THE RECURRENCE OF HEALTH IN URBAN PLANNING: TOWARDS AN INTEGRATION OF ENVIRONMENTAL HEALTH ASPECTS

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Abstract

While urban planning and health were initially interlinked, in the twentieth century planning practice slowly moved away from its public health origins. In recent years however there is a growing interest in the health effects of our spatial organization. Although the direct impact of the physical environment on health has decreased – due to better standards of living, sanitary developments, improved housing – environmental quality still deserves our attention. First, the focus has shifted from life expectancy to health expectancy and quality of life. Public health impact no longer predominantly involves clear mortality risks, but rather comprises aspects of human well-being in a broad sense. Several direct impacts, like noise or air pollution, do not immediately kill people, but cause physical or mental disorders on the long term or severely reduce the quality of life of people. Second, the physical environment has many indirect effects on lifestyle and health, for example a reduced physical activity caused by a lack of walkable neighborhoods. A final important reason to justify this research is the aspect of environmental justice. The spatial characteristics responsible for direct and indirect health effects are spatially heterogeneously distributed, causing important differences in health status and healthy life expectancy between various residential neighborhoods.

Today a lot of research exists on different health impacts caused by aspects of the physical environment. Most of this research focuses on one single impact (e.g. noise) or one spatial aspect (e.g. a road). An integrated approach, in which all the impacts and aspects are combined, seems to be lacking. However, there is a giant need for a better understanding of this issue, to inform community leaders and spatial planners about which community design and land-use choices are most effective in improving the physical, mental and social well-being of people.

In this paper an attempt is made to give an overview of the main environmental characteristics with an effect on people's health and well-being. The aim is to evaluate the evidence of the existing research output and to explore the relevance for spatial planning.

Finally the results are discussed and recommendations for urban planning policy are formulated. Here the aspect of environmental justice comes into view, the right on a healthy living environment for every citizen regardless of social and economic status.

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1. Introduction

Health and urban planning are historical allies. In the mid-19th century a tremendous population drift from the countryside to larger industrial cities took place, causing overpopulation in cities with an underdeveloped public hygiene. Modern planning originated expressly in order to combat these unsanitary, overcrowded and inhumane urban conditions. Endemic problems of poor water supply, sanitation, light and air triggered a response in terms of not only infrastructure engineering but also urban design (de Hollander and Staatsen, 2003; Galea and Vlahov, 2005; Barton, 2010).
In the mid-to-late 20th century planning practice moved away from its public health origins. Original objectives of clean air and water are still deeply entrenched in planning and building control systems, but contemporary diseases have been ignored in many ways. Planning policies have facilitated if not actually fostered the powerful trend towards car-dependent, sedentary and privatized lifestyles, with their negative effects on health and well-being. We have been literally building unhealthy conditions into our local human habitat (Barton and Grant, 2006; Barton et al., 2009).
At the beginning of the 21st century a resurgence of interest in the relationship between 'place' and 'health and well-being' can be noted. Recent concerns about levels of physical activity, asthma, sleep disturbance, stress and increasing environmental inequality have put the aspect of health back on the spatial planning agenda. We now realize that how we design the built environment may hold tremendous potential for addressing many of the greatest current public health concerns (Jackson, 2003a; Barton and Grant, 2006).

The development and significance of environmental health can be analyzed using a conceptual model (Ruwaard and Kramers, 1998). This model (figure 1) shows that health status can be regarded as a function of a variety of determinants. Up until the 20th century the physical environment was the largest source of avoidable disease burden in the Western world, with an attributable fraction of 70-80% (de Hollander and Staatsen, 2003). Since the public health revolution from the 19th and 20th century, this factor is only directly responsible for minor health loss, while life-style is responsible for the bulk of the current avoidable disease burden (de Hollander et al., 1999; Smith et al., 1999; Melse and de Hollander, 2001). Especially among young people and lower socio-economic classes trends in unhealthy behavior are alarming (smoking, dietary habits, sedentary life-styles) (van Oers, 2003).

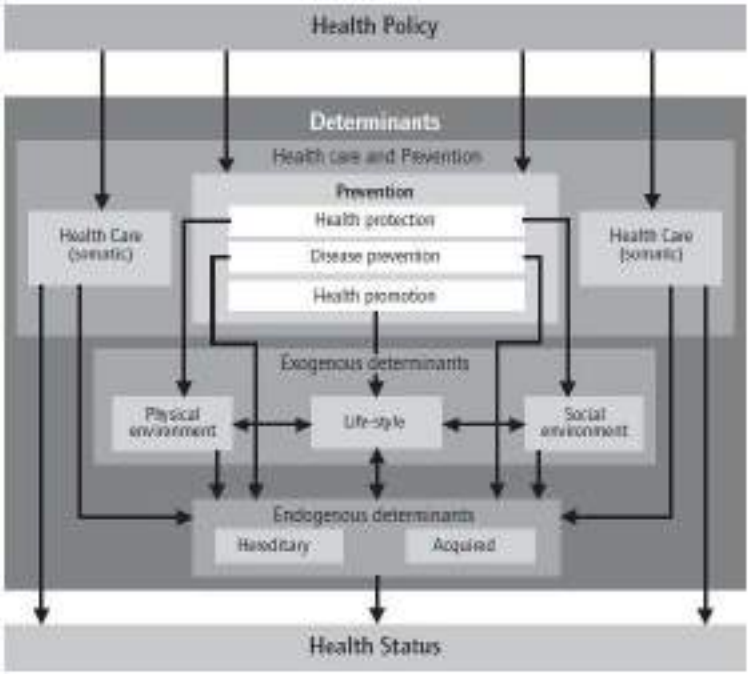

Figure 1. Conceptual model - determinants of public health status (Ruwaard and Kramers, 1998)

The increasing importance of life-style in the public health status of Western countries is a consequence of the growing control over other determinants. In fact, modern post-industrial people have become very healthy people, thanks to public hygiene, vaccination programs, antibiotics, a general improvement in standards of living and a comprehensive system of health protection (de Hollander and Staatsen, 2003). Today, the health loss due to exposure from the physical environment is much higher in low-income countries compared with Western countries (lack of access to clean water, inappropriate housing, infectious diseases, indoor air pollution, malnutrition …). Further, the health risks associated with industrialization, such as large scale air (and noise) pollution generated by transport and energy production, do now receive a lot of attention, but in fact these problems did make many more victims in the past (Lomborg, 2001). Many of the impacts of environmental factors have been annihilated or reduced to be 1/10 or 1/20 of their original impact (de Hollander and Bol, 2004).
Because of this conclusion, one can wonder whether the physical environment still deserves our attention when it comes to public health. Three reasons can be given why this focus is still useful.

From quantity of life to quality of life
The main reason why environmental quality is still a valuable research theme is the shift from quantity of life to quality of life. Public health impact no longer predominantly involves clear mortality risks or loss of life expectancy, but rather comprises aspects of well-being and quality of life in a broad sense (de Hollander and Staatsen, 2003; de Hollander and Bol, 2004). Firstly, this includes the

aggravation of pre-existing disease symptoms, e.g. asthma, chronic bronchitis, cardiovascular disorder. Secondly severe annoyance, like sleep disturbance or a reduced ability to concentrate and communicate, is comprised. A third category consists of feelings of insecurity or alienation, unfavorable health perception and stress in relation to poor environmental quality. Environmental annoyances, like noise pollution, do not lead to many supplementary deaths, but do affect the quality of life of people and cause stress and concentration and communication problems.
The World Health Organization (WHO) already adopted this broad definition in 1946, stating that health is "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (WHO, 1946). Also in research the concept of health has expanded beyond a mere absence of illness and objective indicators of health, to address well-being and quality of life (O'Neill and Simard, 2006).

Indirect effects of the physical environment on lifestyles and health
The physical environment also has important indirect (and complex) effects on health, through impacting life-styles (Barton and Grant, 2006). This can easily be illustrated by Barton's settlement health map, depicting the ecosystem of a human settlement (figure 2). Each outer sphere (natural environment, built environment, activities) affects the health and well-being of people, represented by the inmost sphere, directly or through an effect on local economy, community or lifestyle – the intermediate spheres. The built environment can for example provide attractive walkable neighborhoods with mixed land use, thus stimulating a physically more active lifestyle and consequently a better health status.
Because of these clear links between environmental quality and life-style (see also Pickett and Pearl, 2001; Roux et al., 2001), a study remains useful, but one has to be aware of selection processes that can have more impact than actual causal relationships.

Environmental justice
The spatial characteristics responsible for direct and indirect health effects are spatially heterogeneously distributed, causing problems of environmental inequality. It has been recognized that environmental hazards in urban areas disproportionately affect low-income people and members of minority groups (Brulle and Pellow, 2006). This is due to a social polarization of opportunity, which ties some people to locality, making them increasingly vulnerable (Barton et al., 2009). These people often cannot afford to live in relatively healthier neighborhoods and bear a greater burden of risk (Dannenberg et al., 2003; Moudon, 2009).
There exists empirical evidence that low income is associated with higher noise exposures (e.g. Seto et al., 2007) and higher air pollution exposures (e.g. Laurent et al., 2007). Moreover, members of minority groups are relatively more exposed to air pollutants than whites, independent of income and urbanization (e.g. Perlin et al., 1999). Kohlhuber et al. (2006) add that not only the perceived exposure differs but also the generation of environmental problems may be distributed unequally. Poor people are less likely to own a car than wealthier people, they contribute less to environmental pollution but suffer disproportionately more often from it.

These three arguments show that the relation between urban planning and health or well-being still deserves our attention. The main line of thought is that every citizen has the right on a living environment that stimulates health and well-being, regardless of his or her social and economic status. This basic principle of the right on well-being and environmental quality connects an ecocentric with an anthropocentric view, clearly illustrated by Barton's settlement health map (Barton, 2005, 2009) (figure 2). On the one hand this diagram expresses an ecocentric view on human settlements, by depicting an ecosystem with different spheres, that are interconnected in different ways and have to be in a good balance to ensure healthy settlements. On the other hand people are placed at the heart of the map, reflecting the anthropocentric definition of sustainable development, aimed at improving the livability and the quality of life (e.g. IUCN, 1980; Newman, 1999).

Figure 2. Human ecology model of a settlement (Barton and Grant, 2006)

To include the health aspect in spatial planning and design, a good scientific basis is needed. We need to know which impacts are important, what health effects they bring about, and how these impacts can be spatially influenced (Jackson, 2003b).
Today a lot of research exists on different health impacts caused by aspects of the physical environment. Most of this research however focuses on one single impact (e.g. noise) or one spatial aspect (e.g. a road), and results are typically not widely shared across disciplines (Dannenberg et al., 2003).
The spatial planning discipline should strive to this integration of the different associations between aspects of the built environment and impacts on health and well-being. Starting from this concern for an integrative approach, a PhD research project has been started up focusing on the combination of impacts and the modeling

of environmental health. The remaining part of this paper presents the results of an exploratory literature study, carried out to discern the main environmental impacts, originating in aspects of the built environment, and relevant for spatial planning and design decisions.

2. Framework

To guide the literature study, two important choices were made, concerning the range of impacts included and the spatial scale of the effects. To discern the environmental characteristics that are relevant for spatial planning, the analysis was focused on impacts caused by the physical environment, and not the social environment, and on impacts that generate differences at a local neighborhood level, and not the building or regional level (for an analysis of impacts on other scales, see Jackson, 2003a).

As a framework for the assessment of the different impacts, a scheme was used that consists of three parts (figure 3): 1) spatial conditions, 2) impacts and 3) effects on health and well-being.

Figure 3. Framework

A simple example is the spatial configuration of a highway (1), generating traffic noise (2) with an effect on sleep quality of neighbors (3).
The aim was to characterize the different impacts following this scheme. The linking parts, the ‘impacts’, will be considered as the steppingstones of the research project. This is partly due to the aim of the further research steps, modeling the environmental quality based on a combination of the most relevant impacts.

The literature study was carried out on an exploratory basis. It was not the aim to be exhaustive and complete, nor to give the most recent insights in the domain. The purpose was to get a broad view of the different impacts, their importance, the scope of their effects and the value of the existing empirical evidence. Nevertheless it was attempted to select primarily those sources that are cited regularly and that incorporate possible confounding variables. One of the main lacunas is the primary reliance on cross-sectional studies, because of the limited availability of longitudinal studies.
Notwithstanding several shortcomings, the literature review should give a broad view on the relation between the built environment and health or well-being and set the scene for further research. Based on this analysis it should be possible to select the most important impacts for further modeling.

3. Impacts

Based on the literature review, four important impacts could be discerned, with sufficient scientific evidence. These are: air pollution, noise, the absence of green space as a restorative environment and the lack of physical activity.
For other impacts the effects on health and well-being have limited evidence, the spatial component is less pronounced or the spatial differentiation at a neighborhood scale is unsure. Among these non-included impacts are the lack of social interaction (e.g. Leyden, 2003), soil pollution (e.g. Vrijheid, 2000), electromagnetic fields (e.g. Röösli, 2008), the urban heat island effect (e.g. Tan et al., 2010) and unhealthy food environments (e.g. Rose and Richards, 2004).

3.1. Air pollution

Figure 4. Environmental impact scheme: air pollution

Air pollution is definitely one of the most important environmental impacts at a local scale. The local differentiation is mainly due to the spatial organization of roads and the accompanying traffic. Also industry can contribute to local air pollution but few research focuses on this aspect.

The relation between air pollution levels and roads has been investigated extensively. A lot of studies show that traffic intensity and/or distance to major streets or highways are important predictors of differences in measured pollutant concentrations, for NO_2 (Roorda-Knape et al., 1998), $PM_{2.5}$[3] (Fischer et al., 2000; Janssen et al., 2001), (ultra)fine particles (Hitchins et al., 2000; Zhu et al., 2002), elemental carbon or 'soot' (Roorda-Knape et al., 1998; Kinney et al., 2000), CO (Zhu et al., 2002), benzene (Fischer et al., 2000) and ozone (Kuhler et al., 1994). These relations indicate that the measured pollutants are related to vehicle exhaust emissions.
For most traffic volumes and pollutants, the major decrease in traffic-based pollutants occurs in the first 100 meters and then levels off somewhat after 150 meters (Zhu et al., 2002). However, until 1000 m of a highway a contribution of the road to local air pollution can be measured (Fischer et al., 2007).

[3] Particulate Matter (PM) with a diameter of 2.5 micrometers or less.

Today there is sufficient scientific evidence to conclude that living alongside busy roads is less healthy than situations with a bigger distance between the home and major roads.
The most important and most described health effects are in the field of the respiratory system, with increased *respiratory symptoms, lung growth deficits* and *allergy development* in children.
Many studies show an association between high vehicle traffic and chronic respiratory symptoms like cough and wheeze in children (e.g. Wjst et al., 1993; Oosterlee et al., 1996; Van Vliet et al., 1997; Hirsch et al., 1999; Venn et al., 2001; Nicolai et al., 2003; Shima et al., 2003; Andersen et al., 2008), or asthmatic symptoms and/or asthma hospitalizations (e.g. English et al., 1999; Lin et al., 2002; Brauer et al., 2007; Morgenstern et al., 2008; Nordling et al., 2008). A recent research by Gehring et al. (2010) provides further evidence that traffic-related air pollution exposure may contribute to the development of asthma in children, and not only aggravates existing symptoms.
Some cross-sectional studies in Europe have shown that deficits in lung function growth in children – associated with morbidity and mortality in adulthood (e.g. Knuiman et al., 1999) – are related to residential exposure to high (truck) traffic (Brunekreef et al., 1997; Sugiri et al., 2006). A highly cited research of Gauderman et al. (2007) showed that pronounced deficits in attained lung function at age 18 years were recorded for those living within 500 m of a freeway, for both asthmatic and non-asthmatic children, thus giving evidence for adverse effects of traffic exposure on otherwise healthy children.
Associations between distance to the nearest main road and the risk of allergy development and exacerbation of allergic reactions have also been demonstrated (e.g. Krämer et al., 2000; Brauer et al., 2007; Morgenstern et al., 2008; Nordling et al., 2008).

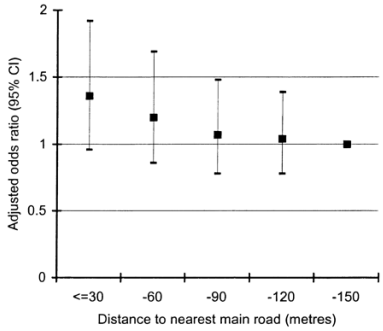

Figure 5. Exposure-response relationship between distance of the home from nearest main road and parent-reported wheeze in primary schoolchildren (Venn et al., 2001)

Further, chronic exposure to air pollution from traffic is associated with *increased mortality risks*. Several studies show that individuals who live close to major roads have an increased risk of mortality, although relative risks are generally small (e.g. Roemer and van Wijnen, 2001; Hoek et al., 2002; Finkelstein et al., 2004; Gehring et al., 2006; Beelen et al., 2008).

The assumption that increased mortality is primarily associated with a higher prevalence of *atherosclerosis* (the hardening of arteries) and *coronary disease* is supported by the research of Hoffman et al. (2007), who found that long-term residential exposure to high traffic is associated with the degree of coronary atherosclerosis, and Gan et al. (2011), who observed an association between exposure to road traffic and adverse cardiovascular outcomes.

In terms of proximity, most studies use distances of 50 to 300 meters to indicate exposure to traffic-related air pollution, but adverse effects on health have been observed in people living up to 1000 m from a busy road.
It is clear that the closer to a road people live, the higher the increase in adverse health effects, but there are no studies available that give evidence about an acceptable distance or a mathematical relationship. Each choice for an 'acceptable' distance between residential location and major roads or highways is not based on thresholds of health, but on the societal acceptability (Fischer et al., 2007).

3.2. Noise

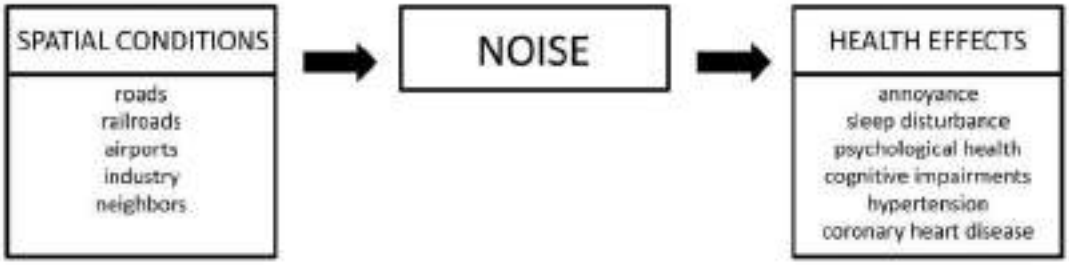

Figure 6. Environmental impact scheme: noise

Noise, defined as 'unwanted sound', is perceived as an environmental stressor and nuisance. It is an increasingly prominent feature of the urban environment and is being seen as an important environmental public health issue (Clark and Stansfeld, 2007). Noise is a phenomenon that is sensed and evaluated by everybody, and this is why noise exposure is one of the most frequent complaints of populations living in large cities (Muzet, 2007).

The direct auditory effects of noise on humans – like hearing loss – are well established. The corresponding sound levels and effects however do not occur in normal urban settings. Non-auditory effects, on the other hand, cannot be explained as a consequence of sound energy, but are the result of noise as a general stressor (Clark and Stansfeld, 2007).
Annoyance is the most reported problem caused by noise exposure and is often the primary outcome used to evaluate the effect of noise on communities (Ouis, 2001). Noise annoyance is a feeling of resentment, displeasure, discomfort, dissatisfaction, or offense when noise interferes with someone's thoughts, feelings or actual activities (Passchier-Vermeer and Passchier, 2000). Of all health effects associated

with noise, the dose-response relationship between community noise and annoyance is the most developed (Seto et al., 2007).
Associated with annoyance, there is both objective and subjective evidence for *sleep disturbance* by noise. Exposure to night-time noise can potentially interfere with the ability to fall asleep, shorten sleep duration, cause awakenings and reduce quality of sleep (Michaud et al., 2007). Sleep disturbance can have an important impact on well-being, causing after-effects during the day: annoyance, irritation, low mood, fatigue, low vigilance and impaired task performance (Stansfeld and Matheson, 2003; Muzet, 2007). Community studies of traffic noise exposure have found consistent evidence for a direct effect on sleep disturbance (e.g. Öhrström, 2002; Miedema and Vos, 2007).
Given the effect of chronic noise exposure on annoyance responses, it has been hypothesized that also *psychological health* might be affected. Studies of adults have confirmed that noise exposure relates to an increase in the number of reported psychological symptoms, such as anxiety and depression, higher levels of psychological distress and a higher prevalence of hyperactivity (e.g. Jones et al., 1981; Stansfeld et al., 1993; Haines et al., 2001a).
Further, strong evidence is available for a direct effect of noise on the *cognitive development of children*. Several studies have established that children exposed to noise experience some cognitive impairments – especially impaired reading comprehension and sustained attention – with the suggestion that the children's further cognitive development may be affected (e.g. Haines et al., 2001a; Haines et al., 2001b; Stansfeld et al., 2005). A highly cited field study was the naturally occurring longitudinal quasi-experiment reported by Evans and colleagues, examining the effect of the relocation of Munich airport on children's health and cognition (Evans et al., 1998; Hygge et al., 2002), demonstrating a causal link between noise exposure and cognitive effects.

There is also consistent and strengthening evidence for a small but significant effect of transport noise on *hypertension and coronary heart disease* (Babisch, 2006; Clark et al., 2007). One of the most striking results comes from Jarup et al. (2008), who found an increased risk of hypertension related to long-term aircraft and road traffic noise exposure. Other studies demonstrated an effect of transport noise exposure on the use of anti-hypertensive drugs (Greiser et al., 2007), self-reported hypertension (Rosenlund et al., 2001; Bluhm et al., 2007), heart attack (Babisch et al., 2005; Selander et al., 2009) and heart disease (Babisch et al., 2003; Babisch, 2006). Recently, findings of Gan et al. (2012) made clear that there are independent effects of traffic-related noise and air pollution on cardiovascular disease and mortality.

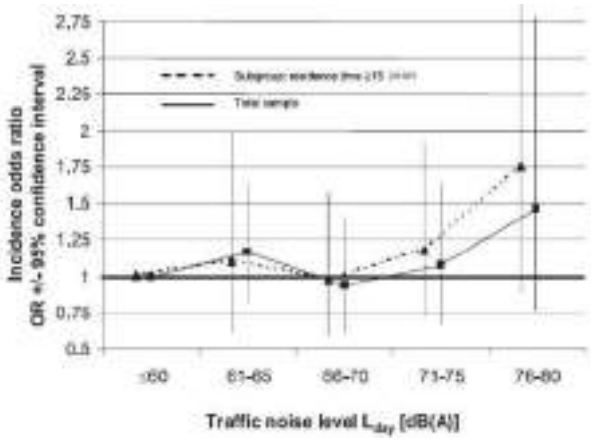

Figure 7. Association between road traffic noise level and incidence of heart attack (total sample vs. subgroup with minimum 15 years of residence time) (Babisch et al., 2005)

This overview shows that effects of noise are strongest for those outcomes – like annoyance and sleep disturbance – that can be classified under 'quality of life' rather than illness (Stansfeld and Matheson, 2003). What these effects lack in severity is made up for in numbers of people affected, as these responses are very widespread, and the chronic nature of exposure.

3.3. Absence of green space as a restorative environment

Figure 8. Environmental impact scheme: absence of a restorative environment

Since the beginning of the 21st century, a new research field has been set up, concerning the relation between the availability of green space in a neighborhood, associations with several health outcomes and the restorative effect as the mechanism behind. In this point of view, green space has to been seen as "open, undeveloped land with natural vegetation", including parks, forests, playing fields, and river corridors (Mitchell and Popham, 2008).

Today, evidence has been found for a positive relation between the amount of green space in the neighborhood and *self-perceived health* (de Vries et al., 2003; Maas et al., 2006; Mitchell and Popham, 2007; Sugiyama et al., 2008), a measure that

coincides very good with actual health and well-being (Jylhä, 2009). In these studies the relations are usually stronger for people with a lower social-economic status, and for youth and elderly. Further these studies suggest that quality of green spaces also plays an important role (Mitchell and Popham, 2007).
A recent study of Maas et al. (2009) showed that 15 of 24 assessed types of disease were less prevalent in living environments with more green space in a 1 km radius. The found relation between green space and physician-assessed morbidity was comparable with the relation between age and morbidity. The strongest association was found for *anxiety disorder and depression*, suggesting that mental health in particular might be affected by the amount of local green space. Also Nielsen and Hansen (2007) found a relation between access to green space around the dwelling and prevalence of *stress*.

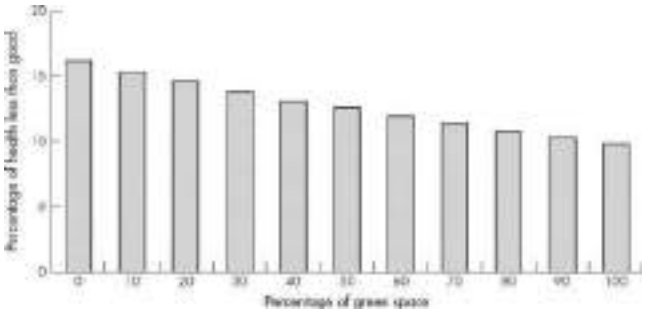

Figure 9. Relation between amount of green space (in a 3 km radius) and self-perceived health (Maas et al., 2006)

Further, the availability of green space seems to have a *moderating effect*. It was demonstrated that inequality in all-cause and circulatory mortality related to income deprivation is lower in populations who live in the greenest areas than in those who have less exposure to green space (Mitchell and Popham, 2008) and that the relationships of stressful life events with the number of health complaints, were significantly moderated by the amount of green space in the neighborhood (Wells and Evans, 2003; van den Berg et al., 2010). Other studies found a moderating effect of availability of green space on stress-related psychosocial symptoms from noise exposure (Gidlöf-Gunnarsson and Öhrström, 2007) and on the damage of traffic stress on individual's well-being (Song et al., 2007). These results support the notion that green space can provide a buffer against the negative health impacts of a lower social economic status, stressful life events or environmental stress factors.

Despite the growing amount of empirical evidence on the relation between availability of green space and human (mental) health, the way in which green space exerts a beneficial effect on health is uncertain. However, strong scientific evidence has been found for the positive effects of nature on recovery from stress and attention fatigue, the so-called Attention Restoration Theory (Kaplan and Kaplan, 1989; Verheij et al., 2008). Most of the evidence for the restorative effect comes from laboratory experiments that exposed participants to photographic simulations of various types of natural environments (van den Berg et al., 2003; van den Berg et al.,

2007), or controlled field studies that compared residents with natural elements in their view from the window to residents without such view (Kaplan, 2001). Several experimental studies have suggested that exposure to green spaces (either physical or visual) can also reduce blood pressure (Hartig et al., 2003; Pretty et al., 2005).

It can be concluded that the absence of green space in residential neighborhoods can have serious impacts on the health and especially the well-being of people. Probably the restorative quality of these small nature areas is the most important mechanism for this effect. Policy makers however tend to view green space more as a luxury good than as a basic necessity, and appear to overlook its potentially important effects on health and well-being (Groenewegen et al., 2006).

3.4. Lack of physical activity

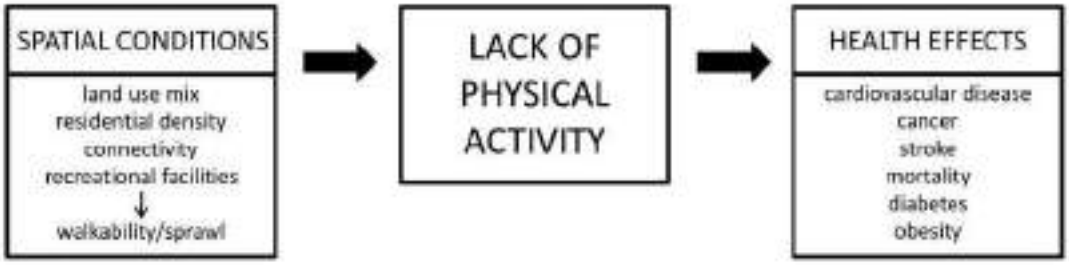

Figure 10. Environmental impact scheme: lack of physical activity

In recent years the relation between the built environment and physical activity has gained a lot of research interest. The idea is that low residential density, single-use zoning and low connectivity are associated with less walking and cycling (Frank, 2000; Frumkin, 2002).

Low levels of physical activity threaten health both directly and indirectly. The direct effects of a sedentary lifestyle consist of a higher risk on cardiovascular disease, stroke and all-cause mortality (e.g. Wannamethee et al., 1998; Sesso et al., 1999; Wannamethee and Shaper, 1999; Wei et al., 1999; Lee et al., 2000; Lee et al., 2003) and some cancers (e.g. Oliveria and Christos, 1997; Lee et al., 1999). Today, it is the second leading modifiable risk factor for chronic disease after smoking and it contributes significantly to total mortality in Western countries (Mathers et al., 2000).
In addition, lack of physical activity contributes significantly to the risk of being overweight, which in itself is a well-established risk factor for a number of diseases: heart disease, hypertension, stroke, osteoarthritis, gall bladder disease, some cancers and diabetes (e.g. Must et al., 1999; Mokdad et al., 2000). Also mortality is associated with obesity (e.g. Adams et al., 2006).
Obesity prevalence has risen steadily over the past decades. It is recognized as a major threat to public health, accounting for substantial disability and costs (e.g. Flegal et al., 2005; Olshansky et al., 2005; Caballero, 2007). Research has recently

expanded from a focus on individual determinants of obesity to investigating upstream influences in a social ecological model, including how the environment in which people live influences their lifestyle and weight. Of course, urban design does not fully account for increasingly sedentary lives, and physical inactivity does not tell the entire story of the epidemic of being overweight, but today there is a growing consensus on the environmental contribution to obesity (e.g. Hill et al., 2000; Frumkin, 2002).

Empirical research into the effects of the built environment on physical activity and obesity has increased dramatically in recent years (Day and Cardinal, 2007). Several recent review papers discuss the evidence to date (Saelens et al., 2003a; Booth et al., 2005; Duncan et al., 2005; Davison and Lawson, 2006; Kaczynski and Henderson, 2007; Papas et al., 2007; Wendel-Vos et al., 2007; Black and Macinko, 2008; Lee and Moudon, 2008; Feng et al., 2010; Renalds et al., 2010; Durand et al., 2011; Ding and Gebel, 2012). The concluding part of this subsection will go more deeply into the different measures that have been shown to be related to physical activity and obesity. The focus is on spatial characteristics that can be modified through urban policies and planning initiatives, not on simple design interventions.

Many reviews approve the relation between physical activity and the concept of *walkability* of a neighborhood, a measure mostly based on a combination of at least residential density, street connectivity and land use mix (Saelens et al., 2003b; Frank et al., 2007). A large amount of studies show that adults who live in walkable neighborhoods walk and cycle more for transportation and are more physically active (e.g. Takano et al., 2002; Berke et al., 2007; Frank et al., 2007; Handy et al., 2008; Lee and Moudon, 2008). Also the county *sprawl* index of Ewing et al. (2003), based on measures of low residential density and poor street accessibility, is related to physical activity, with residents of sprawling counties walking significantly less.
The variables used to form these two measures are also individually associated with physical activity levels. *Land use mix*, notably mixed commercial-residential land use, is associated with higher levels of physical (walking) activity (e.g. Doyle et al., 2006; Frank et al., 2006; Li et al., 2008). Also the related characteristic of proximity to retail stores and commercial establishments appears to increase physical activity levels (e.g. Berke et al., 2007; Nagel et al., 2008). Some studies confirm the association of *residential density* with physical activity, for example using measures based on population density (Frank et al., 2005) or compactness of urban settings (Frank et al., 2006). Also *connectivity* of the local transport network is associated with physical activity levels, with positive relations found for bike lane connectivity (Titze et al., 2008), intersection density (Frank et al., 2006) or size of neighborhood blocks (Wood et al., 2008).
Finally there is substantial evidence that proximity to a *variety of accessible recreational facilities* (such as parks, playgrounds, sports grounds, recreation areas) is associated with higher physical activity levels. The relation has been found for all ages (e.g. Giles-Corti and Donovan, 2002; Wendel-Vos et al., 2004) as well as for specific target groups like children (Roemmich et al., 2006), adolescents (Babey et al., 2008), and elderly (Kemperman and Timmerman, 2009).

Concerning obesity, in general the available reviews conclude that there is a lot of evidence available about a relation with the built environment, but much uncertainty about the specific associations. Given the large-range factors which affect weight status and potential time-lags between exposure and change in bodyweight, the lack of a strong association with weight outcomes found in cross-sectional studies is however unsurprising (Durand et al., 2011).
Based on the selected reviews obesity or increased body mass index can be linked to *walkability* (e.g. Frank et al., 2004; Frank et al., 2007; Rundle et al., 2008), *sprawl* (e.g. Kelly-Schwartz et al., 2004; Ewing et al., 2006; Joshu et al., 2008), *mixed land use* (e.g. Frank et al., 2004; Mobley et al., 2006; Bodea et al., 2008; Rundle et al., 2008), *population density* (e.g. Lopez-Zetina et al., 2006; Rundle et al., 2007; Stafford et al., 2007) and *access to recreational facilities* (e.g. Giles-Corti et al., 2003; Burdette and Whitaker, 2004).

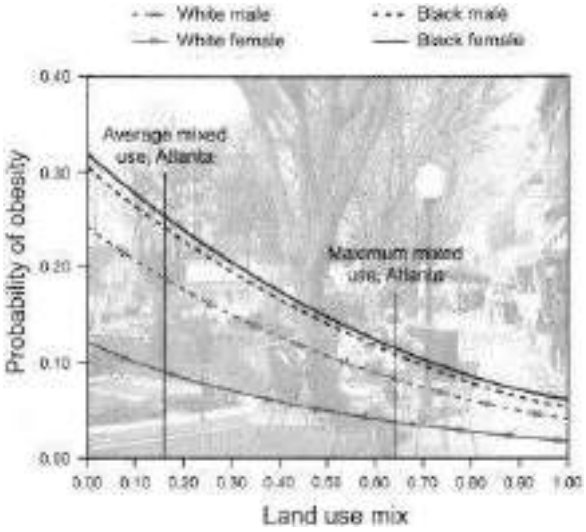

Figure 11. Probability of obesity in relation to land use mix, for different gender and race (Frank et al., 2004)

Although the importance of several urban design measures is evident, there is no agreement about which factors would be the most effective or efficient targets for intervention. It is however clear that (a combination) of the discussed measures can be used to support urban design choices and to evaluate neighborhood suitability for physical activity.

4. Discussion

Without having the ambition to give a complete overview of the state of the art knowledge, the exploratory literature study in this paper shows that the relation between urban planning and health definitely needs our attention. The health relevance of the four described impacts is founded by a considerable amount of empirical evidence, of which only a part is mentioned in this paper. Although no firm

conclusions can be provided on the quantification of these impacts, it is very likely that for each impact a comparable impact-effect relation exists, with higher negative impacts leading to more serious health and well-being consequences.
These four impacts are of high relevance for urban planning, because they can be acted on by urban planners and designers. The location of infrastructures like roads and railroads and the traffic intensity can have an effect on air pollution and noise, the planning of green space in cities can create restorative environments and increase the mental health and well-being of nearby residents, the residential density and mixed land use of neighborhoods can contribute to higher levels of physical activity. These examples show that it is important that the results from environmental research are incorporated in spatial planning policy and design. Despite planning concern for the 'quality of life', a conspicuous lack of integration of disciplines in relation to settlement planning remains (Barton, 2005). There is definitely a need for more collaboration between environmental scientists and urban planners and designers, in order to know more about which community design and land-use choices are most effective in improving the physical, mental and social well-being of people (Dannenberg et al., 2003).

The four discussed impacts create differences in health and well-being at a neighborhood scale and thus contribute greatly to environmental inequality. This supports the idea of implementing environmental justice as a generic rule in urban planning, based on the idea of well-being and living quality as a universal right for every citizen. In realizing this objective, interventions at the neighborhood level are needed, to come to equity at a city level. These spatial planning interventions can be very diverse. To influence the impacts of air pollution and noise, both measures to limit the emissions as measures to limit the exposure are possible. An example of the former is an urban transport policy aimed at lowering private car use in the city. An example of the latter is the avoidance of construction of certain buildings (schools, hospitals, houses) within a certain distance from major roads, by setting out setbacks (Hitchins et al., 2000). Some legislations (e.g. British Columbia Ministry of Environment, 2006) already implement such distance measures. To influence the impacts of absence of green space and absence of environments stimulating physical activity, interventions apply most to the urban design process. For example, urban designers can take care of the availability of green and the realization of a mixed residential and commercial land use in urban renewal processes.
It is however impossible to create a perfect living environment with the ideal conditions for human health. On the one hand, the spatial conditions of the four concerned impacts are often interfering with each other. For example, the higher the population density and mixed residential and commercial land use in a neighborhood, the more physically active people will be, but also the more people will complain about neighbor and activity noise, and vice versa (see Gauderman et al., 2007; Moudon, 2009). On the other hand, the financial means of cities and planning departments are usually restricted, making it necessary to make choices.

To support a health promoting planning policy, insight is needed in the effects of a combination of different impacts and in the amount of people that are positively or

negatively affected in their health and well-being by planning decisions. To the best of our knowledge, today no studies can be found where the combined effect of different impacts is assessed. Thus there is definitely need for a more integrative approach, in which different health impacts are combined into one framework, to make an integral assessment of environmental quality (The Health Council of the Netherlands, 2008).
The research project at hand, in which this paper forms a first step, can substantially contribute to this aim. The project wants to create a spatial geographical model (with GIS software) in which the different impacts with an effect on health and well-being can be presented layer by layer, and be combined in a final 'environmental health map' of an urban region. This model would start from the discerned impacts in this literature study and available quantification methods. If the modeling is successful, a tool will be available that can be used by spatial planners to evaluate the combined environmental quality of a spatial location. This tool would make it easier to understand spatial variations in environmental impacts and health effects and city planners may use it to better balance the health effects of spatial interventions. Also, this tool would make it possible to track the health of a community as it develops, and to suggest spatial interventions where the most people would benefit. In this way the tool can help urban planning in the pursuit of fulfilling the universal right of well-being and living quality for every citizen.

References

Adams, K. F., Schatzkin, A., Harris, T. B., Kipnis, V., Mouw, T., Ballard-Barbash, R., Hollenbeck, A., Leitzmann, M. F., 2006. Overweight, obesity, and mortality in a large prospective cohort of persons 50 to 71 years old. New England Journal of Medicine, 355(8), pp. 763-778.

Andersen, Z. J., Loft, S., Ketzel, M., Stage, M., Scheike, T., Hermansen, M. N., Bisgaard, H., 2008. Ambient air pollution triggers wheezing symptoms in infants. Thorax, 63(8), pp. 710-716.

Babey, S. H., Hastert, T. A., Yu, H., Brown, E. R., 2008. Physical activity among adolescents: when do parks matter? American Journal of Preventive Medicine, 34(4), pp. 345-348.

Babisch, W., 2006. Transportation noise and cardiovascular risk: updated review and synthesis of epidemiological studies indicate that the evidence has increased. Noise and Health, 8(30), pp. 1-29.

Babisch, W., Beule, B., Schust, M., Kersten, N., Ising, H., 2005. Traffic noise and risk of myocardial infarction. Epidemiology, 16(1), pp. 33-40.

Babisch, W., Ising, H., Gallacher, J. E. J., 2003. Health status as a potential effect modifier of the relation between noise annoyance and incidence of ischaemic heart disease. Occupational and Environmental Medicine, 60(10), pp. 739-745.

Barton, H., 2005. A health map for urban planners. Built Environment, 31(4), pp. 339-355.

Barton, H., 2009. Land use planning and health and well-being. Land Use Policy, 26(Supplement 1), pp. S115-S123.

Barton, H., 2010. Strengthening the roots of planning. Planning Theory & Practice, 11(1), pp. 95-101.

Barton, H., Grant, M., 2006. A health map for the local human habitat. The Journal of the Royal Society for the Promotion of Health, 126(6), pp. 252-253.

Barton, H., Grant, M., Mitcham, C., Tsourou, C., 2009. Healthy urban planning in European cities. Health Promotion International, 24(suppl 1), pp. i91-i99.

Beelen, R., Hoek, G., van den Brandt, P. A., Goldbohm, R. A., Fischer, P., Schouten, L. J., Jerrett, M., Hughes, E., Armstrong, B., Brunekreef, B., 2008. Long-term effects of traffic-related air pollution on mortality in a Dutch cohort (NLCS-AIR study). Environmental Health Perspectives, 116(2), pp. 196-202.

Berke, E. M., Koepsell, T. D., Moudon, A. V., Hoskins, R. E., Larson, E. B., 2007. Association of the built environment with physical activity and obesity in older persons. American Journal of Public Health, 97(3), pp. 486-492.

Black, J. L., Macinko, J., 2008. Neighborhoods and obesity. Nutrition Reviews, 66(1), pp. 2-20.

Bluhm, G. L., Berglind, N., Nordling, E., Rosenlund, M., 2007. Road traffic noise and hypertension. Occupational and Environmental Medicine, 64(2), pp. 122-126.

Bodea, T., Garrow, L., Meyer, M., Ross, C., 2008. Explaining obesity with urban form: a cautionary tale. Transportation, 35(2), pp. 179-199.

Booth, K. M., Pinkston, M. M., Poston, W. S. C., 2005. Obesity and the built environment. Journal of the American Dietetic Association, 105(5, Supplement), pp. 110-117.

Brauer, M., Hoek, G., Smit, H. A., de Jongste, J. C., Gerritsen, J., Postma, D. S., Kerkhof, M., Brunekreef, B., 2007. Air pollution and development of asthma, allergy and infections in a birth cohort. European Respiratory Journal, 29(5), pp. 879-888.

British Columbia Ministry of Environment, 2006. Environmental best management practices for urban and rural land development in British Columbia: air quality BMPs and supporting information.

Brulle, R. J., Pellow, D. N., 2006. Environmental justice: human health and environmental inequalities. Annual Review of Public Health, 27, pp. 103-124.

Brunekreef, B., Janssen, N. A., de Hartog, J., Harssema, H., Knape, M., van Vliet, P., 1997. Air pollution from truck traffic and lung function in children living near motorways. Epidemiology (Cambridge, Mass.), 8(3), pp. 298-303.

Burdette, H. L., Whitaker, R. C., 2004. Neighborhood playgrounds, fast food restaurants, and crime: relationships to overweight in low-income preschool children. Preventive Medicine, 38(1), pp. 57-63.

Caballero, B., 2007. The global epidemic of obesity: an overview. Epidemiologic Reviews, 29(1), pp. 1-5.

Clark, C., Myron, R., Stansfeld, S., Candy, B., 2007. A systematic review of the evidence on the effect of the built and physical environment on mental health. Journal of Public Mental Health, 6(2), pp. 14-27.

Clark, C., Stansfeld, S. A., 2007. The effect of transportation noise on health and cognitive development: a review of recent evidence. International Journal of Comparative Psychology, 20(2).

Dannenberg, A. L., Jackson, R. J., Frumkin, H., Schieber, R. A., Pratt, M., Kochtitzky, C., Tilson, H. H., 2003. The impact of community design and land-use choices on public health: a scientific research agenda. American Journal of Public Health, 93(9), pp. 1500-1508.

Davison, K., Lawson, C., 2006. Do attributes in the physical environment influence children's physical activity? A review of the literature. International Journal of Behavioral Nutrition and Physical Activity, 3(1).

Day, K., Cardinal, B. J., 2007. A second generation of active living research. American Journal of Health Promotion, 21(4s), pp. iv-vii.

de Hollander, A. E. M., Bol, P., 2004. Friend and foe: health and the environment from an historical-epidemiological perspective. In: Assessing and evaluating the health impact of environmental exposures “Deaths, DALYs or Dollars?”, Bilthoven: RIVM, pp. 9-29.

de Hollander, A. E. M., Melse, J. M., Lebret, E., Kramers, P. G. N., 1999. An aggregate public health indicator to represent the impact of multiple environmental exposures. Epidemiology, 10(5), pp. 606-617.

de Hollander, A. E. M., Staatsen, B. A. M., 2003. Health, environment and quality of life: an epidemiological perspective on urban development. Landscape and Urban Planning, 65, pp. 53-62.

de Vries, S., Verheij, R. A., Groenewegen, P. P., Spreeuwenberg, P., 2003. Natural environments - healthy environments? An exploratory analysis of the relationship between greenspace and health. Environment and Planning A, 35(10), pp. 1717-1731.

Ding, D., Gebel, K., 2012. Built environment, physical activity, and obesity: What have we learned from reviewing the literature? Health & Place, 18(1), pp. 100-105.

Doyle, S., Kelly-Schwartz, A., Schlossberg, M., Stockard, J., 2006. Active community environments and health: the relationship of walkable and safe communities to individual health. Journal of the American Planning Association, 72(1), pp. 19-31.

Duncan, M., Spence, J., Mummery, W. K., 2005. Perceived environment and physical activity: a meta-analysis of selected environmental characteristics. International Journal of Behavioral Nutrition and Physical Activity, 2(1).

Durand, C. P., Andalib, M., Dunton, G. F., Wolch, J., Pentz, M. A., 2011. A systematic review of built environment factors related to physical activity and obesity risk: implications for smart growth urban planning. Obesity Reviews, 12(5), pp. e173-e182.

English, P., Neutra, R., Scalf, R., Sullivan, M., Waller, L., Zhu, L., 1999. Examining associations between childhood asthma and traffic flow using a geographic information system. Environ Health Perspect, 107(9), pp. 761-7.

Evans, G. W., Bullinger, M., Hygge, S., 1998. Chronic noise exposure and physiological response: a prospective study of children living under environmental stress. Psychological Science, 9(1), pp. 75-77.

Ewing, R., Brownson, R. C., Berrigan, D., 2006. Relationship between urban sprawl and weight of United States youth. American Journal of Preventive Medicine, 31(6), pp. 464-474.

Ewing, R., Pendall, R., Chen, D., 2003. Measuring sprawl and its transportation impacts. Transportation Research Record: Journal of the Transportation Research Board, 1831(-1), pp. 175-183.

Feng, J., Glass, T. A., Curriero, F. C., Stewart, W. F., Schwartz, B. S., 2010. The built environment and obesity: a systematic review of the epidemiologic evidence. Health & Place, 16(2), pp. 175-190.

Finkelstein, M. M., Jerrett, M., Sears, M. R., 2004. Traffic air pollution and mortality rate advancement periods. American Journal of Epidemiology, 160(2), pp. 173-177.

Fischer, P. H., Hoek, G., van Reeuwijk, H., Briggs, D. J., Lebret, E., van Wijnen, J. H., Kingham, S., Elliott, P. E., 2000. Traffic-related differences in outdoor and indoor concentrations of particles and volatile organic compounds in Amsterdam. Atmospheric Environment, 34, pp. 3713-3722.

Fischer, P. H., Marra, M., Wesseling, J., Cassee, F. R., 2007. Invloed van de afstand tot een drukke verkeersweg op de lokale luchtkwaliteit en de gezondheid: een quick scan. Rijksinstituut voor Volksgezondheid en Milieu (RIVM).

Flegal, K. M., Graubard, B. I., Williamson, D. F., Gail, M. H., 2005. Excess deaths associated with underweight, overweight, and obesity. Journal of the American Medical Association, 293(15), pp. 1861-7.

Frank, L. D., 2000. Land use and transportation interaction. Journal of Planning Education and Research, 20(1), pp. 6-22.

Frank, L. D., Andresen, M. A., Schmid, T. L., 2004. Obesity relationships with community design, physical activity, and time spent in cars. American Journal of Preventive Medicine, 27(2), pp. 87-96.

Frank, L. D., Saelens, B. E., Powell, K. E., Chapman, J. E., 2007. Stepping towards causation: do built environments or neighborhood and travel preferences explain physical activity, driving, and obesity? Social Science & Medicine, 65(9), pp. 1898-1914.

Frank, L. D., Sallis, J. F., Conway, T. L., Chapman, J. E., Saelens, B. E., Bachman, W., 2006. Many pathways from land use to health: associations between neighborhood walkability and active transportation, body mass index, and air quality. Journal of the American Planning Association, 72(1), pp. 75-87.

Frank, L. D., Schmid, T. L., Sallis, J. F., Chapman, J., Saelens, B. E., 2005. Linking objectively measured physical activity with objectively measured urban form: Findings from SMARTRAQ. American Journal of Preventive Medicine, 28(2, Supplement 2), pp. 117-125.

Frumkin, H., 2002. Urban sprawl and public health. Public Health Reports, 117, pp. 201-217.

Galea, S., Vlahov, D., 2005. Urban health: evidence, challenges, and directions. Annual Review of Public Health, 26(1), pp. 341-365.

Gan, W. Q., Davies, H. W., Koehoorn, M., Brauer, M., 2012. Association of long-term exposure to community noise and traffic-related air pollution With coronary heart disease mortality. American Journal of Epidemiology, 175(9), pp. 898-906.

Gan, W. Q., Koehoorn, M., Davies, H. W., Demers, P. A., Tamburic, L., Brauer, M., 2011. Long-term exposure to traffic-related air pollution and the risk of coronary heart disease hospitalization and mortality. Environ Health Perspect, 119(4), pp. 501-7.

Gauderman, W. J., Vora, H., McConnell, R., Berhane, K., Gilliland, F., Thomas, D., Lurmann, F., Avol, E., Kunzli, N., Jerrett, M., Peters, J., 2007. Effects of exposure to traffic on lung development from 10 to 18 years of age: a cohort study. Lancet, 369, pp. 571-577.

Gehring, U., Heinrich, J., Krämer, U., Grote, V., Hochadel, M., Sugiri, D., Kraft, M., Rauchfuss, K., Eberwein, H. G., Wichmann, H. E., 2006. Long-term exposure to ambient air pollution and cardiopulmonary mortality in women. Epidemiology, 17(5), pp. 545-551.

Gehring, U., Wijga, A. H., Brauer, M., Fischer, P., de Jongste, J. C., Kerkhof, M., Oldenwening, M., Smit, H. A., Brunekreef, B., 2010. Traffic-related air pollution and the development of asthma and allergies during the first 8 years of life. American Journal of Respiratory and Critical Care Medicine, 181(6), pp. 596-603.

Gidlöf-Gunnarsson, A., Öhrström, E., 2007. Noise and well-being in urban residential environments: The potential role of perceived availability to nearby green areas. Landscape and Urban Planning, 83(2–3), pp. 115-126.

Giles-Corti, B., Donovan, R. J., 2002. The relative influence of individual, social and physical environment determinants of physical activity. Social Science & Medicine, 54(12), pp. 1793-1812.

Giles-Corti, B., Macintyre, S., Clarkson, J. P., Pikora, T., Donovan, R. J., 2003. Environmental and lifestyle factors associated with overweight and obesity in Perth, Australia. American Journal of Health Promotion, 18(1), pp. 93-102.

Greiser, E., Greiser, C., Janhsen, K., 2007. Night-time aircraft noise increases prevalence of prescriptions of antihypertensive and cardiovascular drugs irrespective of social class—the Cologne-Bonn Airport study. Journal of Public Health, 15(5), pp. 327-337.

Groenewegen, P. P., van den Berg, A. E., de Vries, S., Verheij, R. A., 2006. Vitamin G: effects of green space on health, well-being, and social safety. BMC Public Health, 6(1).

Haines, M. M., Stansfeld, S. A., Job, R. F. S., Berglund, B., Head, J., 2001a. Chronic aircraft noise exposure, stress responses, mental health and cognitive performance in school children. Psychological Medicine: A Journal of Research in Psychiatry and the Allied Sciences, 31(2), pp. 265-277.

Haines, M. M., Stansfeld, S. A., Job, R. F. S., Berglund, B., Head, J., 2001b. A follow-up study of effects of chronic aircraft noise exposure on child stress responses and cognition. International Journal of Epidemiology, 30(4), pp. 839-845.

Handy, S. L., Cao, X., Mokhtarian, P. L., 2008. The causal influence of neighborhood design on pysical activity within the neighborhood: evidence from Northern California. American Journal of Health Promotion, 22(5), pp. 350-358.

Hartig, T., Evans, G. W., Jamner, L. D., Davis, D. S., Gärling, T., 2003. Tracking restoration in natural and urban field settings. Journal of Environmental Psychology, 23(2), pp. 109-123.

Hill, J. O., Wyatt, H. R., Melanson, E. L., 2000. Genetic and environmental contributions to obesity. Medical Clinics of North America, 84(2), pp. 333-346.

Hirsch, T., Weiland, S. k., Von Mutius, E., Safeca, A. f., Gräfe, H., Csaplovics, E., Duhme, H., Keil, U., Leupold, W., 1999. Inner city air pollution and respiratory health and atopy in children. European Respiratory Journal, 14(3), pp. 669-677.

Hitchins, J., Morawska, L., Wolff, R., Gilbert, D., 2000. Concentrations of submicrometre particles from vehicle emissions near a major road. Atmospheric Environment, 34, pp. 51-59.

Hoek, G., Brunekreef, B., Goldbohm, S., Fischer, P., Van den Brandt, P. A., 2002. Association between mortality and indicators of traffic-related air pollution in the Netherlands: a cohort study. Lancet, 360, pp. 1203-1209.

Hoffman, B., Moebus, S., Möhlenkamp, S., Stang, A., Lehmann, N., Dragano, N., Schmermund, A., Memmesheimer, M., Mann, K., Erbel, R., Jöckel, K.-H., 2007. Residential exposure to traffic is associated with coronary atherosclerosis. Circulation, 116, pp. 489-496.

Hygge, S., Evans, G. W., Bullinger, M., 2002. A prospective study of some effects of aircraft noise on cognitive performance in schoolchildren. Psychological Science, 13(5), pp. 469-474.

IUCN, 1980. World Conservation Strategy. Geneva (Switzerland): International Union for Conservation of Nature and Natural Resources (IUCN).

Jackson, L. E., 2003a. The relationship of urban design to human health and condition. Landscape and Urban Planning, 64, pp. 191-200.

Jackson, R. J., 2003b. The impact of the built environment on health: an emerging field. American Journal of Public Health, 93(9), pp. 1382-1384.

Janssen, N. A. H., van Vliet, P. H. N., Aarts, F., Harssema, H., Brunekreef, B., 2001. Assessment of exposure to traffic related air pollution of children attending schools near motorways. Atmospheric Environment, 35, pp. 3875-3884.

Jarup, L., Babisch, W., Houthuijs, D., Pershagen, G., Katsouyanni, K., Cadum, E., Dudley, M. L., Savigny, P., Seiffert, I., Swart, W., Breugelmans, O., Bluhm, G., Selander, J., Haralabidis, A., Dimakopoulou, K., Sourtzi, P., Velonakis, M., Vigna-Taglianti, F., 2008. Hypertension and exposure to noise near airports: the HYENA study. Environ Health Perspect, 116(3), pp. 329-33.

Jones, D. M., Chapman, A. J., Auburn, T. C., 1981. Noise in the environment: A social perspective. Journal of Environmental Psychology, 1(1), pp. 43-59.

Joshu, C. E., Boehmer, T. K., Brownson, R. C., Ewing, R., 2008. Personal, neighbourhood and urban factors associated with obesity in the United States. Journal of Epidemiology and Community Health, 62(3), pp. 202-208.

Jylhä, M., 2009. What is self-rated health and why does it predict mortality? Towards a unified conceptual model. Social Science & Medicine, 69(3), pp. 307-316.

Kaczynski, A. T., Henderson, K. A., 2007. Environmental correlates of physical activity: a review of evidence about parks and recreation. Leisure Sciences, 29(4), pp. 315-354.

Kaplan, R., 2001. The nature of the view from home: psychological benefits. Environment and Behavior, 33(4), pp. 507-542.

Kaplan, R., Kaplan, S., 1989. The experience of nature: a psychological perspective. Cambridge University Press.

Kelly-Schwartz, A. C., Stockard, J., Doyle, S., Schlossberg, M., 2004. Is sprawl unhealthy? Journal of Planning Education and Research, 24(2), pp. 184-196.

Kemperman, A., Timmerman, H., 2009. Influences of built environment on walking and cycling by latent segments of aging population. Transportation Research Record: Journal of the Transportation Research Board, 2134(-1), pp. 1-9.

Kinney, P. L., Aggarwal, M., Northridge, M. E., Janssen, N. A., Shepard, P., 2000. Airborne concentrations of PM(2.5) and diesel exhaust particles on Harlem sidewalks: a community-based pilot study. Environmental Health Perspectives, 108(3), pp. 213-8.

Knuiman, M. W., James, A. L., Divitini, M. L., Ryan, G., Bartholomew, H. C., Musk, A. W., 1999. Lung function, respiratory symptoms, and mortality: results from the Busselton Health Study. Annals of Epidemiology, 9(5), pp. 297-306.

Kohlhuber, M., Mielck, A., Weiland, S. K., Bolte, G., 2006. Social inequality in perceived environmental exposures in relation to housing conditions in Germany. Environmental Research, 101, pp. 246-255.

Krämer, U., Koch, T., Ranft, U., Ring, J., Behrendt, H., 2000. Traffic-related air pollution Is associated with atopy in children living in urban areas. Epidemiology, 11(1), pp. 64-70.

Kuhler, M., Kraft, J., Bess, H., Heeren, U., Schürmann, D., 1994. Comparison between measured and calculated concentrations of nitrogen oxides and ozone in the vicinity of a motorway. Science of The Total Environment, 146–147(0), pp. 387-394.

Laurent, O., Bard, D., Filleul, L., Segala, C., 2007. Effect of socioeconomic status on the relationship between atmospheric pollution and mortality. Journal of Epidemiology and Community Health, 61(8), pp. 665-675.

Lee, C., Moudon, A. V., 2008. Neighbourhood design and physical activity. Building Research & Information, 36(5), pp. 395-411.

Lee, C. D., Folsom, A. R., Blair, S. N., 2003. Physical activity and stroke risk. Stroke, 34(10), pp. 2475-2481.

Lee, I. M., Sesso, H. D., Paffenbarger, R. S., 1999. Physical activity and risk of lung cancer. International Journal of Epidemiology, 28(4), pp. 620-625.

Lee, I. M., Sesso, H. D., Paffenbarger, R. S., 2000. Physical activity and coronary heart disease risk in men: does the duration of exercise episodes predict risk? Circulation, 102(9), pp. 981-986.

Leyden, K. M., 2003. Social capital and the built environment: the importance of walkable neighborhoods. American Journal of Public Health, 93(9), pp. 1546-1551.

Li, F., Harmer, P. A., Cardinal, B. J., Bosworth, M., Acock, A., Johnson-Shelton, D., Moore, J. M., 2008. Built environment, adiposity, and physical activity in adults aged 50–75. American Journal of Preventive Medicine, 35(1), pp. 38-46.

Lin, S., Munsie, J. P., Hwang, S.-A., Fitzgerald, E., Cayo, M. R., 2002. Childhood asthma hospitalization and residential exposure to state route traffic. Environmental Research, 88(2), pp. 73-81.

Lomborg, B., 2001. The skeptical environmentalist. Cambridge University Press.

Lopez-Zetina, J., Lee, H., Friis, R., 2006. The link between obesity and the built environment. Evidence from an ecological analysis of obesity and vehicle miles of travel in California. Health & Place, 12(4), pp. 656-664.

Maas, J., Verheij, R. A., de Vries, S., Spreeuwenberg, P., Schellevis, F. G., Groenewegen, P. P., 2009. Morbidity is related to a green living environment. Journal of Epidemiology and Community Health, 63(12), pp. 967-973.

Maas, J., Verheij, R. A., Groenewegen, P. P., de Vries, S., Spreeuwenberg, P., 2006. Green space, urbanity, and health: how strong is the relation? Journal of Epidemiology and Community Health, 60, pp. 587-592.

Mathers, C. D., Vos, E. T., Stevenson, C. E., Begg, S. J., 2000. The Australian Burden of Disease Study: measuring the loss of health from diseases, injuries and risk factors. The Medical journal of Australia, 172(12), pp. 592-6.

Melse, J. M., de Hollander, A., 2001. Environment and health within the OECD-region: lost health, lost money. Bilthoven, the Netherlands: National Institute of Public Health and the Environment (RIVM).

Michaud, D. S., Fidell, S., Pearsons, K., Campbell, K. C., Keith, S. E., 2007. Review of field studies of aircraft noise-induced sleep disturbance. The Journal of the Acoustical Society of America, 121(1), pp. 32-41.

Miedema, H. M. E., Vos, H., 2007. Associations between self-reported sleep disturbance and environmental noise based on reanalyses of pooled data from 24 studies. Behavioral Sleep Medicine, 5(1), pp. 1-20.

Mitchell, R., Popham, F., 2007. Greenspace, urbanity and health: relationships in England. Journal of Epidemiology and Community Health, 61(8), pp. 681-683.

Mitchell, R., Popham, F., 2008. Effect of exposure to natural environment on health inequalities: an observational population study. Lancet, 372, pp. 1655-1660.

Mobley, L. R., Root, E. D., Finkelstein, E. A., Khavjou, O., Farris, R. P., Will, J. C., 2006. Environment, obesity, and cardiovascular disease risk in low-income women. American Journal of Preventive Medicine, 30(4), pp. 327-332.

Mokdad, A. H., Serdula, M. K., Dietz, W. H., Bowman, B. A., Marks, J. S., Koplan, J. P., 2000. The continuing epidemic of obesity in the United States. Journal of the American Medical Association, 284(13), pp. 1650-1651.

Morgenstern, V., Zutavern, A., Cyrys, J., Brockow, I., Koletzko, S., Krämer, U., Behrendt, H., Herbarth, O., von Berg, A., Bauer, C. P., Wichmann, H.-E., Heinrich, J., 2008. Atopic diseases, allergic sensitization, and exposure to traffic-related air pollution in children. American Journal of Respiratory and Critical Care Medecine, 177, pp. 1-7.

Moudon, A. V., 2009. Real noise from the urban environment. How ambient community noise affects health and what can be done about it. American Journal of Preventive Medicine, 37(2), pp. 167-171.

Must, A., Spadano, J., Coakley, E. H., Field, A. E., Colditz, G., Dietz, W. H., 1999. The disease burden associated with overweight and obesity. Journal of the American Medical Association, 282(16), pp. 1523-9.

Muzet, A., 2007. Environmental noise, sleep and health. Sleep Medicine Reviews, 11(2), pp. 135-142.

Nagel, C. L., Carlson, N. E., Bosworth, M., Michael, Y. L., 2008. The relation between neighborhood built environment and walking activity among older adults. American Journal of Epidemiology, 168(4), pp. 461-468.

Newman, P. W. G., 1999. Sustainability and cities: extending the metabolism model. Landscape and Urban Planning, 44(4), pp. 219-226.

Nicolai, T., Carr, D., Weiland, S. K., Duhme, H., von Ehrenstein, O., Wagner, C., von Mutius, E., 2003. Urban traffic and pollutant exposure related to respiratory outcomes and atopy in a large sample of children. European Respiratory Journal, 21(6), pp. 956-963.

Nielsen, T. S., Hansen, K. B., 2007. Do green areas affect health? Results from a Danish survey on the use of green areas and health indicators. Health & Place, 13(4), pp. 839-850.

Nordling, E., Berglind, N., Melén, E., Emenius, G., Hallberg, J., Nyberg, F., Pershagen, G., Svartengren, M., Wickman, M., Bellander, T., 2008. Traffic-related air pollution and childhood respiratory symptoms, function and allergies. Epidemiology, 19(3), pp. 401-408.

O'Neill, M., Simard, P., 2006. Choosing indicators to evaluate Healthy Cities projects: a political task? Health Promotion International, 21(2), pp. 145-152.

Öhrström, E., 2002. Sleep studies before and after - results and comparison of different methods. Noise and Health, 4(15), pp. 65-67.

Oliveria, S. A., Christos, P. J., 1997. The epidemiology of physical activity and cancer. Annals of the New York Academy of Sciences, 833(1), pp. 79-90.

Olshansky, S. J., Passaro, D. J., Hershow, R. C., Layden, J., Carnes, B. A., Brody, J., Hayflick, L., Butler, R. N., Allison, D. B., Ludwig, D. S., 2005. A potential decline in life expectancy in the United States in the 21st century. New England Journal of Medicine, 352(11), pp. 1138-1145.

Oosterlee, A., Drijver, M., Lebret, E., Brunekreef, B., 1996. Chronic respiratory symptoms in children and adults living along streets with high traffic density. Occupational and Environmental Medicine, 53(4), pp. 241-247.

Ouis, D., 2001. Annoyance from road traffic noise: a review. Journal of Environmental Psychology, 21(1), pp. 101-120.

Papas, M. A., Alberg, A. J., Ewing, R., Helzlsouer, K. J., Gary, T. L., Klassen, A. C., 2007. The built environment and obesity. Epidemiologic Reviews, 29(1), pp. 129-143.

Passchier-Vermeer, W., Passchier, W. F., 2000. Noise exposure and public health. Environmental Health Perspectives, 108(Suppl.1), pp. 123-131.

Perlin, S. A., Sexton, K. E. N., Wong, D. W. S., 1999. An examination of race and poverty for populations living near industrial sources of air pollution. 9(1), pp. 29-48.

Pickett, K. E., Pearl, M., 2001. Multilevel analyses of neighbourhood socioeconomic context and health outcomes: a critical review. Journal of Epidemiology and Community Health, 55(2), pp. 111-122.

Pretty, J., Peacock, J., Sellens, M., Griffin, M., 2005. The mental and physical health outcomes of green exercise. International Journal of Environmental Health Research, 15(5), pp. 319-337.

Renalds, A., Smith, T. H., Hale, P. J., 2010. A systematic review of built environment and health. Family & Community Health, 33(1), pp. 68-78.

Roemer, W. H., van Wijnen, J. H., 2001. Daily mortality and air pollution along busy streets in Amsterdam, 1987-1998. Epidemiology, 12(6), pp. 649-653.

Roemmich, J. N., Epstein, L. H., Raja, S., Yin, L., Robinson, J., Winiewicz, D., 2006. Association of access to parks and recreational facilities with the physical activity of young children. Preventive Medicine, 43(6), pp. 437-441.

Roorda-Knape, M. C., Janssen, N. A. H., De Hartog, J. J., Van Vliet, P., Harssema, H., Brunekreef, B., 1998. Air pollution from traffic in city districts near major motorways. Atmospheric Environment, 32(11), pp. 1921-1930.

Röösli, M., 2008. Radiofrequency electromagnetic field exposure and non-specific symptoms of ill health: A systematic review. Environmental Research, 107(2), pp. 277-287.

Rose, D., Richards, R., 2004. Food store access and household fruit and vegetable use among participants in the US Food Stamp Program. Public Health Nutrition, 7(08), pp. 1081-1088.

Rosenlund, M., Berglind, N., Pershagen, G., Järup, L., Bluhm, G., 2001. Increased prevalence of hypertension in a population exposed to aircraft noise. Occupational and Environmental Medicine, 58(12), pp. 769-773.

Roux, A. V. D., Kiefe, C. I., Jacobs, D. R., Haan, M., Jackson, S. A., Nieto, F. J., Paton, C. C., Schulz, R., 2001. Area characteristics and individual-level socioeconomic position indicators in three population-based epidemiologic studies. Annals of Epidemiology, 11(6), pp. 395-405.

Rundle, A., Diez Roux, A. V., Freeman, L. M., Miller, D., Neckerman, K. M., Weiss, C. C., 2007. The urban built environment and obesity in New York City: a multilevel analysis. American Journal of Health Promotion, 21(4s), pp. 326-334.

Rundle, A., Neckerman, K. M., Freeman, L., Lovasi, G. S., Purciel, M., Quinn, J., Richards, C., Sircar, N., Weiss, C., 2008. Neighborhood food environment and walkability predict obesity in New York City. Environ Health Perspect, 117(3).

Ruwaard, D., Kramers, P., 1998. Public health status and forecasts report 1997. Health prevention and health care in the Netherlands until 2015. Bilthoven, The Netherlands: National Institute for Public Health and the Environment (RIVM).

Saelens, B., Sallis, J., Frank, L., 2003a. Environmental correlates of walking and cycling: Findings from the transportation, urban design, and planning literatures. Annals of Behavioral Medicine, 25(2), pp. 80-91.

Saelens, B. E., Sallis, J. F., Black, J. B., Chen, D., 2003b. Neighborhood-based differences in physical activity: an environment scale evaluation. American Journal of Public Health, 93(9), pp. 1552-8.

Selander, J., Nilsson, M. E., Bluhm, G., Rosenlund, M., Lindqvist, M., Nise, G., Pershagen, G., 2009. Long-term exposure to road traffic noise and myocardial infarction. Epidemiology, 20(2), pp. 272-279.

Sesso, H. D., Paffenbarger, R. S., Ha, T., Lee, I. M., 1999. Physical activity and cardiovascular disease risk in middle-aged and older women. American Journal of Epidemiology, 150(4), pp. 408-416.

Seto, E. Y. W., Holt, A., Rivard, T., Bhatia, R., 2007. Spatial distribution of traffic induced noise exposures in a US city: an analytic tool for assessing the health impacts of urban planning decisions. International Journal of Health Geographics, 6(24).

Shima, M., Nitta, Y., Adachi, M., 2003. Traffic-related air pollution and respiratory symptoms in children living along trunk roads in Chiba Prefecture, Japan. Journal of epidemiology / Japan Epidemiological Association, 13(2), pp. 108-19.

Smith, K. R., Corvalán, C. F., Kjellström, T., 1999. How much global ill health is attributable to environmental factors? Epidemiology, 10(5), pp. 573-584.

Song, Y., Gee, G. C., Fan, Y., Takeuchi, D. T., 2007. Do physical neighborhood characteristics matter in predicting traffic stress and health outcomes? Transportation Research Part F: Traffic Psychology and Behaviour, 10(2), pp. 164-176.

Stafford, M., Cummins, S., Ellaway, A., Sacker, A., Wiggins, R. D., Macintyre, S., 2007. Pathways to obesity: Identifying local, modifiable determinants of physical activity and diet. Social Science & Medicine, 65(9), pp. 1882-1897.

Stansfeld, S. A., Berglund, B., Clark, C., Lopez-Barrio, I., Fischer, P., Öhrström, E., Haines, M. M., Head, J., Hygge, S., van Kamp, I., Berry, B. F., 2005. Aircraft and road traffic noise and children's cognition and health: a cross-national study. The Lancet, 365(9475), pp. 1942-1949.

Stansfeld, S. A., Matheson, M. P., 2003. Noise pollution: non-auditory effects on health. British Medical Bulletin, 68(1), pp. 243-257.

Stansfeld, S. A., Sharp, D. S., Gallacher, J., Babisch, W., 1993. Road traffic noise, noise sensitivity and psychological disorder. Psychological Medicine, 23(04), pp. 977-985.

Sugiri, D., Ranft, U., Schikowski, T., Kramer, U., 2006. The influence of large-scale airborne particle decline and traffic-related exposure on children's lung function. Environ Health Perspect, 114(2), pp. 282-8.

Sugiyama, T., Leslie, E., Giles-Corti, B., Owen, N., 2008. Associations of neighbourhood greenness with physical and mental health: do walking, social coherence and local social interaction explain the relationships? Journal of Epidemiology and Community Health, 62(5).

Takano, T., Nakamura, K., Watanabe, M., 2002. Urban residential environments and senior citizens' longevity in megacity areas: the importance of walkable green spaces. Journal of Epidemiology and Community Health, 56(12), pp. 913-918.

Tan, J., Zheng, Y., Tang, X., Guo, C., Li, L., Song, G., Zhen, X., Yuan, D., Kalkstein, A., Li, F., Chen, H., 2010. The urban heat island and its impact on heat waves and human health in Shanghai. International Journal of Biometeorology, 54(1), pp. 75-84.

The Health Council of the Netherlands, 2008. Gevoelige bestemmingen luchtkwaliteit. Den Haag.

Titze, S., Stronegger, W. J., Janschitz, S., Oja, P., 2008. Association of built-environment, social-environment and personal factors with bicycling as a mode of transportation among Austrian city dwellers. Preventive Medicine, 47(3), pp. 252-259.

van den Berg, A. E., Hartig, T., Staats, H., 2007. Preference for nature in urbanized societies: stress, restoration, and the pursuit of sustainability. Journal of Social Issues, 63(1), pp. 79-96.

van den Berg, A. E., Koole, S. L., van der Wulp, N. Y., 2003. Environmental preference and restoration: (How) are they related? Journal of Environmental Psychology, 23(2), pp. 135-146.

van den Berg, A. E., Maas, J., Verheij, R. A., Groenewegen, P. P., 2010. Green space as a buffer between stressful life events and health. Social Science & Medicine, 70(8), pp. 1203-1210.

van Oers, J. A. M., (Eds.), 2003. Health on course? National public health status and forecast report 2002. Bilthoven, the Netherlands: National Institute for Public Health and the Environment.

Van Vliet, P., Knape, M., de Hartog, J. J., Janssen, N. A. H., Harssema, H., Brunekreef, B., 1997. Motor vehicle exhaust and chronic respiratory symptoms in children living near freeways. Environmental Research, 74, pp. 122-132.

Venn, A. J., Lewis, S. A., Cooper, M., Hubbard, R., Britton, J., 2001. Living near a main road and the risk of wheezing illness in children. American Journal of Respiratory and Critical Care Medicine, 164(12), pp. 2177-2180.

Verheij, R. A., Maas, J., Groenewegen, P. P., 2008. Urban—rural health differences and the availability of green space. European Urban and Regional Studies, 15(4), pp. 307-316.

Vrijheid, M., 2000. Health effects of residence near hazardous waste landfill sites: a review of epidemiologic literature. Environmental Health Perspectives, 108(Suppl 1), pp. 101-112.

Wannamethee, S. G., Shaper, A. G., 1999. Physical activity and the prevention of stroke. Journal of cardiovascular risk, 6(4), pp. 213-6.

Wannamethee, S. G., Shaper, A. G., Walker, M., 1998. Changes in physical activity, mortality, and incidence of coronary heart disease in older men. The Lancet, 351(9116), pp. 1603-1608.

Wei, M., Kampert, J. B., Barlow, C. E., Nichaman, M. Z., Gibbons, L. W., Paffenbarger, R. S., Blair, S. N., 1999. Relationship between low cardiorespiratory fitness and mortality in normal-weight, overweight, and obese men. Journal of the American Medical Association, 282(16), pp. 1547-53.

Wells, N. M., Evans, G. W., 2003. Nearby nature: a buffer of life stress among rural children Environment and Behavior, 35(3), pp. 311-330.

Wendel-Vos, W., Droomers, M., Kremers, S., Brug, J., Van Lenthe, F., 2007. Potential environmental determinants of physical activity in adults: a systematic review. Obesity Reviews, 8(5), pp. 425-440.

Wendel-Vos, W., Schuit, J., De Niet, R., Boshuizen, H. C., Saris, W. H. M., Kromhout, D., 2004. Factors of the physical environment associated with walking and bicycling. Medicine & Science in Sports & Exercise, 36(4), pp. 725-730.

WHO, 1946. Constitution of the World Health Organization.

Wjst, M., Reitmeir, P., Dold, S., Wulff, A., Nicolai, T., Loeffelholz-Colberg, E. F. v., Mutius, E. v., 1993. Road traffic and adverse effects on respiratory health in children. BMJ, 307(6904), pp. 596-600.

Wood, L., Shannon, T., Bulsara, M., Pikora, T., McCormack, G., Giles-Corti, B., 2008. The anatomy of the safe and social suburb: an exploratory study of the built environment, social capital and residents' perceptions of safety. Health & Place, 14(1), pp. 15-31.

Zhu, Y., Hinds, W. C., Seongheon, K., Shen, S., Sioutas, C., 2002. Study of ultrafine particles near a major highway with heavy-duty diesel traffic. Atmospheric Environment, 36, pp. 4323-4335.