]
D. Was the non-response at follow-up not selective?[a]
E. Were outcome measures and procedures valid and reliable (were standardized methods/measures of acceptable quality used)?[a]
F. Were the statistical models used appropriate?[b]
G. Were the correct measures of association (according to the used model) presented?[b]
H. Were confidence intervals and/or p-values for effect estimates given?[a]
I. Were the models adjusted for potential confounders (at least age, sex and an indicator of SES)?[b]

Q. Quality score: high = HQ, medium = MQ; low = LQ based on total number of positive scores weighted for total number of criteria scored

[a] Adapted from: Appendix G Quality appraisal checklist – quantitative studies reporting correlations and associations (NICE, 2009)

[b] From the quality assessment list developed by Ariëns et al. (2000).