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## Green neighbourhood environments - Implications for health promotion, physical activity and well-being

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# Green neighbourhood environments

## Implications for health promotion, physical activity and well-being

HANNA WEIMANN

DIVISION OF OCCUPATIONAL AND ENVIRONMENTAL MEDICINE | LUND UNIVERSITY 2017







# Green neighbourhood environments

Implications for health promotion, physical  
activity and well-being

Hanna Weimann



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DOCTORAL DISSERTATION

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Abstract  <p>The proportion of people living in densely built up areas is gradually increasing, forcing cities to generate new land to build homes upon. In this process there is a risk for an inexplicit decrease of green space. The green features of neighbourhoods help to create a supportive environment for health and physical activity, thus a reduction of greenness may reduce the general well-being in the population.</p> <p>The overall aim of this thesis was to study how green neighbourhood environments are related to physical activity, health and well-being, to better understand the implications for public health. Separate data was used for each paper in the thesis. Objectively measured physical activity in children was used to assess the association with neighbourhood resources. Longitudinal survey data on general and mental health in prognostic groups was related to survey data on qualities in the green neighbourhood. These qualities was also related to cross-sectional data on physical activity and moderated by safety and social coherence. A qualitative interview study using content analysis is also included in the thesis.</p> <p>An association between access to neighbourhood resources and objectively measured physical activity was seen in children aged 4-11 years. Neighbourhood greenness was weakly associated with general health, but not mental health, and a beneficial effect of increased neighbourhood greenness on general health was indicated only in the most vulnerable subgroup. Access to high quality green areas promotes physical activity only among individuals who perceive their neighbourhood as being safe.</p> <p>The size of the study samples and the extensive and partly longitudinal survey data used in two of the papers in this thesis provided unique possibilities to adjust for confounders and avoid single source bias, while at the same time provide new insights on causality.</p> <p>There is rich variety in potential pathways through which greenness may promote well-being. Hence, there is a need to consider the green neighbourhood environment from multiple perspectives when densifying cities or planning for other changes.</p>		
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Hanna Weimann



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*Till er som vet att en mur bara är en bro på högkant*

- Emil Jensen

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## List of papers

The thesis is based on the following papers, which are referred to in text by their respective roman numeral.

I. Hanna Weimann, Jonas Björk, Lars Rylander, Patrick Bergman, Gabriele Eiben. 2015. Neighbourhood environment and physical activity among young children: A cross-sectional study from Sweden. *Scandinavian Journal of Public Health* 2015;43:283–293.

II. Hanna Weimann, Lars Rylander, Maria Albin, Erik Skärbäck, Patrik Grahn, Per-Olof Östergren, Jonas Björk. Effects of changing exposure to neighbourhood greenness on general and mental health: A longitudinal study. *Health & Place* 2015;33:48–56.

III. Hanna Weimann, Matilda Annerstedt van den Bosch, Lars Rylander, Maria Albin, Erik Skärbäck, Patrik Grahn, Jonas Björk. Perception of safety is a prerequisite for the association between neighbourhood green qualities and physical activity: Results from a cross-sectional study in Sweden. *Health & Place* 2017;45:124–130.

IV. Hanna Weimann, Jonas Björk, Carita Håkansson. Perceptions of the urban green local environment as a factor for well-being among adults in the general population: A qualitative study. *Manuscript*.



## Aims and Objectives

The overall aim of this thesis was to study how green neighbourhood environments are related to physical activity, health and well-being by considering these environments as resources for improved public health.

The specific aim of each paper was to:

Investigate the association between the neighbourhood environment and objectively measured physical activity among young children, and to investigate the influences of seasonal variations, age, sex and parental education. (Paper I)

Assess the effect of changes in exposure to the quality of neighbourhood greenness, triggered by changing residence, on self-reported general health and mental health. (Paper II)

Assess the association between exposure to green qualities in close proximity to the residence and self-reported physical activity and general health, and to further assess to which extent this is moderated by the individual perception of safety and social coherence in the neighbourhood. (Paper III)

Describe how the urban green local environment is perceived as supporting for well-being among adults in the general population. (Paper IV)

# Populärvetenskaplig sammanfattning

Befolkningen växer och andelen som vill bo i städer ökar stadigt vilket skapar behov av ny mark att bygga bostäder på. Tidigare har de flesta städer och orter utvecklats genom att växa utåt, vilket har lett till förlust av naturområden och jordbruksmark och ökat beroendet av bilar. Att bygga staden inåt istället, så kallad förtätning, är numera en populär strategi för att minska bostadsbristen. I denna process finns risk att det sker en gradvis minskning av grönområden och andra gröna element i människors livsmiljö. Kvaliteten på den gröna miljön där människor bor har i ett flertal studier förknippats med fysiskt och psykiskt välbefinnande. Tillgång till grönska är potentiellt viktigare bland människor som på grund av exempelvis dålig ekonomi har sämre förutsättningar än andra att ha god hälsa. De gröna inslagen i bostadsområden bidrar till att skapa ett gynnsamt klimat för hälsa och fysisk aktivitet, och en minskning av sådana ytor kan därmed minska det allmänna välbefinnandet i befolkningen.

Det övergripande syftet med denna avhandling var att studera hur grön närmiljö är relaterat till fysisk aktivitet, hälsa och välbefinnande ur ett folkhälsoperspektiv. Avhandlingen beskriver fyra olika studier som alla undersöker sambandet mellan grön närmiljö och hälsa ut olika insynsvinklar och med hjälp av data från olika källor.

I den första studien undersöktes sambandet mellan fysisk aktivitet hos barn i åldern 4-11 år och lekmiljön i närheten av bostaden. Genom att låta alla 205 barn ha på sig en accelerometer mätte vi barnets rörelser under några dagar. Vi mätte också hur bra tillgång respektive barn hade till gång- och cykelvägar, lekplatser och spelplaner, samt skog och öppna grönytor. Två av studierna baserades på data från folkhälsoenkäter som delar av befolkningen i Skåne i åldern 18-80 år har besvarat. För att bedöma hur människor upplever kvaliteten på sin gröna närmiljö använde vi uppgifter från folkhälsoenkäten från år 2008. Med hjälp av en annan folkhälsoenkät som besvarades av en och samma grupp av människor både år 2000, 2005 och 2010 kunde vi undersöka hur dessa personers självrapporterade allmänna och mentala hälsa förändrades om de flyttade till en plats där den gröna närmiljön var bättre eller sämre än tidigare. Med hjälp av enkäten från år 2008 och en enkät från år 2012 undersökte vi också hur sambandet mellan grön närmiljö och fysisk aktivitet påverkades av huruvida man upplevde sitt bostadsområde som säkert eller inte. Vi har också genomfört en så kallad kvalitativ studie där 16 personer intervjuades om sin gröna närmiljö och fick beskriva hur de använde och upplevde denna.

Vi fann att barn med högre andel lekplatser m.m. i närheten av bostaden också var mer fysiskt aktiva. Vidare såg vi ett svagt samband mellan kvaliteten i den gröna närmiljön och allmänna hälsa, men inte mental hälsa. Den mest gynnsamma

effekten på hälsa av att flytta till en plats med ökad grönska fanns bland de människor som hade sämst förutsättningar att ha en god allmän hälsa. Vi såg också att tillgång till en grön närmiljö av god kvalitet främjade fysisk aktivitet, men bara bland personer som också upplevde sitt bostadsområde som säkert.

Två av studierna i denna avhandling är så kallade tvärsnittsstudier och kan därför inte användas för att bestämma orsakssamband. Det innebär att det, utifrån dessa studier, inte går att veta om det är den gröna närmiljön i sig som gör människor friskare, eller om friska människor oftare väljer, och har möjlighet, att flytta till grönare miljöer. Sambanden i studierna har justerats för faktorer som ålder, kön, ekonomiska förutsättningar och bostadstyp, men det kan fortfarande finnas andra faktorer som påverkar de samband som vi funnit.

Det finns en mängd olika sätt på vilket den gröna närmiljön har potential att främja hälsa och fysisk aktivitet. Det finns därför ett behov av att ta hänsyn till grön närmiljö från flera perspektiv när man planerar att förtäta städer eller genomföra andra förändringar, för att inte riskera att dessa förändringar får negativa effekter på hälsa och välbefinnande i befolkningen.

## Abstract

The proportion of people living in densely built up areas is gradually increasing, forcing cities to generate new land to build homes upon. In this process there is a risk for an inexplicit decrease of green space. The green features of neighbourhoods help to create a supportive environment for health and physical activity, thus a reduction of greenness may reduce the general well-being in the population.

The overall aim of this thesis was to study how green neighbourhood environments are related to physical activity, health and well-being, to better understand the implications for public health. Separate data was used for each paper in the thesis. Objectively measured physical activity in children was used to assess the association with neighbourhood resources. Longitudinal survey data on general and mental health in prognostic groups was related to survey data on qualities in the green neighbourhood. These qualities was also related to cross-sectional data on physical activity and moderated by safety and social coherence. A qualitative interview study using content analysis is also included in the thesis.

An association between access to neighbourhood resources and objectively measured physical activity was seen in children aged 4-11 years. Neighbourhood greenness was weakly associated with general health, but not mental health, and a beneficial effect of increased neighbourhood greenness on general health was indicated only in the most vulnerable subgroup. Access to high quality green areas promotes physical activity only among individuals who perceive their neighbourhood as being safe.

The size of the study samples and the extensive and partly longitudinal survey data used in two of the papers in this thesis provided unique possibilities to adjust for confounders and avoid single source bias, while at the same time provide new insights on causality.

There is rich variety in potential pathways through which greenness may promote well-being. Hence, there is a need to consider the green neighbourhood environment from multiple perspectives when densifying cities or planning for other changes.

## Abbreviations

ART	Attention Restoration Theory
BMI	Body Mass Index
PA	Physical Activity
MVPA	Moderate to Vigorous Physical Activity
CPM	Counts Per Minute
GH	General Health
MH	Mental Health
GIS	Geographic Information Systems
SGS/SGS5	Scania Green Score
PHS	Public Health Survey in Scania
SPHC	Scania Public Health Cohort
WHO	World Health Organization
OR	Odds Ratio
IDEFICS	Identification and prevention of dietary- and lifestyle-induced health effects in children and infants



# Introduction

## Public health and health promotion

Public health is the combined health and disease status of a population and the between group differences in this pattern. It is a broad term that includes individual lifestyle factors as well as community services and resources (1).

A significant part of the Swedish public health policies and procedures derive from the proposition to promote public health that was adopted by the Swedish Parliament (i.e. Riksdagen) in year 2003 (2). The proposition states the overall public health objective in Sweden, which from this time has been "to create social conditions for good health on equal terms for the entire population." (3), and defines eleven target areas to guide the public health work at all levels of society. The proposition also put a special emphasis on the need to improve the public health situation in the population groups that are most vulnerable to ill health.

The focus of this thesis is most clearly related to three of the specified target areas. These areas are; number three, which concerns the living conditions of children, number five, regarding healthy environments, and target area number nine about physical activity. In target area five, the need for available green space for recreation, is explicitly mentioned (2).

In 1999 the Swedish Parliament adopted another proposition including 15 environmental quality objectives. One of the objectives addresses the built environment and, among other things, state that the living environment should meet society's demands on access to sunlight, clean water, clean air, nature and green space, and freedom from noise (4).

## **Health influencing factors**

Within the public health field there are different approaches to address health, with the main strategies being referred to as health promotion and disease prevention. A health promotion approach implies a greater focus on factors that promote health, rather than on factors that prevent disease. This approach includes also healthy people, and not only those at risk of getting sick, which is considered to increase the opportunities to preserve and enhance health and well-being in the population (1). An individual's health is affected by a variety of factors which are usually called determinants of health. These include biological and personal factors, socioeconomic factors, health behaviours, and environmental factors (5). Within preventive health, it is essential to search for environmental factors that can create good health. These factors may be included in the concept of supportive environments (1). Supportive environments can be divided into physical and social environment, and includes all environments where people spend time, for example home environments and environments for work and leisure (6). The essence of the concept of supportive environments involves creating conditions for people to live their lives and conduct their activities in such a way that it promotes health in everyday life (7).

## **Environmental characteristics**

Research on environmental impact on human health has traditionally focused on the negative health effects associated with toxins, heavy metals, noise, air pollution etcetera, whilst the health promoting aspects of the environment has been given less attention so far. Much of the environmental exposure on humans occur in or in close proximity to the residence and exposure to any given environmental factor may be easier or harder to avoid or achieve. To identify hazard risks like air pollution and environmental toxins could be difficult for the ordinary citizen without special knowledge. On the other hand, identifying a place to live where the environmental characteristics fulfil personal wishes in a health promoting way is possibly less hard, but may be hindered by other factors such as economic and practical circumstances.



## **Landscape, cities and neighbourhoods**

Today, 87% of the population in Sweden live in a densely built-up area (i.e. a place with continuous settlement and a population of at least 200 inhabitants) (8). The number of inhabitants per km<sup>2</sup> in Sweden as a whole has increased from 21 in the early 1990s to almost 25 in year 2015. In Scania (Skåne), which is the county in Sweden that constitutes the geographical setting for three of the papers in this thesis, the number of inhabitants per km<sup>2</sup> has increased from 98 to 119 during the same time period (9). The population is highly concentrated to the metropolitan areas surrounding the largest cities. The number of inhabitants per km<sup>2</sup> in the three largest cities in Sweden; Stockholm, Gothenburg and Malmö, has increased by 23%, 18% and 23%, respectively, from year 2000 to year 2015(9). As the population grows, the need for new housing of various types is rapidly increasing. This puts massive pressure on the largest and most attractive cities to generate new land to build homes upon. Previously, most cities and towns have developed by growing outwards. This has led to the loss of natural areas and farmland and increased the dependence on cars. To build the city inwards instead, so called densification, has grown in popularity in recent years and is seen as a strategy to build housing without claiming valuable land space (10). In this process there is a risk for an unnoticed decrease of the natural environments and green space needed for people, plants and animals. Cities include a variety of greenness, from single trees, ditches and flower pots, to large parks, and all types of greenness needs to be fully valued. Established parks in cities are seldom built upon, while other, less defined green spaces and features, could more easily become subjects for densification (11). Also small urban green spaces has been shown to have implications for perceived restorativeness among people living in cities (12).

## **Neighbourhood greenness**

In this thesis, I have considered the neighbourhood greenness to be the outdoor environment that is situated in connection to the residence and that is visited or watched, often or rarely, by the resident. The neighbourhood environment in this sense includes both the private garden or balcony, when one exists, and the public green areas surrounding the residence. In paper IV, each respondent was free to individually define the boundaries of his or her green neighbourhood environment. For this reason, in paper IV, we use the term “green local environment” instead of “green neighbourhood environment”. What features that constitutes the neighbourhood greenness and how far from the residence that this area stretches differs between individuals and contexts. So does also the motivation for visiting green spaces (13, 14) and the activities taking place in these areas (15). People appear to favour and use specific environments based on preferences (16) and the

utilization of public green environments is influenced by the individual perception of factors like attractiveness, accessibility, distance and safety (17-20). Shorter distance to parks and other public open spaces increases the utilization rate for physical activity, with subsequent health benefits (19, 21) also among children (22, 23) and the elderly (24). Thus, the green features of neighbourhoods help create a supportive environment for health and physical activity improvements.

## Theoretical background on nature and health

### **Attention Restoration Theory**

The Attention Restoration Theory (ART) was developed in the early 1990s by Rachel and Stephen Kaplan and colleagues. As human beings, we are constantly handling information. Throughout history, being able to manage large amounts of information, for example about where to find food, has been crucial for survival. In modern life we are being flooded with new types of information from multiple sources. Some of this information is actually vital and important, but most times it is either trivial or unimportant. Yet, sorting through and identifying the important parts of information requires concentration, attention and effort. Kaplan et.al. 1998 explains that:

“Peoples capacity for such directed attention is limited. Even if the work that needs to be done is enjoyable and important and one wants to do it, one can only spend so long at it without needing a break. In other words, the capacity to direct attention wears one down. This is a situation we refer to as mental fatigue” (25).

According to the ART, recovering from mental fatigue is facilitated by being exposed to restorative settings (26). While there are many settings and activities that can provide such opportunities, nature and natural environments have some characteristics that make them especially suitable and efficient for restoration. The ART describes four properties; being away, extent, fascination and compatibility, that makes a setting restorative. “Being away” means being some place other than the source of the fatigue. This can be a physical change of place, but could also be achieved by, for example, looking out through a window. “Extent” is achieved when being in a place so large that its boundaries are not evident. As for “being away”, “extent” can also be created in the mind as well as in reality. Further, the ART describes how nature is full of “fascination” in terms of animals, water, growth, light and other assets, and focusing on this helps giving the fatigued attention a rest. The final property required for a setting to be restorative is that

there is “compatibility” between the environmental circumstances and personal preferences (25).

The design and manage of natural environments can be done in ways that encourage recovery from mental fatigue (27). Having access to settings with restorative properties in close proximity to the residence is likely to facilitate this process and could possibly also prevent the occurrence of mental fatigue.

### **Greenness as a resource for health and physical activity**

A large part of people’s lives are spent in or close to home and there is growing consensus that high quality green spaces in residential environments is of importance for promoting public health (28-31). Evidence suggest that perceptions of the neighbourhood, e.g. as being green, walkable or noisy, are important for health, also after controlling for objective measures of identical or similar features (32, 33). In general, quality of greenness seems to be more important than quantity (34, 35). The health promoting properties of green environments works in different ways within different parts of the population with stronger beneficial effects from exposure to green space on disease risk and mortality seen in low-income groups (36, 37). Amount and quality of neighbourhood greenness is likewise associated with physical activity in adults (14, 38-41) and possibly also in children (22, 42). How parks and other green areas are used for physical activity is affected by local cultural behaviours (43) and perception of safety (20, 44). Among children, parental perception of safety impact physical activity levels (45, 46). So does also the characteristics of the school outdoor environment (47, 48).

## Sensory dimensions in green environments

To be able to assess the importance of perceived neighbourhood greenness and quality for health, knowledge about how people use and experience urban open green spaces is required. Between year 1995 and 2005, a number of studies within the field of environmental psychology and landscape architecture was conducted via interviews in three urban parts of Sweden. As a result of these studies, eight qualities (dimensions) of the outdoor environment that was especially appreciated by the study participants were revealed (49, 50). Five of these qualities constitute the fundamental basis for the exposure assessments used in paper II and paper III in this thesis. The five dimensions; serene, wild, species richness, space and cultural history, is presented in table 1 together with the characteristics of each dimension as presented in Grahn et.al. 2005 (49). The additional three dimensions (not included in table 1, nor in the exposure assessments used in paper II and III) where; the common/prospect (a green open place admitting of vistas and stay), the pleasure garden/refuge (an enclosed, safe and secluded place, where you can relax and be yourself and also experiment and play), and festive/social (a meeting place for festivity and pleasure).

**Table 1. The five dimensions applied in paper II and III and the characteristics of each dimension**

Serene	Peace, silence and care. Sounds of wind, water, birds and insects. No rubbish, no weed, no disturbing people.
Wild	Fascination with wild nature. Plants seem self-sown. Lichen- and moss-grown rocks. Old paths.
Species richness	A room offering a variety of species of animals and plants.
Space	A room offering a restful feeling of “entering another world” a coherent whole, like a beech forest.
Cultural history	A historical place offering fascination with the course of time.

# Definitions and measures of health and physical activity

## Health

How the concept of health should be defined is an ongoing discussion and a definition that can be used in all contexts is still missing. The previous definition by the World Health Organization (WHO) about health as a state of complete physical, mental and social well-being is fading away and instead WHO choose to focus on health as a long, healthy, rich and equal life. These four value concepts shall each be regarded as equivalent and equally important (1). Health can also be defined as a continuous scale with health and disease on each end and where a person can move between spots on the scale (51). This salutogenic perspective focuses on factors that promote better health and is the opposite to pathogenesis which is the study of the cause and origin of disease (1).

In surveys, general health is often measured on a scale using one single question. This one item approach to measure health is a strong and independent predictor of mortality (52). In the public health surveys used for data on general health in paper II (53) and III (54) in this thesis, the respondents are asked to grade their current health status in two ways; on a 7-point scale and with five defined response alternatives, ranging from very bad to very good. These two measures have been shown to represent equivalent assessments of subjective health (55). Also the more psychological properties of health can be assessed in questionnaires. A common method to measure self-reported mental health is by using the twelve item General Health Questionnaire (GHQ-12) (56). The GHQ-12 is a validated and commonly used screening instrument to detect the early signs of bad mental health (57).

## Physical activity

Physical activity has multiple health benefits and the capacity to improve both physical and mental health (58). WHO defines physical activity as “any bodily movement produced by skeletal muscles that requires energy expenditure” (59). The WHO recommendations state that adults aged 18–64 and adults aged 65 and above should do at least 150 minutes of moderate-intensity aerobic physical activity throughout the week. Correspondingly, children and youth aged 5–17 should accumulate at least 60 minutes of moderate- to vigorous-intensity physical activity daily. Additional physical activity will create additional health benefits (60). It is not only the amount of physical activity that has implications for health, but also the intensity. In recent years, more research has been focused on the negative effects of having an inactive and sedentary lifestyle (61, 62).

Level of physical activity can be assessed in multiple ways, by objective measures such as an accelerometer or by subjective measures with one or many self-reported questions of diverse complexity. An accelerometer is a type of measuring sensor which creates an electric signal that is proportional to the speed change (i.e. acceleration) that the sensor is subjected to. The accelerometer can be sensitive for movements in one, two or three directions. The device is usually attached to the hip of the user with a belt. A common approach is to record physical activity in epochs of 15 seconds, but the accelerometer can be set to register acceleration with both higher and lower detail. When measuring physical activity it is important that the accelerometer is worn for a continuous period of several days to achieve a true average value. A general suggestion among both children and adults is to measure physical activity over a period of seven days (63-65). However, the number of days needed varies with age and studies indicate less day-to-day variability in younger compared to older children (65). In paper I (66) in this thesis, physical activity was measured among young children using accelerometers. All children with at least one day of 600 min wear time were included. For children there are differences in day-to-day variability between weekdays and weekend days (67, 68) and for adults between work and leisure time physical activity (69). The wear time each day is also an important factor when measuring levels of physical activity with accelerometer, with more wear time yielding more stable results (70, 71).

Measuring physical activity using accelerometers or other objective methods is considered to give more accurate results compared to using subjective measures(72). However, in large study samples, like the Public Health Survey used for data on physical activity in paper III (n=23 693), usually only subjective measures are plausible. In surveys, subjective (i.e. self-reported) physical activity can be measured with a single categorical or open question. In general, questions with categorical answers have a better validity than open questions when assessing subjective physical activity in adults (73).

## Qualitative research

To gain reliable knowledge about a question, issue or problem, it is crucial that the subject is being illuminated from different directions, so called triangulation. To reach this goal in research, a combination of both quantitative and qualitative methods is often a successful approach. Quantitative methods answers questions of “how much”; while qualitative questions deal with the contents of a phenomenon an answers questions of “how” and “what”. While quantitative research often include questionnaire studies with fixed alternatives, qualitative studies uses methods like diaries, observation, deep interviews and focus groups. The purpose

of a qualitative study, regardless of methodology, is to identify, describe, characterise and understand a certain phenomenon.

To this point, a majority of the research conducted on green environments and health and physical activity, has been quantitative. Qualitative methods propose a complement to quantitative studies and have the potential to generate a greater understanding of the health promoting aspects of the green neighbourhood environment. The qualitative research that has been conducted so far includes studies on park visitation (13, 15) and favourite places (74-76). While most studies have focused on the experiences of specific parts of the population like children (77, 78), adolescents (79), older people (80) or vulnerable groups (81, 82), it is less common that studies reflect the views of adults in the general population.





# Material and methods

## Design overview

**Table 2** Design overview of papers I-IV.

	Paper I	Paper II	Paper III	Paper IV
Title	Neighbourhood environment and physical activity among young children.	Effects of changing exposure to neighbourhood greenness on general and mental health.	Perception of safety is a prerequisite for the association between neighbourhood green qualities and physical activity.	Perceptions of the urban green local environment as a factor for well-being among adults in the general population.
Participants	205 children 4-11 years	13 604 adults 18-80 years	23 693 adults 18-80 years	16 adults 26-70 years
Material	Objective neighbourhood resources  Objective physical activity	Perceived neighbourhood greenness  Self-reported : general health mental health	Perceived neighbourhood green qualities  Self-reported : physical activity general health	Semi-structured individual interviews
Study design	Cross-sectional	Longitudinal	Cross-sectional	Qualitative
Analysis method	Mixed linear regression	Random effects logistic regression in prognostic groups	Ordinal and logistic regression with stratifications	Content analysis

## Geographical settings

The study area for paper I was the municipality of Partille in West Sweden. Being located just east of the larger city of Gothenburg, this suburban municipality had about 35 000 inhabitants in 2010 when the data for paper I was collected (9). Partille is located in a valley and crossed by the highway E20. The residential areas are relatively dense and well-defined, with forests and lakes in between. There are some areas dominated by apartment buildings and these areas are generally separated from areas dominated by townhouses and villas. Most of the housing originates from the 1950s and onwards, with most apartment areas originating from the 1960s and 1970s. The presence of sidewalks, walking paths and bike paths as well as playgrounds etcetera are normal for the Swedish context.

The study area for paper II and III was the county of Scania (Skåne) in south Sweden. When the first data for paper II was collected in year 2000, the Scania region had 1.13 million inhabitants. By year 2010, the population had grown to 1.24 million (9). The population in Scania is centred to the south west where the largest city of the region, Malmö, is located. Malmö had a population of 260 000 in year 2000, which had increased to 299 000 in year 2010. Other larger cities in the region are Helsingborg, Lund and Kristianstad which had 118 000, 99 000 and 74 000 inhabitants, respectively, in year 2000 (9). The land use of the Scania region is characterized by fields and open land in the south west and larger areas of deciduous and coniferous forests in the north east. The area has clear seasonal variations with spring, summer, autumn and winter, but rarely experiences any major amounts of snow during winter. Scania has a coastline in the west, south and east direction.

The study area for paper IV was also the county of Scania, but the participants was predominantly residing in the western parts of Scania, either in Malmö or Lund or in a densely populated village on the countryside.

# Materials

## Materials paper I

The material for paper I was based on the European study IDEFICS (Identification and Prevention of Dietary- and Lifestyle-Induced Health Effects in Children and Infants) and geographic data covering the municipality of Partille.

### *IDEFICS*

This prospective cohort study include a total of 16 224 children from Sweden, Germany, Hungary, Italy, Cyprus, Spain, Belgium and Estonia (83, 84). In each country, one intervention and one control region that was comparable with regard to their infra-structural, sociodemographic and socioeconomic characteristics, was selected. The aim of the IDEFICS study was partly to assess the prevalence of overweight and obesity and partly to develop, implement and evaluate intervention programs for prevention of obesity. Children, aged 2-9 years, were recruited through school and kindergarten settings and were initially examined between September 2007 and May 2008. The data for paper I is taken from the follow-up survey conducted two years later (i.e. between September 2009 and May 2010).

In paper I we only use material from a small subset of the children included in the full IDEFICS study. In Sweden, the IDEFICS study included 1538 children. The data in the paper reflect children in the Swedish intervention region who were part of a sub-study on physical activity (85). The sub-study included 249 children and after exclusions a total of 205 children remained and were included in the analyses.

### *Measures of physical activity*

The outcome data for paper I was three different variables of objectively measured physical activity. Each child was assigned a uniaxial accelerometer device set to record physical activity in epochs of 15 seconds. Two technically identical models were used (ActiGraph GT1M or ActiTrainer). The accelerometer was to be worn during waking hours for three consecutive days and removed only for bathing, or water sports. When the accelerometer was assigned, the parents were instructed how to attach it on the right hip of the child and asked to make sure that the child wore the accelerometer at all times. The physical activity data for paper I include only data from weekdays when a minimum of 600 minutes of data remained after the deletion of non-wear time. It also only includes leisure time (i.e. the time interval from 3:10 p.m. to 6:46 p.m.). To be able to assess any differences due to intensity, we used three different physical activity variables; a) counts per minute

(cpm), b) sedentary time, and c) time in moderate- to vigorous physical activity (MVPA). We calculated cpm as the mean count during the measurement

period. Sedentary time was calculated as the sum of all epochs with counts <100 cpm and MVPA was calculated as the sum of all epochs with a count >2000 cpm.

### *Measures of environmental attributes*

The exposure data for paper I was three different variables of environmental attributes. We based our exposure assessment on the GIS (Geographic Information Systems) data file of the study area that the municipal office kindly provided us with. This data file included information about built areas and the type of housing (i.e. townhouse/villa area or apartment area), network of foot and bike paths and land use (i.e. distribution of forests, water, lawns and built land etcetera). It was manually complemented with public playgrounds maintained by the municipality, private playgrounds maintained by housing companies, playfields and schoolyards. From the GIS, we identified three environmental attributes which we believed to have an impact as positive resources for physical activity. We also defined the exposure area as the area within a radius of 300 m of the home of each child. The three attributes were; a) kilometres of foot and bike paths, b) number of non-restricted destinations (playgrounds, schoolyards and playfields) and c) recreational areas (pine forest, leaf forest and open ground) as a percentage of the total area. Figure 1 shows a section from the GIS data file which illustrate how the environmental attributes is distributed within the exposure area of six children in the study.

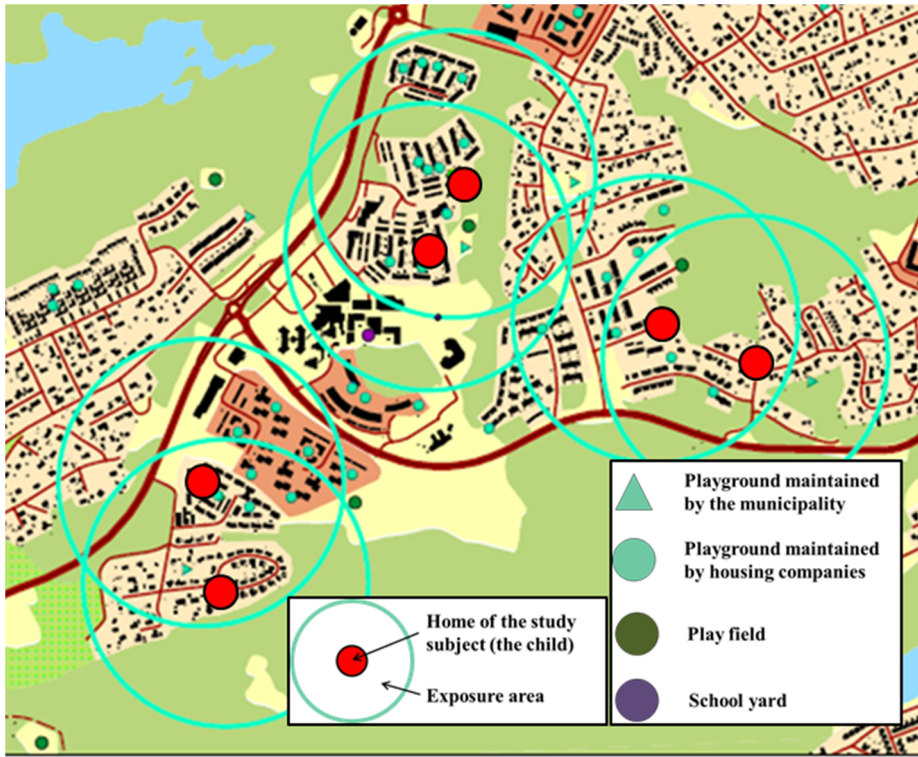


Figure 1. GIS data file with exposure area for six of the children included in the study for paper I.

Each environmental attribute was classified into three levels; 1=low, 2=medium and 3=high presence. We noticed that the ranges of each environmental attribute differed depending on type of housing and therefore the classification of environmental attributes was done separately for children living in a townhouse or villa and for children living in an apartment. We also created a score to describe the overall neighbourhood resources for physical activity of each child. The score was defined based on the sum of the three attributes and classified into three groups: worst (sum score 3–4; n=36), intermediate (sum score 5–7; n=121) or best (sum score 8–9; n=48).

As covariates in the statistical model, we adjusted for age and sex of the child, type of housing (i.e. townhouse/villa or apartment) of the child, parental education, and if the physical activity assessment was conducted during autumn (i.e. September to October), winter (i.e. November to January) or early spring (i.e. February to March). We also included a random intercept for each family to adjust for the significant within family variation of physical activity in the data, and used weighted least squares to account for differences in accelerometer measurement time.

## Materials paper II and III

The material for paper I and II was based on public health surveys conducted in Scania in year 2000, 2005, 2008, 2010 and 2012. The cross-sectional survey from 2008 provided exposure data for both paper II and paper III. Outcome data for paper II was taken from the longitudinal survey conducted in 2000, 2005 and 2010, while outcome data for paper III was taken from the cross-sectional survey from year 2012. See figure 3 and 4.

### *Public Health surveys – purpose and description*

In year 2000 the first Public Health Survey in Scania (PHS) was conducted. The study was performed by the division of Social Medicine and Global health, Lund University and the unit of Public Health and Social Sustainability, Region Skåne, in collaboration with The Swedish Association of Local Authorities and the Region Skåne Regional Social Insurance Office. All participants in the PHS from year 2000 received follow-up questionnaires in year 2005 and 2010, forming the longitudinal Scania Public Health Cohort (SPHC) (data included in paper II). An additional follow-up questionnaire was sent out in year 2016 (data not included in the thesis). The SPHC data is collected by the Division of Social Medicine and Global Health independently. Additional PHS questionnaires was sent out in year 2004 (data not included in the thesis), year 2008 (data included in paper II and III) and year 2012 (data included in paper III). The overall purpose of both the PHS and the SPHC is to monitor the current health status and health distribution in the population in order to develop a basis for prevention and priorities in Region Skåne and the Scania municipalities. The questionnaires cover a variety of aspects relevant for health and well-being such as questions about; living conditions, economy, occupational health, drug use, sleep habits, dental health, social relationships, threats and violence and confidence in public institutions.

The baseline population for the public health survey from year 2000 consisted of all inhabitants between 18-80 years of age that was registered in the Scania region in November 1999. The population was stratified into 60 strata based on age sex and geographical area. For each stratum, about 400 individuals were randomly selected (86). The baseline questionnaire was mailed to these 24 922 individuals in November 1999 and consisted of 106 questions. After three postal reminders and one reminder by telephone a total of 13 604 participants (55%) answered the questionnaire (87). The original responders from year 2000 who were still alive and residing in Scania received the questionnaire again in September 2005 (n=12 504) and 2010 (n=11 652). The number of respondents in 2005 and 2010 was 10 475 (84%) and 9 031 (78%), respectively. In paper II, all respondents to the year 2000 survey are part of the baseline cohort whether or not these persons also responded to the questionnaires in year 2005 and 2010.

The baseline population for the 2012 survey consisted of all inhabitants, aged 18-80 years, registered in the Scania region in the end of year 2012. A stratified selection sample of men and women was drawn from the baseline population (88). An extensive questionnaire with about 140 questions was mailed to these 54 250 individuals in November 2012. Participants were invited to answer the questionnaire either by post or on the internet. After three postal reminders a total of 28 029 participants (52%) had answered the questionnaire. In paper III, all respondents to the year 2012 survey are part of the study cohort.

For both paper II and paper III, we used exposure data on neighbourhood green qualities from the 2008 public health survey, i.e. a sample which is independent from the SPHC and the 2012 survey. The sample selection process in 2008 was similar to the ones used in 2000 and 2012 and conducted among 18-80 year olds living in Scania (89). A total of 28 198 participants (54%) answered the questionnaire. The respondents to the year 2008 survey only provide data on neighbourhood green qualities (i.e. the outcome) and are not part of the study cohort for either paper II or paper III. Geocoded residential addresses were used to link exposure data with outcome data. For paper II geocoded residential address was retrieved for three time points, corresponding to when the surveys were sent out. For paper III, we obtained geocoded residential addresses for year 2012.

### *Questions about mental health*

In paper II, we assessed the effect of changes in exposure to neighbourhood green qualities on mental health, as well as the cross-sectional associations between neighbourhood green qualities and mental health. We assessed mental health using the twelve item General Health Questionnaire (GHQ-12) (56). The GHQ-12 includes both positive and negative mental health items, with four possible answers on each item. The answer on each question was dichotomised to indicate positive or negative mental health status. Any respondent that rated on the negative scale for three questions or more were classified as having poor mental health and the rest of the cohort was classified as having good mental health. The 12 questions were phrased identically in all three questionnaires (e.g. in year 2000, 2005 and 2010) and cover aspects such as feeling useful, feeling under strain, being able to concentrate and having problems sleeping due to anxiety.

### *Questions about general health*

In paper II, we assessed the effect of changes in exposure to neighbourhood green qualities on general health, as well as the cross-sectional associations between neighbourhood green qualities and general health. In paper III we focus on the cross-sectional associations between neighbourhood green qualities and general health only. In both paper II and III we combined two survey questions in order to increase specificity in the assessment of good general health. The two questions

were dichotomized separately and then combined, with missing answers excluded from analysis. The first question, phrased as; “How do you rate your physical and mental health at present?”, had a seven-point scale ranging from 1 (“very bad, could not feel worse”) to 7 (“very good, could not feel better”) and was dichotomized as positive if the answer was 6 or 7 and negative if the answer was between 1 and 5. The second question, phrased as; “How is your present health status in general?” had five possible answers and was dichotomized as positive if the respondent had answered “very good” or “good” and negative if the answer was “fairly good”, “bad” or “very bad”. The requirement for having good general health was to have given a positive answer on both questions.

### *Question about physical activity*

In paper III, we assessed the cross-sectional associations between neighbourhood green qualities and physical activity. Level of physical activity was measured as self-reported number of hours spent being physically active in an ordinary week. The survey question was phrased: “How much time do you spend in a normal week doing moderately exhausting activities that make you warm, e.g. walking briskly, gardening, heavy housework, cycling or swimming?” Answers consisted of five categories; “1) 5 hours per week or more, 2) more than 3 hours but less than 5 hours per week, 3) between 1 and 3 hours per week, 4) no more than one hour per week, 5) not at all”. One additional category stated “do not know/cannot take position”. This category was regarded as equal to non-response and not included in analyses. The question about physical activity was not dichotomized.

### *Prognostic scores*

In paper II we were especially interested in investigating if and how general health and mental health was affected by changes in exposure to neighbourhood green qualities in groups with diverse likelihood of having good health. We decided to address these differences using prognostic scoring. Prognostic scores is a type of risk stratification where the study individuals are grouped according to their likelihood to develop a certain disease or other outcome. This method limits the number of subgroups and is commonly used in both epidemiological and clinical research. The prognostic scores can be used to assess effect modification if the cohort is stratified according to the prognostic scores. In our case, we wanted to divide the individuals in the cohort into groups according to their likelihood of having good general health and good mental health, respectively.

Substantial efforts were put into identifying all covariates, available from the year 2000 public health survey, which were associated ( $p\text{-value} \leq 0.05$ ) with general or mental health status. In total, 13 socio demographic and lifestyle characteristics were identified. Most of these covariates were relevant for both general and mental health at the same time, but with a few exceptions. Body Mass Index (BMI) and



educational level was associated with general health but not with mental health, while high alcohol consumption and having children under the age of 25 living at home were factors associated with mental health only. Additional covariates identified and used in paper II were sex, age, long-term illness, smoking habits, civil status, country of origin, type of housing, problems with paying bills and occupation. We used logistic regression to cross-sectionally model the probability of good general health and good mental health based the identified covariates. We stratified the cohort into four prognostic groups. The cohort was firstly divided into two clusters, with or without long-term illness (as long-term illness was very strongly associated with good general health), and secondly these two clusters were divided on whether the individual fitted probability was below or above the median in each of the two groups.

### *Moderation*

Moderation is when a cohort is divided into groups based on a certain characteristic in order to be able to assess the size of an association within each of these groups separately. In paper III we wanted to investigate the potentially moderating effects of safety and social coherence on the association between neighbourhood green qualities and physical activity and general health. We moderated the data by stratifying the cohort into groups with high and low perception of safety and high and low perception of social coherence, respectively. The question about safety was phrased: “How safe and secure do you feel when you are walking alone in your neighbourhood after dark?” The response alternatives; “very safe” and “quite safe” were dichotomized as high perception of safety, while “quite unsafe”, “very unsafe” and “I am never out alone after dark” were regarded as low perception of safety. The question about social coherence was phrased: “Are you rooted and feel a strong coherence with your neighbourhood?” The response alternative “to a high degree” was regarded as high perception of social coherence, while “to some extent”, “not particularly” and “not at all” was regarded as low perception of social coherence. Missing answers on any of the moderating factors were excluded from analysis. In paper III we adjusted the models using the covariates relevant for general health that were identified in paper II, but also added a covariate that reflects the urbanity of the area where each respondent was residing.

### *Green qualities, and the Scania Green Score (SGS)*

Data on neighbourhood green qualities was taken from the 2008 public health survey. This part of the survey builds on five of the eight sensory dimensions in park and green environments that have been identified as particularly appreciated by humans (49). One question with five statements was used to assess the five qualities; serene, wild, species richness, space and cultural history. Table 3 shows the phrasing of the five statements and the corresponding quality. The respondent

rated each statement (i.e. quality) on a 4-graded ordinal scale. Response alternatives “Agree” and “Agree completely” were regarded as positive assessments while response alternatives “Disagree completely”, “Disagree” and “Do not know/cannot say” were regarded as negative assessments (i.e. quality not present in the neighbourhood) together with missing answers.

**Table 3. Phrasing of the five statements together with the quality corresponding to each statement.**

<p>“Think of nature within 5-10 minutes walking distance from where you live. For example this can be green spaces, parks or forest areas. Do you agree with the following statements?”</p> <p>“Nature in the area where I live...</p>	
<p>..is quiet, one can hear nature’s own sound.”</p>	<p>serene</p>
<p>..is wild, it has developed without human impact.”</p>	<p>wild</p>
<p>..has a large diversity of animal and plant species.”</p>	<p>species richness</p>
<p>..is a large cohesive area.”</p>	<p>space</p>
<p>..makes you feel the historical heritage, for example ancient monuments, old trees and constructions.”</p>	<p>cultural history</p>

Individual assessments of the presence of each of the five green qualities were available from 28 016 respondents. Using the geocoded for each survey participant it was now possible to create an overview of the presence of each green quality throughout the Scania area. This was done by dividing the entire Scania area into a grid of areas of 1 km<sup>2</sup> each. Residential addresses for one or more respondent was located in 3656 different 1 km<sup>2</sup> areas. Consequently, no exposure assessment of the green qualities was available for any 1 km<sup>2</sup> area where there was no 2008 survey-respondent residing.

In each 1 km<sup>2</sup> area we estimated the proportion of positive assessments for each item using a random effects logistic regression (ecometric) model with adjustment for sex, age, highest level of education, economic difficulties, country of origin and type of residence (described in detail in de Jong et.al. 2011 (90). When using this method to calculate proportions, areas with very few individuals obtain a

proportion that is similar to the overall mean. A special variable, the Scania Green Score (SGS/SGS5), in which all five items/qualities were combined, was also created. SGS was calculated for each 1 km<sup>2</sup> area as the sum of the five estimated area-level proportions. SGS and each quality individually was standardized (mean = 0, standard deviation = 1) across all 3656 areas, to create z-scores. Z-scores are created by calculating the number of standard deviations by which the SGS/quality value of each area was above or below the mean value of all areas. Observed values above the mean have positive standard scores, while values below the mean have negative standard scores. Areas with SGS above the mean (i.e. above zero) were generally less densely populated areas. Most of the respondents thus lived in areas with a low SGS value, and only 27% of the respondents lived in an area with a standardized SGS value above average. This shift is reflected in the bottom section of the descriptive tables (Table 1) in the published paper II and III.

In the analyses presented in paper II we only used SGS as our exposure variable, while in paper III we also assessed associations for the five qualities individually. The abbreviation for Scania Green Score in paper II is SGS and in paper III it is SGS5. The two abbreviations, SGS and SGS5, are identical and both represent the variable in which all five qualities were combined.

#### *Visualization of the Scania Green Score*

Each of the five qualities, serene, wild, species richness, space and cultural history were present in diverse degree across the Scania area. The same is true for the combined Scania Green Score (SGS). Areas with a high SGS are generally located in close access to one or many larger public green spaces or forests, are only partly occupied by townhouses and villas, and tend to be more common in less densely populated parts of the Scania region. Areas with low SGS are more often characterized by having few public green spaces and are often located in suburban areas with a mix of villas, townhouses and apartment buildings (Figure 2).



Figure 2. Aerial photos of the three 1 km<sup>2</sup> areas in Scania with the highest (left) and the lowest (right) SGS value, respectively. ©Lantmäteriet

The correlations (Spearman's rho) on area level (i.e. 1 km<sup>2</sup> areas) between the individual qualities ranged between 0.41 for serene and cultural history to 0.62 for species richness and space (Table 4).

**Table 4. Correlations (Spearman's rho) on area level (i.e. 1 km<sup>2</sup> areas) between the five green qualities; serene, wild, species richness, space and cultural history.**

	<i>Serene</i>	<i>Wild</i>	<i>Species richness</i>	<i>Space</i>	<i>Cultural history</i>
<i>Serene</i>	-	-	-	-	-
<i>Wild</i>	0.43	-	-	-	-
<i>Species richness</i>	0.62	0.53	-	-	-
<i>Space</i>	0.56	0.51	0.62	-	-
<i>Cultural history</i>	0.41	0.46	0.55	0.47	-

The original exposure data material from the 2008 public health survey includes 3656 different 1 km<sup>2</sup> areas. The areas were identified on whether they covered a rural or suburban part of Scania or covered an urban (inner city) part of one of the four largest cities in Scania. Almost all areas represent a rural or suburban environment and only about 3% of the 1 km<sup>2</sup> areas reflect urban parts of a city. However, as the population is not evenly spread across the Scania area, but are concentrated to the city areas, the proportion of respondents in paper III who were living in 1 km<sup>2</sup> areas classified as inner city was 13%. All five qualities were less common in the inner city areas compared to the rural/suburban areas.

A previous cross-sectional study in Scania (de Jong et al., 2012) identified cultural history as the one quality that was most consistently associated with physical activity and general health, as well as with neighbourhood satisfaction. Also the results from paper III indicate stronger associations for cultural history compare to the other four qualities. Areas rated high for cultural history in Scania is often located close to water and usually include areas with historically interesting buildings, old trees or parks. The areas rated highest on cultural history in Scania include "Ramlösa brunn", an old park with spring water in Helsingborg, "Trollskogen" a deciduous forest with old and twisted beech trees in Torna-Hällestad, and "Citadellet", a 16th century fortified castle in Landskrona. Likewise, areas rated low on cultural history often include very densely built residential areas or monotonous farmland.

*Illustration of the study designs for paper II and III*

The same exposure assessment was used in paper II (Figure 3) and III (figure 4). The geocoded residential address of each participant was used to link the exposure assessment from year 2008 to the outcome data from year 2000-2005-2010 and 2012, respectively. The map in figure 4 shows the 3656 areas of 1 km<sup>2</sup> each in Scania, for which an exposure assessment was available.

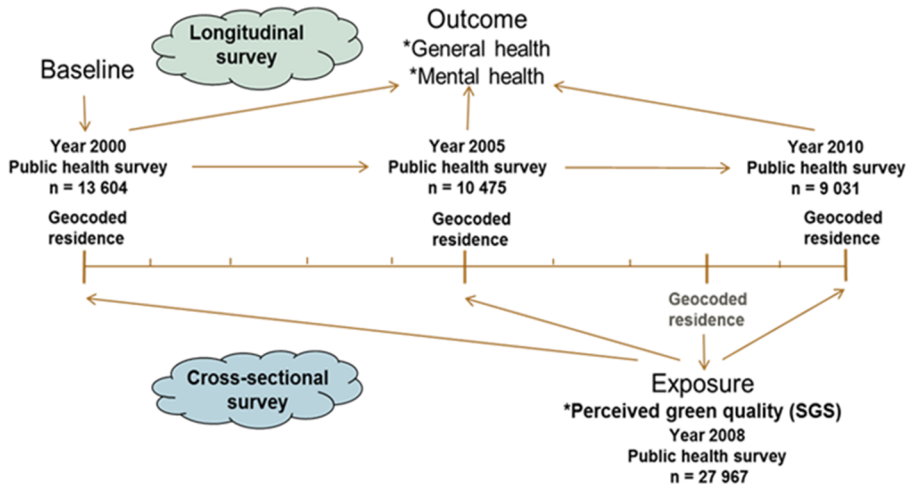


Figure 3. Design overview of the longitudinal study in paper II

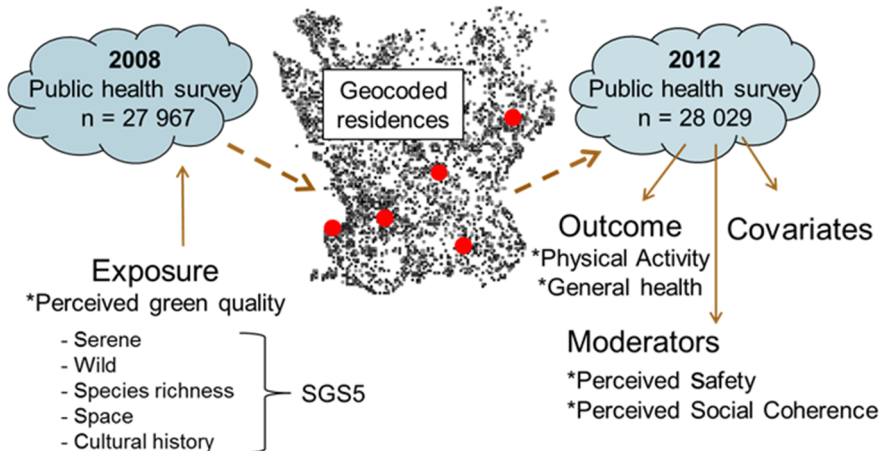


Figure 4. Overview of the cross-sectional study design in paper III

# Statistical analysis

Paper I, II and III are all based on quantitative data and were analysed with different types of regression models using the statistics software package SPSS (version 20.0 or 22.0).

## **Paper I**

In paper I, we used mixed linear regression to investigate the association between the neighbourhood environment and physical activity. The three different assessments of physical activity; counts per minute (cpm), sedentary time, and time in moderate- to vigorous physical activity (MVPA), were all log transformed. We primarily analysed data using the worst-intermediate-best neighbourhood resources score. However, we also analysed the three individual environmental attributes; kilometres of foot and bike paths, number of non-restricted destinations (playgrounds, schoolyards and playfields), and recreational areas (pine forest, leaf forest and open ground) as percent of total area, together in one model. All 205 children were included in the main analyses, regardless of type of housing. All models were adjusted for age, sex, type of housing, parental education, and season of physical activity assessment. All models also included a random intercept for each family and used weighted least squares to account for differences in accelerometer measurement time.

Three different sensitivity analyses were carried out, all using the worst-intermediate-best neighbourhood resources score. Firstly, to exclude any effect from the divergence of environmental attributes between housing types, we performed one analysis including only children living in townhouse or villa areas. Secondly, to diminish the potential effect of season, we performed one analysis including only children measured during winter or early spring. Finally, we performed one analysis, including all children, where we adjusted for Body Mass Index (BMI) and measurement device (ActiGraph GT1M or ActiTrainer) as fixed variables in the model.

## **Paper II**

The statistical analysis for paper II included both a longitudinal and a cross-sectional part. The longitudinal part only included respondents (28% of the cohort) who had changed residency (i.e. moved between 1 km<sup>2</sup> areas) during follow-up. The cross-sectional part includes the full cohort. In both cases we used random effects logistic regression to investigate the effect of/associations with the quality

of the neighbourhood greenness on/with general health and mental health. As described above, the cohort was stratified according to prognostic score at baseline. The analyses were carried out for each of the four prognostic groups separately, including a random intercept on the individual-level. The use of prognostic scores diminish the need for any further confounding control, but a covariate aimed to capture changes in life circumstances (defined as the difference between individual prognostic score and the mean value within the prognostic group at year 2000, 2005 and 2010), was included in the models. In the cross-sectional part we used mean SGS of each individual during follow-up as our exposure measure, while, in the longitudinal part, the exposure measure is the difference between the exposure at each time point and the mean SGS of each individual during follow-up.

### **Paper III**

In paper III the associations between neighbourhood green qualities and physical activity was investigated using ordinal regression, while the associations with general health was assessed using logistic regression. We run models both with the sum score SGS as exposure measure and models where the individual qualities; serene, wild, species richness, space and cultural history were added simultaneously. Both unadjusted and adjusted models were run. The latter ones were adjusted for sex, age group, occupation, if the residing area was urban (i.e. inner city area) or suburban/rural, country of origin, type of residence, civil status, education and economic strain.

The potentially moderating effect of neighbourhood safety and social coherence was assessed by stratifying the cohort on high vs. low individual perception of neighbourhood safety and on high vs. low individual perception of social coherence. The potentially mediating effect of safety and social coherence was reflected upon, but was considered less likely. However, an additional analysis on the association between SGS and general health with social coherence included as a covariate in the model was thus performed.

### **Materials and methods paper IV**

Paper IV differs from the other three papers as it is based on qualitative data and analysed using content analysis.



## **Interviews**

The data for paper IV was collected during interviews with 16 respondents. The inclusion criteria was that all participants had to be between 18 and 70 years of age, be living in an urban or semi-urban area in Scania, and be able to speak either Swedish or English. Participants were recruited through convenience sampling, aiming for a heterogeneous selection in terms of gender, age, and type of housing (i.e. living in an apartment or in a detached building). Each respondent completed one interview. All interviews were audio recorded and were then transcribed, word by word. During the interviews, a semi-structured interview guide was used. The guide consisted of four main items with multiple keywords for each item. In the first question, respondents were asked to describe the characteristics of the local green environment surrounding the current residence. The keywords elaborated on which places and areas that was included in this environment and which aspects that was appealing, not appealing or missing. In the second question the respondents were asked to explain and describe how the characteristics of the environment affected them, for example in terms of physical and mental health, social relations, neighbourhood satisfaction and general well-being. The third question considered how they used the environment in their daily life, with keywords about current activities and events close to home, requirements and wishes about things to do, and if there were any seasonal differences. Finally, the respondents were asked to think about places where they had previously lived and to reflect upon if and how the green local environment of the previous places affected their experiences at the current residence. It should be noted that each respondent was free to independently define the boundaries of his or her green local environment according the own perception. Therefore, the outdoor areas described by the participants range in distance from the residence.

A pilot interview was performed in July 2014 and the following interviews were conducted during the spring of 2015 and 2016. The pilot interview and the interviews conducted in 2015 were transcribed within some weeks after each interview, but were not analysed until 2016. This break between work periods was due to parental leave. Also the interviews conducted in 2016 were transcribed within a short time period after each interview. The analysis process started after the completion of the first ten interviews and was conducted in parallel with the completion of the last six interviews.

## **Content analysis**

This method to analyse data originates from the communication research in the 1950s (91) and is now commonly used, for example in nursing and health care research (92). Content analysis can be performed on different levels of abstraction.

Either, the researcher only focus on what it is directly expressed in the text, the manifest content. Or, the researcher makes an interpretation of the meaning of the text, the latent content. This interpretation can be more or less profound.

Our analysis was inspired by the course of action described by Graneheim and Lundman in 2004 (92). We started by reading each interview multiple times and then we identified and coded meaning units. Within each interview, codes with approximately the same meaning were combined into groups. We then joined the codes from the first and the second interview and combined them into a rough outline of groups. The codes from the next four interviews were then added and the process repeated. These groups were named and were now regarded as categories with a varying number of subcategories each. The codes from the remaining interviews were added and data was regrouped until the final pattern of categories and subcategories emerged.

When the research team has agreed on the categories and subcategories, the outline of the written result may start. Now, the content of all meaning units within each category, or subcategory when available, shall be condensed into an easily accessible and readable text which constitutes one combined version of the examined phenomenon. Quotes taken directly from the interviews should preferably be included in the presented results, to further illustrate the context of each category/subcategory.

# Results and comments

## Paper I - Physical activity in children

### **Main results**

The results for paper I indicate that neighbourhood environments that lack sufficient neighbourhood resources is associated with lower physical activity. Main results showed that the total volume of physical activity (i.e. counts per minute) was 1.23 times higher in the intermediate group and 1.11 times higher in the best group, compared to the reference group (i.e. the group with worst amount of neighbourhood resources). A similar pattern was seen also for sedentary time with 0.91 and 0.95 times less sedentary time among children in the intermediate and best groups, compared to the reference group. For all three variables of physical activity, the differences between groups were significant ( $p$ -value  $< 0.05$ ) between the worst and the intermediate group, whereas the comparisons between the worst and the best group were more statistically uncertain. Considering the individual attributes; access to foot and bike paths seemed to be more important for physical activity than access to non-restricted outdoor destinations and recreational areas.

### **Comments**

Paper I only include data collected during leisure time in weekdays. The 205 young children were divided into three groups; worst, intermediate or best, depending on amount of environmental attributes; a) kilometres of foot and bike paths, b) number of non-restricted destinations and c) recreational area, within 300 m surrounding the home of each child. Three physical activity variables; a) counts per minute (cpm), b) sedentary time, and c) time in moderate- to vigorous physical activity (MVPA) were modelled with the environmental attributes in mixed linear regression models adjusted for age, sex, parental education, season and type of housing. The cross-sectional design of this study makes it impossible to draw any conclusions on causality of the associations found. Also, as the children were not

monitored with GPS etcetera, we lack information about outdoor time and where the physical activity was actually performed (93).

The study in paper I reflect physical activity patterns and environmental characteristics in a less commonly studied age group (i.e. 4-11 years) and setting (i.e. Scandinavia). The study was restricted to leisure time, by excluding time in school or kindergarten, as the exposure assessment reflected the outdoor environment surrounding the home of each child. We also excluded physical activity collected during weekend days as characteristics of physical activity in children on weekdays and weekend days are essentially diverse (67, 68). The generally short measurement times were addressed using the weighted least square function giving children with longer measurement time a larger impact on the final result. As shown in previous studies (47, 94, 95) we also saw less physical activity in winter and early spring compared to autumn.

The three environmental attributes give a broad description of relative neighbourhood resources in the study area and the categorisation into groups of worst, intermediate and best neighbourhood resources has limitations. Still, to categorize all children equally, regardless of type of housing, would not have been feasible due to the huge skewness in ranges of individual attributes. Both access to, preferences for, and use of different attributes in the neighbourhood environment is likely to vary with age, and there may also be differences between older boys and girls with regard to the intensity of the physical activity generated (96-99).

The three physical activity variables are generated from the same data but reflect different aspects of physical activity. This action enabled us to assess how the environment may be associated with, not only the overall physical activity intensity (i.e. cpm), but also high (i.e. MVPA) and low (i.e. sedentary time) intensity physical activity. It is an established truth that physical activity during childhood has numerous health benefits (100) and that sedentary behaviours are negative for health (101). Previous studies have found significant positive associations between access, density and proximity to parks and objectively measured physical activity among children (22, 23, 102) and it is likely that different outdoor environments and characteristics encourage physical activity of varying intensity. Access to different outdoor environments with multiple opportunities for play and activities may increase the total amount of physical activity, especially as recent research has concluded that children (aged 8-11 years) tend to compensate for increased sedentary time by being more active on the same or the following day (103).

# Paper II – General health and mental health

## Main results

The cross-sectional results for paper II show that individuals living in areas with more green qualities had higher likelihood of good general and mental health. However, the longitudinal results showed small and statistically uncertain effects of increased greenness, with OR 1.04 (95% CI 0.98–1.10) for general health, and OR 1.07 (95% CI 1.00-1.14) for mental health. The most pronounced positive effect on general health from moving to a neighbourhood with more green qualities was indicated among subjects with lowest prognostic of good general health (OR 1.24; 95% CI 1.01 – 1.52). We conclude that a considerable change of the standardized SGS (i.e. green qualities) is required to trigger a noticeable increase in the likelihood of wellbeing.

## Extended analyses

In an additional analysis, not included in the published paper II, I assessed the impact from the individual qualities (i.e. serene, wild, species richness, space and cultural history) instead of SGS. In the analyses of general health, a significant effect in the most vulnerable prognostic group (i.e. GH 1-) was seen only for serenity (OR 1.20; 95% CI 1.02-1.41). Corresponding analysis for mental health yielded no significant results.

When the results from the four prognostic groups are weighted together as described below, there is a risk that the reported p-value is lower than what is true. Therefore, I have also run a logistic regression model where, instead of using the prognostic score as a covariate, I included all individual covariates relevant for general or mental health, respectively. This action only marginally altered the overall results, but the p-value for the GH 1- group thus changed from 0.04 (OR 1.24; 95% CI 1.01-1.52) to 0.07 (OR 1.22; 95% CI 0.99-1.50) in the analysis of general health (results not shown in paper II).

## Comments

Paper II uses a novel approach where the cohort was stratified according to prognostic score at baseline. Analyses were run in each of the four prognostic groups separately and results for the total cohort were obtained by weighting the group specific estimates with the inverse of the standard error of each estimate.

The exposure was assessed as a combination (SGS) of five green qualities. Two independent exposure measures were included simultaneously in the model: a) the mean SGS of each individual during follow-up (i.e. SGSAverage) and b) the difference between the exposure at each time point and the mean SGS of each individual (i.e. SGSCurrent - SGSAverage). The longitudinal design of the study allowed us to draw some conclusions regarding causality.

Cross-sectional studies are prone to self-selection bias (104) and single source bias (105), and evidence suggest that perceptions of the neighbourhood, and not only objective assessments, are important for health (33, 106). Using neighbourhood assessments based on an independent sample from the same study area, the problem of single source bias in studies of the perceived environment can be avoided (107). This was achieved by the use of green quality assessments from the 2008 public health survey, and health outcomes from the year 2000-2005-2010 survey. A strength of the study was the longitudinal design with repeated measurements of both exposure and outcome, which allows study individuals to change their exposure while serving as their own controls. However, the fact that only about a third of the study cohort changed residency during follow-up limits the power of the longitudinal analyses. Despite this and other limitations (described in detail in paper II), this study adds important knowledge about how perceived quality of greenness effect wellbeing in subgroups with varying vulnerability.

## Paper III –Physical activity and general health

### Main results

The adjusted results for paper III show a significant association between neighbourhood green qualities (i.e. SGS) and physical activity (OR 1.06; 95% CI 1.02-1.10) and that this relationship is moderated by perception of safety in the neighbourhood. The association was OR 1.07 (95% CI 1.02-1.11) in the group with high safety, and OR 0.89 (95% CI 0.79-1.00) in the group with low safety. While access to high quality green areas promotes physical activity, the direct association for general health was weak (OR 1.02; 95% CI 1.00-1.04) and statistically uncertain, and was not evidently moderated by perception of safety. The associations between SGS and physical activity or general health were not moderated by perception of social coherence in the neighbourhood. Cultural history was the only individual green quality associated with both physical activity (OR 1.07; 95% CI 1.00-1.13) and general health (OR 1.06; 95% CI 1.02-1.10). After stratification, significant associations for cultural history remained only in the groups with high safety.

### Extended analyses

The correlation (Spearman's rho) between safety and social coherence in this study was 0.16. As reported in paper III, in the group who perceived the safety of the neighbourhood as low, the p-value for the interaction between SGS and sex on physical activity was 0.08. An analysis of the associations between green qualities and physical activity stratified on perception of safety for men than women, respectively, show that perceived safety has an impact on both men and women (Table 5).

**Table 5. Associations for physical activity with SGS. Results presented for men and women separately and with additional stratifications for high or low perception of safety. The presented effect estimates from generalized linear mixed models imply the odds ratio (OR) for physical activity for each increase of the standardized SGS equal to one standard deviation. Results adjusted for age, education, economic difficulties, country of origin, type of residence, urban or suburban/rural area, civil status and occupation**

		PHYSICAL ACTIVITY							
		Men				Women			
		n	OR	95% CI	p-value	n	OR	95% CI	p-value
<i>ALL</i>		<b>9232</b>	1.06	1.00-1.12	0.075	<b>10919</b>	1.06	1.01-1.12	<b>0.029</b>
<i>PER-CEIVED SAFETY</i>	HIGH	<b>8513</b>	1.06	1.00-1.13	<b>0.045</b>	<b>8806</b>	1.07	1.00-1.13	<b>0.036</b>
	LOW	<b>654</b>	0.77	0.60-0.99	<b>0.039</b>	<b>1965</b>	0.93	0.81-1.07	>0.30

<sup>a</sup> Scania Green Score consisting of the mean of the five green qualities; serene, wild, species richness, space and cultural history.

An analysis of the associations between SGS and physical activity stratified for urbanity showed no association among study participants living in urban (i.e. inner city) areas (OR 1.00; 95% CI 0.85-1.18; n=2 579). When this group was further stratified on perception of safety, the estimates remained roughly the same (Table 6).

**Table 6. Associations for physical activity with SGS. Results are presented for respondents living in urban and suburban/rural areas separately and with stratifications for high or low perception of safety. The presented effect estimates from generalized linear mixed models imply the odds ratio for physical activity for each increase of the standardized SGS equal to one standard deviation. Results adjusted for sex, age, education, economic difficulties, country of origin, type of residence, civil status and occupation.**

		PHYSICAL ACTIVITY							
		Urban Areas				Suburban/ Rural Areas			
		n	OR	95% CI	p-value	n	OR	95% CI	p-value
<i>ALL</i>		<b>2579</b>	1.00	0.85-1.18	>0.30	<b>17572</b>	1.06	1.02-1.11	<b>0.006</b>
<i>PER-CEIVED SAFETY</i>	HIGH	<b>2117</b>	0.96	0.80-1.15	>0.30	<b>15202</b>	1.07	1.02-1.12	<b>0.003</b>
	LOW	<b>439</b>	0.97	0.64-1.45	>0.30	<b>2180</b>	0.88	0.78-1.00	0.054

<sup>a</sup> Scania Green Score consisting of the mean of the five green qualities; serene, wild, species richness, space and cultural history.



## **Comments**

In paper III we assessed the potentially moderating effect of safety and social coherence on the relationship between green qualities and two measures of wellbeing, i.e. physical activity and general health. The associations were tested in regression models adjusted for sex, age, education, economic difficulties, country of origin, type of residence, civil status and occupation, and we also report the unadjusted results. The risks for single source bias was diminished by using the health outcomes from the year 2012 public health survey and objective exposure assessments from the year 2008 survey. However, due to the cross-sectional design of this study, no conclusions about causality can be made, and the risks for self-selection bias (i.e. that individuals with higher well-being choose to live in neighbourhoods that support a healthy lifestyle) remain. We choose to test the impact of safety and social coherence using moderation (i.e. by stratifying the cohort into groups of high and low) rather than modification (i.e. by including safety or social coherence as a covariate in the regression model) as we believe these factors to be mostly exogenous in relation to the specific green aspects of the outdoor environment, and not so much a consequence of them.

The lack of an association between SGS and physical activity among individuals living in urban inner city areas, and the absence of any moderating effect from safety in this group, may potentially be related to a wider range of indoor facilities for physical activity (e.g. gyms, swimming pools etcetera) in the city centres.

## **Paper IV – Qualitative well-being**

### **Main results**

The aim in paper IV was to describe how the urban green local environment is perceived as supporting for well-being among adults in the general population. We identified six categories which answered to the study aim. We also found three aspects that were prerequisites for the health promoting properties of the green local environment. The categories and corresponding subcategories are presented in table 7, and fully illustrated by quotes in paper IV.

**Table 7. Presentation of the six categories with subcategories**

<b>Categories</b>	<b>Subcategories</b>
<i>1) Promoting activities</i>	a) Motivation b) Fascination to discover
<i>2) Supporting social contacts</i>	
<i>3) Stimulating sensory impressions</i>	a) Visual stimuli b) Sound experiences c) Experiences of light d) Change over time
<i>4) Providing a retreat</i>	a) Freedom from demands b) Serenity c) Emotional management
<i>5) Offering ways to influence</i>	a) Creativity b) Self-determination
<i>6) Creating sense of coherence</i>	a) Coherence with other people b) Interconnectedness with nature

The first category, “promoting activities”, describes the potential of the green local environment to motivate the participants into being active, partly through the possibility to discover new and old places. Category number two, ”supporting social contacts”, evolve around the social activities that are facilitated, or sometimes made possible, by the existence of open public green areas and neighbourhoods where people are visible to each other. The third category, “stimulating sensory impressions”, reflect experiences that the participants perceived through their ears, eyes, and sense of time. The views and sounds of nature gave feelings of happiness and provided a sense of relief from unwelcome noise exposure. The “providing a retreat” category also reflect the potential within the green environments to offer shield and relief, but from the demands and pressure of everyday life, rather than negative stimulation of the senses. This category also reflects the psychological properties of nature as a place to handle emotional challenges. Also the fifth category, “offering ways to influence”, has properties that are psychological, rather than physical. Participants described how their creativity was expressed in a green environment, sometimes through cultivation and gardening. This category also reflect how the own garden or balcony could be shaped to suit personal taste and needs, thus providing a place for self-determination and autonomy. Finally, the “creating sense of coherence” category describes the importance of being part of a larger context, together with nature, as well as through a sense of coherence with other people.

Besides the six categories, we also identified three factors that were all strong prerequisites for the health promoting properties of the green local environment. The first prerequisite was *availability*, which to a high degree determined how and how often an environment was used. The *presence of contrasts* in the green local environment was the second prerequisite raised by the participants. Finally, participants raised concerns regarding the *maintenance* and design of public spaces and expressed fear that highly appreciated green areas would be changed or built upon in the future.

## **Comments**

The results of this study demonstrate the rich variety in potential pathways through which the green local environment may promote well-being. The 16 participants who contributed to the results of paper IV all had their own personal experience of, and relation to, the green local environment where they lived. Each participant was also free to independently define the boundaries of his or her green local environment, as it has been previously proved to be wide variations in how people define this area (108). Consequently, the aspects reflected in the identified categories and prerequisites were each mentioned by a various number of participants, and emphasized to different degrees by different participants.

The trustworthiness of a qualitative study is evaluated in relation to the methods used to generate the presented results (92) and in paper IV the analysis process took place in close cooperation within the research team. The interview process however, may have been influenced by my previous knowledge on and preunderstanding of the potential health promoting aspects of the urban green local environment. Being the only interviewer, I also acquired new insights to the research topic and improved my interview skills over time, which likewise might have influenced the interview process. However, there is no reason to believe that this affected the rest of the research team or the analysis process.



# Discussion and conclusions

## General discussion

Most people spend a large part of their lives in the outdoor environment at home and in the closest neighbourhood. These settings have the potential to promote health by acting as supportive environments. Research has shown that the amount and quality of greenness in the neighbourhood affect the supportive properties of an environment. Subsequently, neighbourhood greenness is positively associated with health. However, many pieces in the puzzle that explains the causal links in these associations are still missing. Also, several alternative explanations and potential bias remain to be considered before the size and effect of this association is fully clarified. The result from paper II in this thesis add to this field by providing new insights on the association between greenness and health in groups of respondents with varying vulnerability to poor health (i.e. between the prognostic groups), and on the effect of a change of greenness exposure within the same groups. Paper II and III also discern the meaning of perceived environmental quality in a study design where the risk of single source bias has been diminished. Nevertheless, it should be noted that none of the studies in this thesis can fully compensate for the selection bias that most likely occur as an effect of the possibility that individuals with more resources and higher well-being choose to live in neighbourhoods that support a healthy lifestyle.

All four papers in this thesis aim to highlight opportunities in, and desirable aspects of, the environment, rather than barriers, risks and threats. Also, all papers utilize positive measures of health, physical activity and well-being rather than measures of disease, ill-health or reduced mobility. Overall, the results of the four papers indicate that there are indeed positive associations between diverse measures of health and the characteristics of the outdoor environment in terms of greenness and other neighbourhood resources (i.e. foot and bike paths and places for children to play. In paper I), albeit with generally low and statistically uncertain estimates. However, our results (especially the results from paper II) highlight the need to exercise caution and understanding of possible bias when interpreting the results from previous studies on nature and health.

In general, the results in this thesis are relevant on an individual level for almost everyone who ever utilize his or her outdoor environment. On a societal level, the results provide important knowledge on the different implications from neighbourhood greenness on health in various parts of the population. A deeper understanding of how the characteristics of the neighbourhood affect people depending on their current health status could help to guide policy decisions so that priorities to improve green neighbourhood environments are more focused on these, most vulnerable, groups. A more comprehensive care for, and preservation of, greenness in small as well as large areas of various types, may be of importance for such diverse aspects of society as the management of storm water, tourist attractiveness and biodiversity, and thus yield additional benefits (10, 11).

## **Generalizability**

The participation rate in the Swedish part of the IDEFICS study was 66%, and the highest among the eight participating countries. Unfortunately no information about non-participants was available. The outcome data for paper I originate from a sub-study on physical activity, in which a proportion of the children already involved in the IDEFICS study, were invited to participate. As the children were already involved in the IDEFICS study, the participation rate for the sub-study was good (83). The study area in paper I, Partille municipality, and its inhabitants, is to be regarded as fairly similar to other suburban communities in Sweden. Hence, the generalizability to children in the same age group, in Sweden and other settings with similar seasonal differences and outdoor composition, can be considered to be good.

For paper II and III, we used available data from public health surveys that had already been collected. The general approach of these surveys reduces the risk for report bias (i.e. that the answers given by the respondent is affected by the purpose of the survey). Non-participation has been studied for the 2008 survey showing an under participation of younger people, people born outside Sweden and men (89). This pattern is most likely similar in the surveys from 2000-2005-2010 and 2012. Still, the generalizability of the study populations is satisfactory.

The qualitative nature of the fourth paper makes generalizability irrelevant to discuss, as being able to draw conclusions about a larger context based on the study sample is not the purpose of a qualitative study.

## **Novelty**

The number of children (n=205) included in paper I is fairly normal for a study using objectively measured physical activity in this age group (4-11 years of age). The approach used to assess neighbourhood resources as amount of foot and bike paths, playgrounds, schoolyards and playfields, and recreational areas allows for comparisons with other studies.

Few previous studies has used prognostics scores to stratify the cohort and assess effects of change in greenness exposure within prognostic groups, as was done in paper II. This innovative approach was made possible by the extensive longitudinal survey data at hand. We were able to eliminate single-source bias, but as the assessment of exposure and health was limited to cross-sectional surveys of the longitudinal cohort, reversed causality, (i.e. that improvement in health leads to the decision to relocate to greener areas rather than vice versa), cannot be ruled out.

Also paper III adds new knowledge to the field by showing the clearly moderating effect of safety on the association between green neighbourhood qualities and self-reported physical activity.

Paper IV was conducted among adults in the general population which distinguishes it from most other recently published qualitative papers on green environments and health/well-being, as these studies more often focus on a smaller part of the population like children, the elderly or people with a certain disease or condition.

## **Ethical considerations**

For the studies in paper I and II, ethical approval was already obtained for the analyses that we wished to conduct. However, to be allowed to perform the desired study design for paper III and IV, we had to apply for ethical approval at the regional ethics board in Lund.

The data for paper I-III was already pre-collected and coded (i.e. the personal identification number had been removed) when I got the data. Even so, the possibility for reverse identification means that the information is still regarded as personal data and should be handled according to the law (i.e. Personuppgiftslagen) and the conditions stated in the ethics approval.

In a qualitative study, there is an obvious risk that the identity of anyone in the study sample may be revealed. Therefore the researcher(s) has to be very careful with the handling of data. It is crucial that that no information which may enable identification of a study subject is included in the presentation of results.

# Methodological discussion

## Exposure assessments

The three environmental attributes used to characterize neighbourhood resources in paper I had some limitations. The first limitation was the huge difference in range of each environmental attribute (i.e. foot and bike paths, playgrounds, schoolyards and playfields, and recreational area) between children depending of housing type (i.e. townhouse or villa compared to apartment building). This was accounted for by applying different rules for children in townhouse/villa and apartment, respectively, when categorizing the children into worst, intermediate and best exposure groups. The second limitation was that there were clear differences in season of activity measurement, with a substantially larger proportion of children in the worst neighbourhood resources group having performed the physical activity measurement during winter. We argue that this divergence is adjusted for in the regression model, which is supported by the results from the sensitivity analysis including only children measured during winter and early spring.

The five green qualities and the Scania Green Score (SGS) used to assess perceived greenness exposure has been previously validated and used to assess the association with health, physical activity and neighbourhood satisfaction (90, 105). However, these studies did not use separate surveys for assessment of exposure and outcome. The 1 km<sup>2</sup> areas used as the neighbourhood level in paper II and III may not correspond with the boundaries that make up the true neighbourhood that influences individual health, but represent a trade of between potential definitions. Different definitions (i.e. 0.5 km<sup>2</sup> and 2 km<sup>2</sup> areas) have been previously tested and showed similar results (90).

A reliability analysis has provided support for our decision to assess the number of positive assessments of green qualities in relation to all respondents in a particular area (i.e. including indefinite/missing assessments as negative assessments). However, the same reliability analysis did not provide consistent support for the decision to dichotomize all five green qualities (i.e. serenity and space), which may impact the validity of the exposure measures used in paper II and III (109).

Finally, this exposure assessment originated from year 2008, while outcome data for paper II was from year 2000, 2005 and 2010, and outcome data for paper III from year 2012. Based on evaluations of landscape experts, we make the explicit assumption that the changes in the environment in general between these years have been minor.



## **Outcome assessments**

The physical activity data for paper I was objectively measure with identical accelerometers, all set to record activity in epochs of 15 seconds. The generally short measurement times was accounted for by using weighted least squares to give children with longer measurement time more impact on the final results. Parents were responsible for ensuring that the accelerometer was used, which may potentially have yielded measurement bias.

In paper II and III we assess general health using a combination of two single questions. The reasoning for this approach was that we wanted to ensure that we really did capture individuals with a good health. This approach limits the possibility to compare our results with the results of other studies. However, in the sensitivity analyses in both paper II and III, we use one of the two single questions about general health (i.e. the one with five defined response alternatives) as our outcome assessment. In these analyses we see no significant associations. Hence, we can conclude that the definition of good general health affect the size of the association with neighbourhood greenness.

## **Statistical considerations**

In this thesis we have used a variety of different approaches and statistical methods, besides the qualitative method used in paper IV.

The extensive questionnaire data available in all three quantitative studies have helped to make detailed confounding control possible. Before the set-up of the logistic regression model used to determine the prognostic groups in paper II, a thorough review of all questions in the longitudinal questionnaire was conducted. This review made me very familiar with the questions in the questionnaires and guided the choice of covariates also for the logistic (physical activity; ordinal outcome) and ordinal (general health; binary outcome) regression analyses in paper III.

The analysis approach in paper III also included an assessment of the potentially moderating effect of perceived neighbourhood safety and perceived neighbourhood social coherence. An alternative approach could have been to test the mediating effect of safety and social coherence (by including safety or social coherence as a covariate in the model). However, the mediating effect of social coherence on general health was thus tested, but showed no difference compared to the analysis without social coherence as a mediator (54).

The statistical power to detect effects of changing greenness exposure in paper II was hampered by the fact that about two thirds of the participants in the study

cohort did not change exposure by moving during follow-up. Hence, there is reason to believe that those subgroups that would benefit most from an increase of neighbourhood greenness also lack abilities to move to such areas.

### **Quantitative and qualitative methods - cooperative benefits**

While quantitative methods can answer questions of “how much”; qualitative methods aim to describe the contents of a certain phenomenon by answering questions of “how” and “what”. These two approaches may seem uniquely different, but can make use of these differences and benefit greatly from each other. While qualitative methods can be used to generate hypotheses, these hypotheses can be tested on a larger scale using quantitative measures. Similarly, a phenomenon identified in a large scale qualitative study can be addressed in greater detail and depth in, for example, an interview or focus group study.

## Conclusions

- There is an association between access to neighbourhood resources for physical activity and objectively measured physical activity in children aged 4-11 years.
- There is some evidence for a beneficial effect of increased neighbourhood greenness, triggered by changing residence, on general health, in groups with low prognostics for good general health.
- Access to high quality green areas seems to promote physical activity only among individuals who perceive their neighbourhood as being safe. Similarly, a negative impact on the same association is implied if the safety of neighbourhood is perceived as low.
- There is rich variety in potential pathways through which the green local environment may promote well-being.
- There is a need to consider the green local environment from multiple perspectives when densifying cities or planning for other changes in the extent and quality of existing green areas.

## Implications for health promotion

The results of the studies included in this thesis have implications for the design and overall planning of cities and urban areas in order to promote health. As cities densify, there is a risk for an unnoticed decrease of green space and other natural environments in populated areas (11). The direct as well as more indirect health implications from the green neighbourhood environment means that a variety of different types of green areas are needed in order to meet the various needs of different groups and individuals. Thus, not only the established parks, but all types of greenness need to be fully valued, maintained and available to people.

Results from paper IV highlight how, when planning for new construction projects and other changes to the neighbourhood environment, clear and secure information from the authorities is needed to reduce feelings of uncertainty, which may otherwise negatively affect well-being. These concerns demonstrate the extensive health values that are at risk when green areas are being downgraded and regarded as less important. It also shows how important it is to be given the opportunity to influence and discuss the future development of one's own neighbourhood environment.

Providing urban environments perceived as safe is one other important factor in order to promote health and facilitate physical activity and interventions to promote physical activity in the outdoor environment should always take safety into account.

Efforts also needs to be undertaken to improve the quality of recreational environments in close proximity to where people live today, as the results of this thesis implies that those individuals who would gain most from a change of exposure may not have resources or ability to move to more salutogenic environments.

## Future research

The results in this thesis highlight the complexity involved in studying the association between green neighbourhood environments and health and the possibly health promoting effects from these environments. Thus, caution is required when interpreting results from previous research on the subject, as it cannot be ruled out that the associations and effects found in these studies are influenced by multiple confounding factors and bias.

In order to improve causal inference, future research should aim for longitudinal study designs with access to detailed monitoring of health outcomes and of changes in perceived and objectively assessed neighbourhood greenness. From a research perspective, it is also important to carefully consider how different needs implied by different groups affect the appropriate study design. Future research using subjective measures of greenness and green quality (i.e. subjective assessments of exposure), need to always consider the risk of single source bias in study designs where the outcome and exposure measures originate from the same respondent. This applies also to longitudinal studies.

Besides complex and high quality data, a wide range of innovative approaches to quantitative as well as qualitative study design and analysis methods is required in order to fully disentangle the intricate links between green environments and diverse health outcomes. Intervention studies in less affluent areas aiming at subgroups that lack abilities to move, or studies specifically focusing on people who do move, may reveal interesting new information. Also, studies of natural experiments in which a population's green exposure changed without an intervention of the environment can be of high importance, especially if they include a combination of qualitative and quantitative methods.

Studies should aim to make use of new technology. For example, GPS signals from cell phones could give exact measures of physical activity while at the same time assess exposure to neighbourhood greenness. Hence, such designs require high awareness and respect for ethical considerations.

Finally, studies including registry data to assess the incidence of different diseases in relation to changes in greenness exposure should also be encouraged.



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During this thesis work, I have lived in three different places and had four offices, all with different views. From watching a large road and a parking lot, to overlooking a pond where the birds raised their young each spring. To me, the environment outside my window mattered.

But can the amount and quality of green neighbourhood environments actually have an impact on the overall health and well-being of the population? Reading this thesis will give you some answers to that question.

