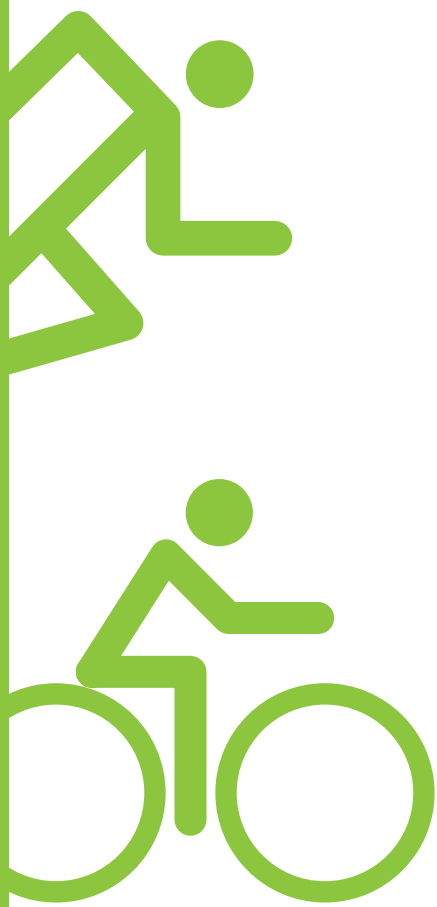
PHYSICAL ACTIVITY

The interplay between individual and neighbourhood factors



MARIËLLE A. BEENACKERS

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PHYSICAL ACTIVITY

The interplay between individual and neighbourhood factors

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Het samenspel tussen individuele en buurtfactoren

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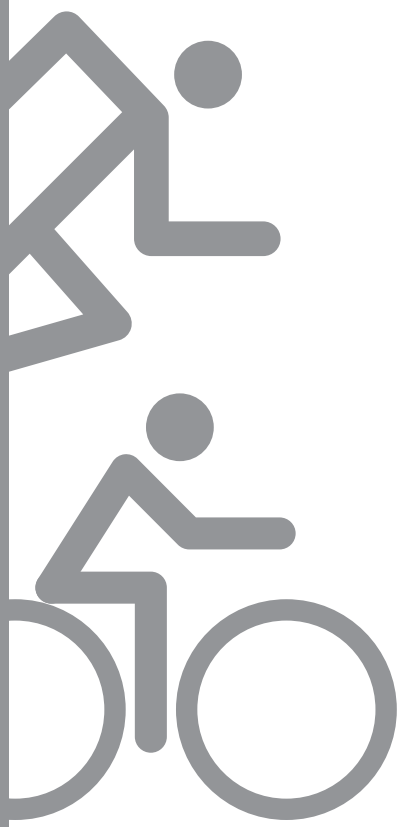

Physical activity in adults – an introduction

GENERAL INTRODUCTION

Physical inactivity is among the most important and prevalent risk factors of many major diseases in developed countries [1-4]. Regular physical activity (PA) plays an important role in the prevention of obesity and major chronic diseases such as diabetes, cardiovascular disease, mental illness, and various types of cancer [1-4]. Although the health benefits of regular exercise and a physically active lifestyle are well known, many people are still rather inactive. In the Dutch adult population, over 40% does not meet the national recommendation of being moderately active for at least half an hour on at least five days a week [5-6]. This inactivity, together with changes in dietary behaviour, is an important underlying cause of the epidemic of obesity in most developed and many developing countries [7-8]. Exactly understanding why people are physically inactive is therefore of key importance in developing strategies to reduce major chronic diseases.

In the end, physical activity is an individual choice. However, there are important reasons to believe that these choices are also determined by underlying environmental factors. One reason for this is the observation that PA and other health-behaviours are in general less favourable among lower socioeconomic groups [9-10]. It is unlikely that lower socioeconomic groups make these unhealthy choices purely based on individual considerations. It is hypothesized that these choices are partly shaped and constrained by environmental factors. Another reason to suppose that environmental factors may matter for PA is that the prevalence of inactivity in adults has increased simultaneously in many countries over the past decades, mainly because of a decrease in transport-related and occupational PA [11-12]. This is not likely to be the result of a change in behavioural choice in the residents of all these countries at exactly the same time.

Several changes in environmental circumstances are likely related to the decreasing trends in physical activity over the past decades. Transport has become more motorized and the environment has changed to facilitate this motorized transport. Also at work, physical activity has decreased because of modern technologies. Therefore, to still get sufficient physical activity, most people will have to incorporate physical activity in their leisure-time activities, such as participation in sports, or recreational walking or cycling. The observed changes in the environment and in population levels of PA, as well as the search for explanations of socioeconomic inequalities in PA, triggered researchers to investigate which environmental determinants matter for PA and to what extent environmental factors contribute to inequalities in PA. A recent report by the Dutch Health Council (Gezondheidsraad) summarised the current state of the evidence and concluded that it is plausible that the built environment can influence physical activity. However, they emphasized the need for more research on the

influences of the neighbourhood environment on physical activity, especially in combination with individual and social factors [11].

Consequently, investigating the role of both environmental and individual factors together was a logical next step in this research field. Thus far, most studies explored the independent association of either environmental or individual factors or the extent to which environmental factors were associated with health behaviours *via* individual-level factors [13-19]. The studies described in this thesis specifically address the interplay between environmental and individual factors in relation to PA, as has been suggested by social-ecological models

This first chapter summarises what is known about the importance of specific individual and environmental factors for PA, provides background information for the research questions, and an introduction to the studies presented in this thesis.

INDIVIDUAL DETERMINANTS OF PHYSICAL ACTIVITY

PA is a complex behaviour influenced by many different factors. Demographic factors such as age and gender are known to influence PA; younger people and men are more likely to be active [20]. Also, socioeconomic factors are often found to be associated with PA [18, 21-22, 20].

Research on determinants of PA, and health behaviour in general, is strongly rooted in social psychology. Commonly used theories in the development of these interventions are the Theory of Planned Behaviour (TPB) [23] and the Social Cognitive Theory (SCT) [24-25]. These theories state that behaviour is caused by psychological cognitions, such as intentions, which are in themselves determined by attitude and self-efficacy (a person's confidence in his or her ability to perform the behaviour, e.g. PA) and by social constructs such as the perceived social norm towards the stated behaviour and perceived social support from others. SCT puts more emphasis on the environment than the TPB. The environment is in the SCT defined as everything external to the individual and also involves the social constructs such as the social norm regarding behaviour. The SCT states that behaviour is the result of the continuous interaction between the personal factors such as attitude and self-efficacy, the environment, and the behaviour.

Previous research has linked individual psychosocial cognitions to PA [26-28, 20]. Of all factors, self-efficacy is consistently correlated with PA [26-28, 20] which is in line with Bandura's theory that self-efficacy is the single most important aspect in changing behaviour [24]. Also attitudes, perceived barriers and benefits, and perceived social norm and social support are

often found to be correlated with PA [14, 16-17, 29] although the evidence is less consistent [26]. Together, these variables explain about 20-40% of the variance in PA [30, 14, 31].

ENVIRONMENTAL DETERMINANTS OF PHYSICAL ACTIVITY

Because changes in individual determinants of PA cannot sufficiently explain the decline in PA and the increase in overweight and obesity over time, the focus of research on determinants of PA has shifted also towards environmental determinants of PA. Environmental factors may also contribute to health inequalities as lower socioeconomic groups seem to be more likely to live in neighbourhoods that are less supportive for engaging in PA [32-33, 22]. Furthermore, information on environmental determinants of PA can inform future policies and interventions. Although interventions that aim to change individual psychosocial cognitions towards PA may be effective, they may be inadequate in establishing long-term maintenance of health behaviours [34-36]. A possible explanation could be that these interventions change behaviour initially but that factors within the environment cause people to return to their previous behaviour.

In the past decades, a large number of different characteristics of the neighbourhood environment have been explored for their association with PA. Different methods have been employed to determine environmental influences on PA, varying from measuring perceptions of the environment by interviews or questionnaires to objectively counting the number of intersections. A neighbourhood characteristic that has been studied frequently is 'walkability' of the neighbourhood, which is an aggregated construct that is based on objectively measured residential density, land use mix, and street connectivity [37]. This construct is often found to be associated with PA, especially transport-related PA [38-42]. Most evidence about the association between walkability and PA derives from the USA and Australia, were walkability is generally much lower than in European countries such as the Netherlands. However, studies by Van Dyck [29, 43-44] have shown that also in Belgium cities, a higher walkability can be conductive to PA. Other neighbourhood factors such as accessibility to recreational facilities or walking and cycling paths, neighbourhood aesthetics, and crime and traffic related safety have been associated with PA although research is not always consistent and results seem to vary between different behaviours [45-48, 20, 49-50]. This suggests that different neighbourhood factors are important for different PA behaviours which emphasize the need for specificity [51-52, 49-50]. For example, an aesthetically pleasing neighbourhood environment seems to be important for walking for exercise or recreation, but not for walking to get to and from places [46].

SOCIAL-ECOLOGICAL MODELS

Individual and environmental determinants of PA are most likely interrelated. This is expressed in many social-ecological models [53]. For example, a plea from Emmons [54] to improve understanding health behaviours in their social context implies that the role of individual factors for health behaviours may depend on the environmental context. Specific health behaviour theories such as the previously mentioned Social Cognitive Theory [24-25] and the Social Ecology Model for Health Promotion [55-56], both widely used and accepted theories for health behaviour, imply reciprocal determinism with continuous interplay between the environment, the person, and the behaviour. In general, ecological perspectives on health behaviour follow four core principles [53]; first, they recognize that there are multiple levels of factors that influence health behaviour and that these influences interact across levels. A consequence is that they pose that multi-level interventions are likely to be the most effective in changing behaviour. Fourth, they are expected to be most powerful when they are behaviour specific.

Most social-ecological models acknowledge the interplay between individual and environmental factors in explaining health behaviours such as PA. However, these models are, in general, very comprehensive and try to capture all aspects that may influence the assumed

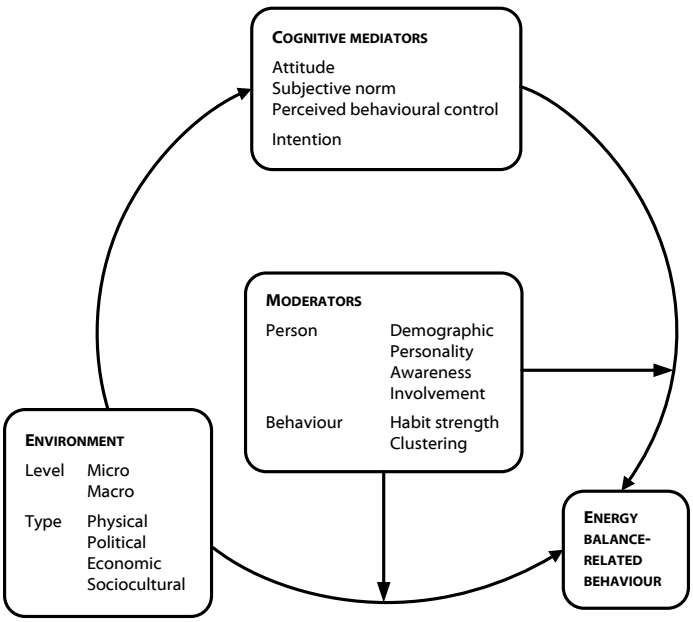

Figure 1-1: Environmental Research framework for weight Gain prevention (EnRG)[59].

interplay [57-58]. They do not provide a clear hypothesis on how these factors interact. An example of an ecological model that goes one step further is the Environmental Research framework for weight Gain prevention (EnRG) by Kremers and colleagues [59] (Figure 1-1). They propose a dual process approach in which the environment is supposed to have a direct effect on energy-related behaviours such as PA and an indirect effect via psychosocial cognitions. It also postulates several moderator variables such as demographic factors and personality. It does not, however, account for the possibility psychosocial cognitions as moderator variables, or in other words: for possible interactions between psychosocial cognitions and environmental factors on PA. This interaction is often recommended to be included in research [60, 47-48, 52] but only very recently studies have emerged that actually empirically investigate these interactions [61-64].

ENVIRONMENT-INDIVIDUAL INTERACTIONS

The current evidence for interplay between individual and environmental factors for PA is growing but still relatively sparse. Cerin and colleagues [62] reported that the presence of outdoor individual sport/fitness facilities was associated with more vigorous leisure-time PA in people with below average self-efficacy and enjoyment. Carlson [61] found, among other things, that walkability was stronger associated with transportation walking in people with more positive cognitions. Prins et al [64] found that intention was stronger associated with sports participation when sports facilities were more readily available. Finally, Deforche and colleagues [63] found, among other things, that lower perceived safety and poorer access to neighbourhood services reduced the likelihood of transport-related PA only among youth with lower self-efficacy while better land-use-mix diversity, neighbourhood aesthetics and better access to recreational facilities increased active transportation in youth with high self-efficacy. All these separate studies indicate that there are two possible underlying mechanisms that are expected to result in neighbourhood-individual interactions. First, in the synergetic mechanism, positive psychosocial cognitions and a supportive neighbourhood environment reinforce each other in stimulating PA. The other mechanism is that people who have less positive psychosocial cognitions towards PA benefit most by a supportive neighbourhood environment. The current evidence does not provide clear evidence for one of these two mechanisms.

An important consideration when investigating possible interactions is to distinguish between a combined effect and an interaction effect. A combined effect is seen when the likelihood that people walk is greatest when both environmental factors and psychosocial cognitions are supportive. It is the sum or the product of these two separate effects. An interaction exist when the influence of the psychosocial cognition and the influence of the

environment combined is *greater* or *less* than the combined effect [65]. When an interaction exists, the effect or association between the psychosocial cognition and PA is different in different neighbourhood environments or the influence of the neighbourhood environment on PA is different for people with different psychosocial cognitions. In other words, one factor modifies the effect or association that another factor has on the outcome of interest. Consequently, epidemiologists often refer to interactions by the term 'effect modification'. In cross-sectional studies, it cannot be determined which of the two factors within the interaction term is considered the effect modifier or moderator. Therefore, the term 'interaction' is used in this thesis.

When statistically testing for interaction in regression models, an interaction term, defined by the product of the two independent predictors, is added to the regression model. The type of regression model will define the interpretation of the interaction [66]. An interaction in a logistic (or Cox) regression model is tested for its departure from multiplicativity (the combined 'effect' of the two factors is larger or smaller that the product of the individual 'effects'). This means that if an interaction term is significantly associated with the outcome, the odds ratio should be interpreted as a multiplicative factor. An interaction in a linear regression model is tested for its departure from additivity (the combined 'effect' of the two factors is larger or smaller that the sum of the individual 'effects'). Although both interactions help understand the complex nature between two factors, additive interactions are often considered more intuitive and more relevant to public health [67, 66]. Several methods are available to additionally quantify interaction as departure from additivity in a logistic regression model (eg. the Relative Excess Risk due to Interaction (RERI)) [68, 66].

RESEARCH QUESTIONS

Physical activity is a complex behaviour that is influenced by many factors. In this thesis, associations of individual and neighbourhood factors with PA are studied with a particular focus on the interplay between these individual and neighbourhood factors.

Socioeconomic status (SES) is an important individual factor that determines PA. Research has shown that low SES groups are often less physically active [69] compared with high SES groups, and that this may be partly related to the less favourable neighbourhood circumstances of low SES groups [18, 21]. However, empirical evidence also suggests that socioeconomic patterns may differ for different domains of PA [15-16]. Patterns may also differ by European region, as illustrated by the North to South gradient in obesity inequalities [6-7]. We therefore want to study how associations of SES with PA differ for different PA domains (e.g. leisure-time PA, transport-relate PA), and for different regions in Europe. Gaining insight

in socioeconomic inequalities in different domains of PA will inform in which behaviour the inequalities are most consistent and therefore what PA behaviours could be targeted to reduce these inequalities in health and health behaviours. Consequently, the first research question is:

1. Are there socioeconomic inequalities in physical activity and are these inequalities similar for different domains of physical activity, and for different European regions?

Many models and review studies have suggested that neighbourhood-individual interactions are important in understanding PA behaviours. However, there is still very little empirical evidence available. Therefore, the second research question of this thesis is:

2. How do psychosocial cognitions and neighbourhood factors interact in explaining physical activity?

To actually intervene on environmental factors to improve PA, it is important to understand whether changes in the neighbourhood environment can actually cause changes in PA. Consequently, the third research question is:

3. Can neighbourhood changes cause changes in physical activity?

OVERVIEW OF THIS THESIS

Chapter 2 provides information on the GLOBE study, which was used in chapter 4, 5, and 6. Hereafter, this thesis is ordered according to the three main research questions.

First, in **chapter 3**, the first research question 'Are there socioeconomic differences in physical activity and are these differences similar for different domains of physical activity , and for different European regions?' will be addressed by means of a systematic review of the literature on socioeconomic inequalities in PA in Europe. Chapter 4, 5, and 6 will focus on the second research question 'How do psychosocial cognitions and neighbourhood factors interact in explaining physical activity?'. In **chapter 4**, the interactions between perceived neighbourhood safety and psychosocial cognitions with respect to sports participation are studied. In **chapter 5**, the associations of perceived neighbourhood safety and social neighbourhood factors such as social cohesion and social network with leisure-time walking are described. In this study, also the interactions between these neighbourhood factors and psychosocial cognitions are explored. The final chapter in this section (**chapter 6**) also focuses on leisure-time walking but in this chapter, objective neighbourhood factors are studied.

The third research question 'Can neighbourhood changes cause changes in physical activity?' will be addressed in **chapter 7**. This chapter describes how exposure to a different neighbourhood environment may stimulate cycling among former non-cycling adults in an Australian city.

Finally, in **chapter 8**, the main results for the three research questions will be summarized and discussed with respect to previous research and methodological considerations. Implications of the results for research and practice will be presented.

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2

Cohort Profile: Understanding socioeconomic inequalities in health and health behaviours – The GLOBE study

Frank J. van Lenthe
Carlijn B.M. Kamphuis
Mariëlle A. Beenackers
Tessa Jansen
Caspar W. Looman
Wilma Nusselder
Johan P. Mackenbach

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3

Socioeconomic inequalities in occupational, leisure-time, and transport related physical activity among European adults: a systematic review

Mariëlle A. Beenackers
Carlijn B.M. Kamphuis
Katrina Giskes
Johannes Brug
Anton E. Kunst
Alex Burdorf
Frank J. van Lenthe

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ABSTRACT

Background: This study systematically reviewed the evidence pertaining to socioeconomic inequalities in different domains of physical activity (PA) by European region.

Methods: Studies conducted between January 2000 and December 2010 were identified by a systematic search in Pubmed, Embase, Web of Science, Psychinfo, Sportdiscus, Sociological Abstracts, and Social Service Abstracts. English-language peer-reviewed studies undertaken in the general population of adults (18–65 years) were classified by domain of PA (total, leisure-time including sport, occupational, active transport), indicator of socioeconomic position (education, income, occupation), and European region. Distributions of reported positive, negative, and null associations were evaluated.

Results: A total of 131 studies met the inclusion criteria. Most studies were conducted in Scandinavia (n = 47). Leisure-time PA was the most frequently studied PA outcome (n = 112). Considerable differences in the direction of inequalities were seen for the different domains of PA. Most studies reported that those with high socioeconomic position were more physically active during leisure-time compared with those with low socioeconomic position (68% positive associations for total leisure-time PA, 76% for vigorous leisure-time PA). Occupational PA was more prevalent among the lower socioeconomic groups (63% negative associations). Socioeconomic differences in total PA and active transport PA did not show a consistent pattern (40% and 38% positive associations respectively). Some inequalities differed by European region or socioeconomic indicator, however these differences were not very pronounced.

Conclusions: The direction of socioeconomic inequalities in PA in Europe differed considerably by domain of PA. The contradictory results for total PA may partly be explained by contrasting socioeconomic patterns for leisure-time PA and occupational PA.

INTRODUCTION

Socioeconomic inequalities in morbidity and mortality are well-documented [1-2]. Differences in health behaviours play an important role in these inequalities [3]. Next to the higher prevalence of smoking in lower socio-economic groups [4-5], evidence suggests that the higher obesity rates are of major importance to health inequalities [6-9].

Obesity levels in Europe are rising rapidly; the prevalence of obesity has tripled since the 1980s [10]. This high prevalence of obesity is estimated to account for 1 million deaths and 12 million life years of ill health in Europe each year [10]. European regions are thought to be in a different stage of the obesity epidemic; when the level of economic development increases, the proportion of positive associations between socioeconomic position (SEP) and overweight and obesity decreases and the proportion of negative association increases [6, 8]. Because overweight and obesity are the result of an excessive energy intake or limited energy expenditure, differences in dietary intake or physical activity (PA) are expected to contribute to the socioeconomic inequalities in overweight and obesity. A recent review of socioeconomic inequalities in nutrition in Europe [11] reported that consistent socioeconomic inequalities in diet were seen for fruit and vegetable consumption and, to a lesser degree, for fibre consumption but not in amounts of energy intake. PA is a health behaviour of major importance as it is strongly associated with obesity and a number of diseases such as metabolic disease and certain cancers [12-13]. However, no systematic review of the evidence of socio-economic differences in PA in Europe has been published to date.

PA is often categorized as low intensity PA (<3 Metabolic Equivalent (MET)) versus moderate (3–6 METs) to vigorous PA (>6 METs) [14]. The latter two categories are regarded as especially important for health. Furthermore, leisure-time, work-related, and transport-related PA are often distinguished from each other. Empirical evidence suggests that socioeconomic patterns may differ for different domains of PA [15-16]. Patterns may also differ by gender, as exemplified by the finding that inequalities in overweight and obesity are larger in women [8], and by European region, as illustrated by the North to South gradient in obesity inequalities [6, 8]. Finally, traditional indicators of SEP, such as income, occupation, and education, may reflect different aspects of one's position in the social stratification [17-18], and may therefore be more strongly or weakly related to specific outcomes.

The purpose of this review is to describe socioeconomic inequalities in different domains of physical activity, across different SEP indicators, in men and women, and across different regions in Europe.

METHOD

Search strategy

Databases and search terms

Major databases (PubMed, EMbase, Web of Science, PsychINFO, SportDiscus, and Sociological Abstracts and Social Services Abstracts) were searched to locate relevant studies published between the first of January 2000 and the 31st of December 2010. Broad search terms, including synonyms, were used to ensure that all potentially relevant articles were included in the search results. When possible, database specific search terms were used to optimize the results. The search strategy and syntax for each database are available from the Authors (MAB) upon request.

Inclusion and exclusion criteria

Publications were included if they were published in English-written peer-reviewed journals. Studies had to be conducted among the general population, which therefore excluded studies utilizing patient groups. Given the interest in occupational physical activity, study participants had to be of working age (18–65 years of age). Studies quantitatively assessed the association between at least one SEP indicator and one domain of physical activity (measured, either in terms of frequency (e.g. times/week), duration (e.g. hours or minutes), and/or intensity (e.g. vigorous)). Indicators of SEP included education, social class (based on occupation), income (either individual or household level), household wealth (e.g. car ownership, housing tenure) or area-based indicators (e.g. area deprivation). Outcomes included were total physical activity, leisure-time physical activity including but not limited to sports and exercise (both organized and unorganized), active transport (walking, cycling), and occupational physical activity. Manuscripts that elicited concerns about the study quality were excluded. These quality concerns were inconsistencies between the results in the text and the results in the tables, missing information on how the outcome or SEP indicator was measured, or missing information on the basic description of the sample, such as sample size.

Data extraction and summarization

Title scanning and selection

As a first step in identifying relevant studies, titles and abstracts were read by the lead author (MAB). Second, the full text was read if studies met the inclusion criteria and when it was clear from the title and/or abstract that the association between SEP and PA was studied. A second researcher (CBMK) executed an independent parallel selection process with a random subsample of 200 titles and abstracts which resulted in a similar selection.

Data synthesis

The following information was extracted into data extraction tables from each included study: country, year (or years) the data were collected, sample size and sample characteristics (in case a subpopulation was studied), age range, percentage males, percentage response, SEP indicator and PA outcomes (Table 3-1).

Classification of the outcome measures

The following guidelines were used to classify the studies into the different domains of PA:

- A PA outcome was categorized as 'total physical activity' (TPA) if it concerned a general PA question (not defined whether they mean occupational PA or leisure-time PA) or if the measure included leisure-time PA as well as occupational PA. Total physical activity was often described as 'usual' or 'daily' physical activity.
- A PA outcome was categorized as 'occupational physical activity' (OPA) if it was specifically identified as occupational PA in the methods with words such as 'occupational' or 'during work'.
- A PA outcome was categorized as 'total leisure-time physical activity' (TLTPA) if it was specifically identified as leisure-time PA in the methods with words such as 'in free time' or 'during leisure time'. Exception: leisure-time physical activity that can be defined as vigorous physical activity (see classification criteria below).
- A PA outcome was categorized as 'vigorous leisure-time physical activity' (VLTPA) if the methods specifically reported that it is about high intensity physical activity, vigorous physical activity, conditioning physical activity, or sports participation. Only vigorous physical activity at leisure time was considered for this category.
- A PA outcome was categorized as 'active transport' (AT) if the outcome measure was defined as walking or cycling to work, school or other destinations such as shops or friends.

For some studies, PA outcomes could not be clearly classified in either of these groups (e.g. heavy manual leisure (like chopping wood) or walking or cycling of which the purpose (leisure or transport) was not clear). Therefore, these outcomes were excluded from the current review.

Classification of the socioeconomic position indicators

The following guidelines were used to classify the SEP indicators in this study.

- Income refers to (net or gross) individual income or household income. When area-level income was used as an indicator, it was classified as 'other' and specified further in the footnotes of the tables.
- Education refers to the highest attained level of education (e.g. university education) or as the total years of education.

- Social class refers to occupation-based social class, such as blue collar or white collar workers, or the British Registrar General classification [19].
- Other SEP indicators that were included were neighbourhood SEP, such as mean/median income of a neighbourhood, material circumstances, such as home ownership, or other individual SEP measures, such as an individual composite SEP score that was constructed from several SEP indicators.

Parental SEP, childhood SEP, or the SEP of the spouse were excluded as a SEP indicator in this review.

Classification of European regions

The results were grouped by European region, based on geographical location and type of welfare regime [20-21]. The regions that were distinguished are:

- Anglo-Saxon region, including Great-Britain and Ireland
- Western European region, including Belgium, France, Germany, Luxembourg, Netherlands, and Switzerland
- Scandinavian region, including Denmark, Finland, Norway, and Sweden
- Southern European region, including Greece, Italy, Portugal, and Spain
- Eastern European region, including Albania, Croatia (Hrvatska), Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, and Slovenia

As many studies included more than one PA domain and/or more than one SEP indicator, the results were analysed on the level of the separate associations rather than the level of complete studies. This is in concordance with methods from McLaren [6] and Ball and Crawford [22]. The advantage is that we could distinguish between the domains of PA behaviour and the SEP indicators. Disadvantages of this method are that all associations are weighted equally and that studies with more associations have more influence than those with only one reported association [6].

Detailed tables in which all the associations reported in the included studies were synthesized are described in the additional tables (Appendix, Tables 3-A1 to 3-A5, one for each domain of PA). A '+' indicates a positive and significant association between the SEP indicator and the PA outcome of interest, a '-' indicates a negative and significant association between the SEP indicator and the PA outcome of interest. A '0' means that there was no significant (linear) association found. Significance was judged with $\alpha = 0.05$. When there were more than two categories, the overall test of significance, or trend test was used (when available). If not available, significance was judged by looking at the significance level of the difference between the two most extreme groups. When there was no trend, or a curvilinear trend, for example when only the middle group was significantly different (but not the extremes), the

Table 3-1: Characteristics of the 131 included studies ordered by European region.

Author, year of publication	Country of study[a]	Study name	Year of data-collection	Sample size + characteristic[b]	Age	% Male[c]	Response[c]	SEP indicator[d]	PA type[e]
EU wide studies									
Martinez-Gonzales *et al*, 2001[23]	EU – 15 countries	Pan-European Union survey	1997	n= 15239	15+	47%	NP	Education	TLTPA
Ståhl *et al*, 2001[24]	BEL, FIN, DEU, NLD, ESP, SWI	MAREPS project	1997-98	n= 3343	18+	43%	54%	Education	TPA
Van Tuyckom & Scheerder, 2008[25]	EU – 27 countries	Eurobarometer 64.3	2005	n= 26688	15+	NP	NP	Education Social class	TLTPA
Van Tuyckom & Scheerder, 2010a[26]	EU – 27 countries	Eurobarometer 64.3	2005	n= 26362	15+	NP	NP	Social class	TLTPA
Van Tuyckom & Scheerder, 2010b[27]	EU – 27 countries	Eurobarometer 64.3	2005	n= 26688	15+	NP	NP	Education	OPA TLTPA AT
Varo *et al*, 2003[29]	EU – 15 countries	Pan-European Union survey	1997	n= 15239	15+	47%	NP	Education	TLTPA
Western European region									
Addor *et al*, 2003[30]	SWI	Health examination survey of adults (MONICA project)	1992-93	n= 1550	25-64	49%	53%	Education	VLTPA
Bertrais *et al*, 2004[31]	FRA	SUVIMAX study	1998	n= 7404	45-68	46%	NP	Education	TLTPA
Chaix & Chauvin, 2003[32]	FRA	2000 French Health Monitoring Survey	2000	n= 12948	16+	49%	66%	Education Income	TLTPA
Dragano *et al*, 2007[33]	DEU, CZE	DEU: Heinz Nixdorf Recall (HNR) Study CZE: Health, Alcohol & Psychosocial Factors in Eastern Europe (HAPIEE)	DEU: 2000-03 CZE: 2002-05	n DEU = 4032 n CZE = 7522	45-69	DEU: 49% CZE: 45%	DEU: 56% CZE: 55%	Education Neighb. SEP	TLTPA
Drieskens *et al*, 2010[34]	BEL	Belgian Health Interview Survey (HIS)	1997 2001 2004	n 1997 = 7431 n 2001 = 8142 n 2004 = 7459	15+	NP	60%	Education	TLTPA
Galobardes *et al*, 2003[35]	SWI	Bus Santé 1993-2000	1993-2000	n= 8194	35-74	51%	57-65%	Education Social class	VLTPA
Kamphuis *et al*, 2008[36]	NLD	Dutch GLOBE study 2004	2004	n= 3839	25-75	48%	64%	Income Education	VLTPA

Table 3-1: Characteristics of the 131 included studies ordered by European region. *(continued)*

Author, year of publication	Country of study[a]	Study name	Year of data-collection	Sample size + characteristic[b]	Age	% Male[c]	Response[c]	SEP indicator[d]	PA type[e]
Kamphuis *et al*, 2009[37]	NLD	Dutch GLOBE study 2004	2004	n= 1994	55-75	48%	62%	Income Education	TLTPA
van Lenthe *et al*, 2005[38]	NLD	Dutch GLOBE study 1991	1991	n= 8767	20-69	NP	70%	Neighb. SEP	TLTPA VLTPA AT
Meyer *et al*, 2005[39]	SWI	Swiss Health Survey 2002	2002	n= 8405 community residents	50+	45%	NP	Income Education	VLTPA
Nocon *et al*, 2008[40]	DEU	German National Health Survey	1998	n= 7124	18-79	48%	NP	Income Education Social class	VLTPA
van Oort *et al*, 2004[41]	NLD	Dutch GLOBE study 1991	1991	n= 16980	15-74	49%	70%	Education	TLTPA
Rathmann *et al*, 2005[42]	DEU	KORA (=Cooperative Health Research in the Region of Augsburg) Survey	2000	n= 1653	55-74	51%	62%	Income Education Social class	TLTPA
Ribet *et al*, 2001[43]	FRA	GAZEL study (G) MONICA – France (M)	G: 1989-92 M: 1994-97	n G = 9486 n M = 534 working, living in couple	40-50	100%	G: 44-87% M: 51-77%	Social class	TLTPA
Scheerder *et al*, 2002[44]	BEL	Sports participation in Flanders - Leuven Growth Study of Flemish Girls - Study on Movement Activities in Flanders	1969 1979 1989 1999	n 1969 = 7479 n 1979 = 18629 n 1989 = 7957 n 1999 = 9143 parents of school children	NP	50%	71-89%	Education Social class	VLTPA
Scheerder *et al*, 2005[45]	BEL	Sports participation in Flanders - Leuven Growth Study of Flemish Girls - Study on Movement Activities in Flanders	1979 1989 1999	n 1979 = 19396 n 1989 = 8624 n 1999 = 10356 parents of school children	NP	50%	71-89%	Education Social class	VLTPA

Table 3-1: Characteristics of the 131 included studies ordered by European region. *(continued)*

Author, year of publication	Country of study[a]	Study name	Year of data-collection	Sample size + characteristic[b]	Age	% Male[c]	Response[c]	SEP indicator[d]	PA type[e]
Schneider & Becker, 2005[46]	DEU	German National Health Survey	1998	n= 3323 employed	18-69	56%	61%	Income Education Social class Individual SEP	VLTPA
Van Dyck *et al*, 2010[47]	BEL	Belgian Environmental Physical Activity Study (BEPAS)	2007-08	n= 1166	20-65	48%	58%	Education Neighb. SEP	TLTPA AT
Verdaet *et al*, 2004[48]	BEL	BELSTRESS study (subsample)	NP	n= 892 working men	35-59	100%	NP	Education	TLTPA
de Vries *et al*, 2008[49]	NLD	SMILE study	2002	n= 9449	12+	42%	NP	Education	TPA
Wagner *et al*, 2003[50]	FRA IRE	PRIME Study – France PRIME Study – Ireland	NP	n FRA = 7359 n IRE = 2398	50-59	100%	NP	Education Household wealth	TLTPA VLTPA AT
Eastern European region									
Drygas *et al*, 2009[51]	POL	National Polish Health Survey, (WOBASZ, Project)	2002-05	n= 12552	20-74	47%	74-79%	Income Education	TLTPA
Frömel *et al*, 2009[52]	CZE	Czech physical activity, environment and SES study	NP	n= 9950	25-64	49%	58%	Individual SEP	TPA VLTPA
Jurakić *et al*, 2009[53]	HRZ	Croatian physical activity study	2007	n= 1032	15+	48%	NP	Income Education	TPA OPA TLTPA AT
Kaleta & Jegier, 2005[54]	POL	Physical activity in Poland	NP	n= 508 employed	adults (42 ± 10)	54%	47%	Income Education	TLTPA
Kaleta & Jegier, 2007[55]	POL	Physical activity in Poland	NP	n= 954	25-64	47%	48%	Income Education	TLTPA
Kwaśniewska *et al*, 2010[56]	POL	The National Multicentre Health Survey (WOBASZ Project)	2004-05	n= 7280 works/studies outside home	20-74	51%	74-79%	Income Education	AT

Table 3-1: Characteristics of the 131 included studies ordered by European region. *(continued)*

Author, year of publication	Country of study[a]	Study name	Year of data-collection	Sample size + characteristic[b]	Age	% Male[c]	Response[c]	SEP indicator[d]	PA type[e]
Leskosek *et al*, 2002[57]	SVN	Sport participation in the Republic of Slovenia	1998	n= 1768	18+	52%	59%	Education	VLTPA
Mišigoj-Durakoviæ *et al*, 2000[58]	HRZ	Zagreb study	1999	n= 594 employed	20-65	50%	20%	Education	OPA TLTPA VLTPA
Nowak, 2010[59]	POL	Western Poland active lifestyle survey	2000-06	n= 3662	20-75	all female	NP	Education	VLTPA
Paulik *et al*, 2010[60]	HUN	Health survey rural Hungary	2006	n= 3380 living in small settlements	18+	47%	83%	Education Household wealth	VLTPA
Pomerleau *et al*, 2000[61]	EST LVA LTU	Three national surveys of adults	1997	n EST = 2018 n LVA = 2303 n LTU = 2140	19-65	EST: 45% LVA: 46% LTU: 44%	EST: 67% LVA: 78% LTU: 73%	Income Education	TLTPA VLTPA
Puska *et al*, 2003[62]	EST LTU FIN	Finbalt project	1994, 1996, 1998	n EST = 3808 n LTU = 5716 n FIN = 9608	20-64	EST: 44% LTU: 44% FIN: 48%	EST: 68-83% LTU: 62-69% FIN: 70-72%	Education	TLTPA
Shapo *et al*, 2004[63]	ALB	Health behaviours and health status in Tirana City	2001	n= 1120	25+	48%	73%	Income Education	TLTPA
Stelmach *et al*, 2004[64]	POL	CINDI programme (Countrywide Integrated Noncommunicable Disease Intervention Programme)	2001-02	n= 1837	18-64	54%	NP	Income Education	TLTPA
Zaletel-Kragelj *et al*, 2006[65]	SVN	CINDI Health Monitor	2001	n= 7718 without disability	25-64	47%	64%	Education Social class	TPA
Southern European region									
Artazcoz *et al*, 2004[66]	ESP	Catalonian Health Survey (CHS)	1994	n= 2866 workers and housewives	25-64	all female	NP	Education	VLTPA
Bolívar *et al*, 2010[67]	ESP	Andalusia Health Survey	1999, 2003	n= 13193	16+	49%	NP	Education Social class Neighb. SEP	TLTPA

Table 3-1: Characteristics of the 131 included studies ordered by European region. *(continued)*

Author, year of publication	Country of study[a]	Study name	Year of data-collection	Sample size + characteristic[b]	Age	% Male[c]	Response[c]	SEP indicator[d]	PA type[e]
Borrell *et al*, 2000a[68]	ESP	Barcelona Health Interview Survey	1992	n= 4171	14+	47%	91%	Occupation	TPA VLTPA
Borrell *et al*, 2000b[69]	ESP	Barcelona Health Interview Survey	1986 1992 1994	n 1986 = 7907 n 1992 = 5004 n 1994 = 2155	14+	1986: 46% 1992: 47% 1994: 44%	88-93%	Occupation	TPA
De Vogli *et al*, 2005[70]	ITA	Health Determinants Surveillance System (HDSS) Survey	2003	n= 3327	18-91	52%	57%	Social class	TLTPA
Gal *et al*, 2005[71]	PRT	Porto health survey	NP	n= 2004	18+	39%	70%	Education Social class	TPA TLTPA
Lera-López & Rapún-Gárate, 2005[72]	ESP	Sport participation and consumer expenditure in Navarra, Spain	2004	n= 700	16-65	NP	NP	Income Education	VLTPA
Meseguer *et al*, 2009[73]	ESP	Non-communicable Disease Risk Factor Surveillance System (NCDRFSS)	2000-05	n= 12037	18-64	49%	65%	Education	TLTPA
Panagiotakos *et al*, 2008a[74]	GRC	ATTICA study	2001-02	n= 3042	18+	50%	75%	Education	TPA
Panagiotakos *et al*, 2008b[75]	GRC	ATTICA study	2001-02	n= 3042	18+	50%	75%	Education	TPA
Pascual *et al*, 2007[76]	ESP	Spanish Health Study	2001	n= 19324	16-74	49%	85%	Income Education Social class Neighb. SEP	TLTPA
Pascual *et al*, 2009[77]	ESP	General survey on customs regarding media and leisure activities	1999	n= 25982	25-74	49%	70%	Income Education Neighb. SEP	VLTPA
Pitsavos *et al*, 2005[78]	GRC	ATTICA study	2001-02	n= 3042	20-89	50%	75%	Income Education Social class	VLTPA
Santos *et al*, 2009[79]	PRT	Azorean Physical Activity and Health Study	2004	n= 9991	18-65	43%	88%	Income Education	TPA

Table 3-1: Characteristics of the 131 included studies ordered by European region. *(continued)*

Author, year of publication	Country of study[a]	Study name	Year of data-collection	Sample size + characteristic[b]	Age	% Male[c]	Response[c]	SEP indicator[d]	PA type[e]
Schröder *et al*, 2004[80]	ESP	Gerona cardiovascular risk factor and lifestyle study	1994-96	n= 1748	25-74	48%	73%	Education	TLTPA VLTPA
Scandinavian region									
Ali & Lindström, 2006[81]	SWE	2000 public health survey in Scania	2000	n= 5180 workforce or unemployed	18-64	56%	59%	Education	TLTPA
Andersen *et al*, 2000[82]	DNK	Copenhagen City Heart Study (CCHS) Copenhagen Male Study (CMS) Glostrup Population Study (GPS) (pooled)	1964-92	n= 30640	20-93	56%	69-95%	Education	TLTPA VLTPA AT
Barengo *et al*, 2006[83]	FIN	National FINRISK Study	1972-97	n= 33712	30-59	49%	71-95%	Education Social class	TPA
Bergman *et al*, 2008[84]	SWE	International Prevalence Study (IPS) Sweden	2003	n= 1470	18-74	47%	59%	Income Education	TPA
Borodulin *et al*, 2008[85]	FIN	National FINRISK Study	2002	n= 4437	25-64	44%	59-70%	Education	TLTPA
Cubbin *et al*, 2006[86]	SWE	Swedish Annual Level of Living Survey	1996-2000	n= 10890	25-64	49%	80%	Individual SEP Neighb. SEP	VLTPA
Engström, 2008[87]	SWE	Sport Habitus Study Sweden	2007	n= 1518	53	NP	77%	Education	VLTPA
Häkkinen *et al*, 2006[88]	FIN	Northern Finland 1966 Birth Cohort	1998	n= 4343	31	46%	76%	Education	TLTPA
Henriksson *et al*, 2003[89]	SWE	Cardiovascular Risk Factor Study in Southern Sweden (CRISS)	1990 1993 1996	n 1990 = 991 n 1993 = 770 n 1996 = 702	37 40 43	100%	1990: 68% 1993: 78%* 1996: 71%* *of baseline	Education	TLTPA
Hu *et al*, 200[90]	FIN	National FINRISK Study	1982, 1987, 1992	n= 14290	35-64	48%	74-88%	Education	OPA TLTPA AT
Kivimäki *et al*, 2007[91]	FIN	Finnish Public Sector Study	2000-02	n= 48592	17-65	19%	68%	Individual SEP	TPA

Table 3-1: Characteristics of the 131 included studies ordered by European region. *(continued)*

Author, year of publication	Country of study[a]	Study name	Year of data-collection	Sample size + characteristic[b]	Age	% Male[c]	Response[c]	SEP indicator[d]	PA type[e]
Korniloff *et al*, 2010[92]	FIN	Finnish type 2 diabetes (FIN-D2D) survey	2007	n= 2778	45–74	47%	64%	Income Education	TLTPA
Laaksonen *et al*, 2002[93]	FIN	Finnish Adult Health Behaviour Survey	1991-98	n= 26014 civil servants	15-64	47%	69-76%	Education	TLTPA
Laaksonen *et al*, 2008[94]	FIN	Finnish Adult Health Behaviour Survey	1979-2001	n= 60608	25-64	48%	62-86%	Education	TLTPA
Lagerros *et al*, 2009[95]	SWE	The Swedish National March Cohort	1997	n= 42150	18-94	36%	NP	Education	TPA
Leijon *et al*, 2010[96]	SWE	Public Health Survey Ostergotland County	2006	n= 6966	18-84	45%	54%	Education Self-reported economy	TPA
Lindström *et al*, 2001[97]	SWE	The Malmö Diet and Cancer Study	1992-94	n= 11837	45-65	45%	39%	Social class	TLTPA
Lindström *et al*, 2003a[98]	SWE	The Malmö Public Health Survey	1986, 1994	n= 3861	21-81	47%	71-74%	Education	TLTPA
Lindström *et al*, 2003b[99]	SWE	The Malmö Public Health Survey	1994	n= 3377	20-80	NP	71%	Education	TLTPA
Mäkinen *et al*, 2009[100]	FIN	Finnish Adult Health Behaviour Survey	1978-2002	n= 50815 employed	25-64	50%	62-86%	Income Education Social class	TLTPA AT
Mäkinen *et al*, 2010a[101]	FIN	The Health 2000 Survey	2000-01	n=3355 employed	30+	46%	85-89%	Social class	OPA TLTPA
Mäkinen *et al*, 2010b[102]	FIN	The Health 2000 Survey	2000-01	n= 7112	30+	45%	84-89%	Income Education Social class	TLTPA
Mäkinen *et al*, 2010c[103]	FIN	National FINRISK study	2002	n= 4408	25-64	44%	60-70%	Education	TLTPA
Molarius, 2003[104]	SWE	Varmland County Survey	2000	n= 6394	25-74	47%	70%	Education	TLTPA
Nielsen *et al*, 2006[105]	DNK	Odense Androgen Study	2002, 2003	n= 783	20-29	100%	73%	Education	TLTPA
Norman *et al*, 2002[106]	SWE	COSM (cohort of Swedish men)	1997	n= 33466	45-79	100%	48%	Education	TPA TLTPA
Novak *et al*, 2006[107]	SWE	Swedish Cohort Study	1981, 1995	n= 1044	16, 30	52%	96%	Education	TPA

Table 3-1: Characteristics of the 131 included studies ordered by European region. *(continued)*

Author, year of publication	Country of study[a]	Study name	Year of data-collection	Sample size + characteristic[b]	Age	% Male[c]	Response[c]	SEP indicator[d]	PA type[e]
Orsini *et al*, 2007[108]	SWE	Swedish Mammography Study (SMC97)	1997	n= 38988	40-75	all female	70%	Education	TPA
Osler *et al*, 2000[109]	DNK	MONICA – Denmark	1982-1984, 1987, 1991-92	n= 6695	30, 40, 50, 60	50%	73-79%	Education	TLTPA
Osler *et al*, 2001[110]	DNK	Children of the Copenhagen City Heart Study	1992	n= 317	19-31	51%	52%	Education	TLTPA
Osler *et al*, 2008[111]	DNK	Metropolit cohort (1965)	2004	n= 6292	51	100%	66%	Education	TLTPA
Petersen *et al*, 2010[112]	DNK	Danish National Health Interview Survey	1987 1994 2000 2005	n 1987 = 4752 n 1994 = 4667 n 2000 = 16688 n 2005 = 14566	16+	49%	1987: 80% 1994: 78% 2000: 74% 2005: 67%	Education	TLTPA
Piro *et al*, 2007[113]	NOR	Oslo Health Study (HUBRO)	2000	n= 14608	30, 40, 45, 60	45%	46%	Income Education Neighb. SEP	VLTPA
Pudaric *et al*, 2000[114]	SWE	Migrants in Sweden Study	1988-89	n= 3100	55-74	47%	80%	Income	TPA
Pulkki *et al*, 2003a[115]	FIN	Cardiovascular Risks in Young Finns (CRYF) study	1983, 1992	n= 1219	12-21, 21-30	44%	62%	Individual SEP	TLTPA
Pullki *et al*, 2003b[116]	FIN	Cardiovascular Risks in Young Finns (CRYF) study	1983, 1992	n= 1125	12-21, 21-30	58%	57%	Education	TLTPA
Salonen *et al*, 2010[117]	FIN	Sub-study of the Helsinki Birth Cohort Study	2001-04	n= 1967	57-71	46%	NP	Education Social class	TLTPA
Schnohr *et al*, 2004[118]	DNK	Copenhagen City Heart Study (CCHS) Copenhagen Male Study (CMS) Glostrup Population Study (GPS) (pooled)	1967-86	n= 30635	20-93	53%	NP	Education	TLTPA
Simonen *et al*, 2003[119]	FIN	Finnish Twin Cohort	1975, 1981	n= 224 monozygotic	35-69	NP	82%	Education	VLTPA
Sjögren & Stjernberg, 2010[120]	SWE	Swedish National Study on Aging and Care (SNAC)	2001-03	n= 999	60-96	45%	61%	Education	TLTPA

Table 3-1: Characteristics of the 131 included studies ordered by European region. *(continued)*

Author, year of publication	Country of study[a]	Study name	Year of data-collection	Sample size + characteristic[b]	Age	% Male[c]	Response[c]	SEP indicator[d]	PA type[e]
Strand & Tverdal, 2004[121]	NOR	Cardiovascular disease study in Norway	1970	n= 44684	35-49	51%	91%	Education	TLTPA
Strandhagen *et al*, 2010[122]	SWE	The INTERGENE research programme	2001-04	n= 3581	25-74	47%	42%	Education	TLTPA
Suadicani *et al*, 2001[123]	DNK	Copenhagen Male Study	1970-71	n= 5028	40-59	100%	87%	Social class	OPA TLTPA
Suadicani *et al*, 2005[124]	DNK	Copenhagen Male Study	1970-71 1985-86	n= 3290	40-74	100%	75-87%	Social class	TLTPA
Tammelin *et al*, 2003[125]	FIN	Northern Finland 1966 Birth Cohort	1998	n= 7794	31	46%	75%	Education	TLTPA
Wang *et al*, 2010[126]	FIN	National FINRISK Study (pooled data)	1972, 1977, 1982, 1987, 1992, 1997, 2002	n= 58208	24-74	49%	65-88%	Education	OPA TLTPA AT
Wemme & Rosvall, 2005[127]	SWE	Scania Health Survey	1999-2000	n= 7169 employed	NP	54%	59%	Education Social class	TLTPA
Anglo-Saxon region									
Adams, 2009[128]	GBR	English Longitudinal Study of Ageing (ELSA)	2002	n= 10864	50+	47%	NP	Education	TPA
Adams, 2010[129]	GBR	2005 UK Time Use Survey (part of National Statistics Omnibus Survey)	2005	n= 3933	16+	48%	49%	Education Social class	AT
Allender *et al*, 2008[15]	GBR	Health Survey for England	2003	n= 13974	16+	45%	66%	Education Social class	TPA TLTPA
Amuzu *et al*, 2009[130]	GBR	British Women's Heart and Health Study	1999-2001	n= 3522	60-79	all female	NP	Individual SEP Neighb. SEP	TPA
Bartley *et al*, 2000[131]	GBR	Health and Lifestyle study (HALS) Health Survey for England (HSfE)	1984 1993	n 1984 = 2176 n 1993 = 4723	20-64	100%	NP	Social class	VLTPA
Bartley *et al*, 2004[132]	GBR	Whitehall II Study	1985-88	n= 5458 civil servants	35-55	74%	73%	Social class	TLTPA

Table 3-1: Characteristics of the 131 included studies ordered by European region. *(continued)*

Author, year of publication	Country of study[a]	Study name	Year of data-collection	Sample size + characteristic[b]	Age	% Male[c]	Response[c]	SEP indicator[d]	PA type[e]
Chaudhury & Shelton, 2010[133]	GBR	Health Survey for England (HSfE)	2006	n= 1550	60-69	46%	NP	Income Social class Neighb. SEP	TPA
Ecob & Macintyre, 2000[134]	GBR	West of Scotland 20-07 Study	1987, 1988	n= 3036	15, 35, 55	NP	NP	Neighb. SEP	VLTPA
Harrison *et al*, 2006[135]	GBR	Physical activity in North-West England	2001	n= 15465	18+	45%	70%	Neighb. SEP Home owner	TPA
Heslop *et al*, 2001[136]	GBR	Cohort of workers recruited from workplaces in Western Scotland between 1970 and 1973	1970-73	n= 958 employed	working age	all female	70%	Education Social class Neighb. SEP	TLTPA
Hillsdon *et al*, 2008[137]	GBR	British Women's Heart and Health Study	1999-2001	n= 4286	60-79	all female	NP	Individual SEP Neighb. SEP	TPA
Lahelma *et al*, 2010[138]	GBR FIN	The London-based Whitehall II study (WHII) The Helsinki Health Study (HHS)	WHII: 1997-99 HHS: 2001-02	n WHII= 2678 n HHS= 8960 white collar employees	WHII: 45-60 HHS: 40-60	WHII: 76% HHS: 17%	WHII: 73% HHS: 67%	Social class	TLTPA
Livingstone *et al*, 2001[139]	IRL	North/South Ireland Food Consumption Survey (NSIFCS)	1997-99	n= 1379	18-64	48%	NP	Social class	VLTPA
Lunn, 2010[140]	IRL	The Survey of Sport and Physical Exercise	2003	n= 2896	18+	NP	67%	Income Education	VLTPA
Mein *et al*, 2005[141]	GBR	Whitehall II study	1997-99	n= 6224 civil servants	45-69	72%	71%	Social class	TLTPA
Mullineaux *et al*, 2001[142]	GBR	Allied Dunbar National Fitness Survey of English Adults (ADNFS)	1990	n= 2005	16+	NP	NP	Education	TPA
Mutrie & Hannah, 2004[143]	GBR	West of Scotland Twenty-07 study (3rd wave)	1995-96	n= 2153	24, 44, 64	42%	NP	Social class	OPA TLTPA
Myint *et al*, 2006[28]	GBR	EPIC study	1993-97	n= 23085	40-79	46%	NP	Social class	TPA

Table 3-1: Characteristics of the 131 included studies ordered by European region. *(continued)*

Author, year of publication	Country of study[a]	Study name	Year of data-collection	Sample size + characteristic[b]	Age	% Male[c]	Response[c]	SEP indicator[d]	PA type[e]
Poortinga, 2007[144]	GBR	Health Survey for England	2003	n= 11617	16-64	NP	NP	Social class	OPA VLTPA
Popham & Mitchell, 2006[145]	GBR	British Household Panel Survey	1996, 1998, 2000, 2002	n= 9473	18-64	48%	74%	Income Education Social class School type (fee-paying)	TLTPA
Popham & Mitchell, 2007[16]	GBR	2003 Scottish Health Survey (SHS)	2003	n= 5287	25-64	44%	60%	Individual SEP	TPA OPA VLTPA
Popham, 2010[146]	GBR	2003 Scottish Health Survey (SHS)	2003	n= 2770	35-54	NP	60%	Social class	VLTPA
Stamatakis & Chaudhury, 2008[147]	GBR	Health Survey for England (HSfE)	1997, 1998, 2003, 2004, 2006	n= 60938	16+	45%	61-71%	Income Education Social class	VLTPA
Stringhini *et al*, 2010[3]	GBR	Whitehall II cohort	1985-88	n= 9590 civil servants	35-55	68%	73%	Social class	TLTPA
Wardle & Griffith, 2001[148]	GBR	British Omnibus Study	1999	n= 1790	16+	50%	70%	Social class	VLTPA
Wardle & Steptoe, 2003[149]	GBR	British Omnibus Study	2000	n= 1691	16+	45%	62%	Social class	VLTPA
Watt *et al*, 2009[150]	GBR	British Women's Heart and Health Study	1999-2001	n= 3523	60-79	all female	NP	Individual SEP	TPA

[a] EU = European Union, ALB = Albania, BEL = Belgium, CZE = Czech Republic, DEU = Germany , DNK = Denmark, ESP = Spain, EST = Estonia, FIN = Finland, FRA = France, GBR = United Kingdom, GRC = Greece, HRZ = Croatia (local name is Hrvatska), HUN = Hungary, IRL = Ireland, ITA = Italy, LTU = Lithuania, LVA = Latvia, NLD = The Netherlands, NOR = Norway, POL = Poland, PRT = Portugal, SVN = Slovenia, SWE = Sweden, SWI = Switzerland.

[b] Sample characteristics only provided when a specific subsample from the population was studied (e.g. working people, civil servants, etc).

[c] NP = Not Provided

[d] SEP = socioeconomic position, Neighb. = neighbourhood, Individual SEP = composite measure of different individual SEP indicators.

[e] PA = Physical Activity, TPA = Total Physical Activity, OPA = Occupational Physical Activity, TLTPA = Total Leisure-time Physical Activity, VLTPA = Vigorous Leisure-time Physical Activity, AT = Active Transport.

association was classified as being non significant. When the symbol is between brackets, no test of significance was reported and difference was judged solely on descriptive measures such as percentages.

When both adjusted and unadjusted results were presented in the manuscripts, the adjusted results were recorded into the table, including a notification of the variables that were used for adjustment. Duplicate articles on the same study population were only included in the tables if they contributed unique associations not previously reported. Distributions of reported positive, negative, and null associations were evaluated by gender, SEP indicator, and European region for each PA outcome (Tables 3-2 and 3-3).

Quality assessment

Since only observational studies were included in this study, methods for quality assessment were limited. Only a few basic quality guidelines were used as exclusion criteria. All included studies were treated equally in the results. To check if quality issues affected the results, sensitivity analyses were conducted for three common quality markers; response, adjustment, and sample size. In these analyses, the results were synthesized again after excluding the articles that did not report a response or studies with a response of less than 50%. In separate analysis, associations that were not adjusted for at least age and gender were excluded from the results. Finally, the results were synthesized for those studies with at least 2000 participants. The results that were found in the subsets of associations were compared with the results obtained when all publications were included.

RESULTS

The search strategy retrieved 7,420 unique and potentially relevant titles (Figure 3-1). After scanning titles and abstracts a total of 193 articles were identified for inclusion. Sixty-two articles were excluded, primarily because no association between SEP and PA was reported (n = 18), because of quality concerns (n = 11), because the population was older than 65 (n = 8), or because the study was conducted outside of Europe (n = 6). As a result, 131 studies were included in the current review.

These 131 studies reported on 105 study populations and 447 unique associations between a SEP indicator and PA outcome (Table 3-1). Most studies were conducted in Scandinavian countries and Great Britain. The majority of the sample sizes were large (e.g. including over 4000 participants) with a range from 224 to 60,938 participants. In most studies the response was higher than 60% (range 20-96%) but approximately one quarter of the studies did not report any response percentage. Apart from the study by Van Dyck and colleagues [47] who

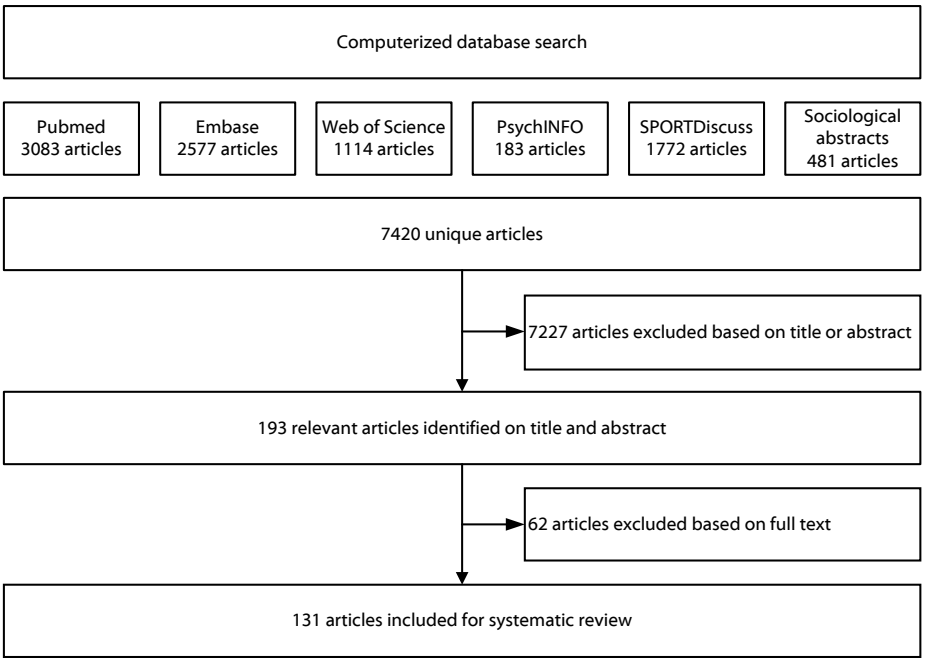

Figure 3-1: Flowchart of search and selection process.

used accelerometer data in addition to self-reported data, all studies relied on self-reported PA. The majority of the studies did not report the validity of the PA measure. The most frequently used validated PA questionnaire was the International PA Questionnaire (IPAQ) [151], other validated measures that were used were the Minnesota Leisure Time PA Questionnaire [152], the MONICA Optional Study of PA Questionnaire (MOSPA-Q) [153], the Short Questionnaire to Assess Health-Enhancing PA (SQUASH) [154], and the Modifiable Activity Questionnaire (MAQ) [153].

Total physical activity

There were 30 studies, with a total of 70 unique associations, which reported on the association between SEP and total PA (Appendix, Table 3-A1). Approximately equal amounts of positive (n = 28), null (n = 19) associations, and negative (n = 23) associations were found (Table 3-2). This pattern did not differ between men and women. While most associations were not statistically significant with income as indicator of SEP, both positive and negative associations were found with education as indicator of SEP (Table 3-2. In Southern Europe, nine out of 12 assessed associations (75%) indicated decreasing levels of physical activity by increasing levels of SEP, while in the Anglo-Saxon countries most (50%) associations showed the opposite pattern (Table 3-3).

Table 3-2: Distribution of positive, negative, and null associations by gender, SEP indicator, and PA domain.[a]

			Socioeconomic indicator																			
Physical activity[b,c]		**Total**				Income				Education				Social class				Other				
			+	0	-		+	0	-		+	0	-		+	0	-		+	0	-	
	Gender[d]	n	%	%	%	n	%	%	%	n	%	%	%	n	%	%	%	n	%	%	%	
TPA	♂	**34**	**41%**	**24%**	**35%**	5	20%	60%	20%	16	50%	6%	44%	6	17%	17%	67%	7	57%	43%	0%	
	♀	**36**	**39%**	**31%**	**31%**	5	0%	80%	20%	16	38%	25%	38%	6	17%	33%	50%	9	78%	11%	11%	
	all	**70**	**40%**	**27%**	**33%**	**10**	**10%**	**70%**	**20%**	**32**	**44%**	**16%**	**41%**	**12**	**17%**	**25%**	**58%**	**16**	**69%**	**25%**	**6%**	
OPA	♂	**10**	**10%**	**20%**	**70%**	1	0%	100%	0%	4	25%	25%	50%	4	0%	0%	100%	1	0%	0%	100%	
	♀	**9**	**11%**	**33%**	**56%**	1	0%	100%	0%	4	25%	25%	50%	3	0%	33%	67%	1	0%	0%	100%	
	all	**19**	**11%**	**26%**	**63%**	**2**	**0%**	**100%**	**0%**	**8**	**25%**	**25%**	**50%**	**7**	**0%**	**14%**	**86%**	**2**	**0%**	**0%**	**100%**	
TLTPA	♂	**104**	**68%**	**31%**	**1%**	17	71%	29%	0%	56	68%	30%	2%	19	79%	21%	0%	12	50%	50%	0%	
	♀	**96**	**68%**	**32%**	**0%**	17	47%	53%	0%	49	78%	22%	0%	19	68%	32%	0%	11	55%	45%	0%	
	all	**200**	**68%**	**32%**	**1%**	**34**	**59%**	**41%**	**0%**	**105**	**72%**	**27%**	**1%**	**38**	**74%**	**26%**	**0%**	**23**	**52%**	**48%**	**0%**	
VLTPA	♂	**56**	**75%**	**25%**	**0%**	12	83%	17%	0%	24	67%	33%	0%	10	80%	20%	0%	10	80%	20%	0%	
	♀	**54**	**78%**	**22%**	**0%**	12	67%	33%	0%	24	75%	25%	0%	10	90%	10%	0%	8	88%	13%	0%	
	all	**110**	**76%**	**24%**	**0%**	**24**	**75%**	**25%**	**0%**	**48**	**71%**	**29%**	**0%**	**20**	**85%**	**15%**	**0%**	**18**	**83%**	**17%**	**0%**	
AT	♂	**26**	**35%**	**31%**	**35%**	4	25%	25%	50%	14	50%	36%	14%	3	33%	33%	33%	5	0%	20%	80%	
	♀	**22**	**41%**	**27%**	**32%**	4	50%	0%	50%	12	58%	25%	17%	3	0%	67%	33%	3	0%	33%	67%	
	all	**48**	**38%**	**29%**	**33%**	**8**	**38%**	**13%**	**50%**	**26**	**54%**	**31%**	**15%**	**6**	**17%**	**50%**	**33%**	**8**	**0%**	**25%**	**75%**	

[a] SEP = socioeconomic position, PA = physical activity

[b] TPA = Total Physical Activity, OPA = Occupational Physical Activity, TLTPA = Total Leisure-time Physical Activity, VLTPA = Vigorous Leisure-time Physical Activity, AT = Active Transport.

[c] The symbol '+' indicates the positive associations (a high SEP is associated with a high PA), the symbol '-' indicates negative associations (a high SEP is associated with a low PA), and '0' indicates the neutral associations (no association found).

[d] ♂ = males, ♀ = females, all = genders combined.

Table 3-3: Distribution of positive, negative, and null associations by gender, European region, and PA domain.[a]

		European region																							
Physical activity[b,c]		EU wide studies				Western European region				Eastern European region				Southern European region				Scandinavian region				Anglo-Saxon region			
			+	0	-		+	0	-		+	0	-		+	0	-		+	0	-		+	0	-
	Gender[d]	n	%	%	%	n	%	%	%	n	%	%	%	n	%	%	%	n	%	%	%	n	%	%	%
TPA	♂	1	100%	0%	0%	1	0%	100%	0%	5	40%	40%	20%	6	17%	0%	83%	10	50%	10%	40%	11	45%	36%	18%
	♀	1	100%	0%	0%	1	0%	100%	0%	5	40%	20%	40%	6	17%	17%	67%	10	30%	40%	30%	13	54%	31%	15%
	all	**2**	**100%**	**0%**	**0%**	**2**	**0%**	**100%**	**0%**	**10**	**40%**	**30%**	**30%**	**12**	**17%**	**8%**	**75%**	**20**	**40%**	**25%**	**35%**	**24**	**50%**	**33%**	**17%**
OPA	♂	1	100%	0%	0%	-	-	-	-	3	0%	67%	33%	-	-	-	-	3	0%	0%	100%	3	0%	0%	100%
	♀	1	100%	0%	0%	-	-	-	-	3	0%	67%	33%	-	-	-	-	2	0%	0%	100%	3	0%	33%	67%
	all	**2**	**100%**	**0%**	**0%**	**-**	**-**	**-**	**-**	**6**	**0%**	**67%**	**33%**	**-**	**-**	**-**	**-**	**5**	**0%**	**0%**	**100%**	**6**	**0%**	**17%**	**83%**
TLTPA	♂	3	100%	0%	0%	20	75%	25%	0%	24	50%	46%	4%	14	71%	29%	0%	33	79%	21%	0%	10	50%	50%	0%
	♀	3	100%	0%	0%	17	88%	12%	0%	24	42%	58%	0%	14	71%	29%	0%	27	81%	19%	0%	11	45%	55%	0%
	all	**6**	**100%**	**0%**	**0%**	**37**	**81%**	**19%**	**0%**	**48**	**46%**	**52%**	**2%**	**28**	**71%**	**29%**	**0%**	**60**	**80%**	**20%**	**0%**	**21**	**48%**	**52%**	**0%**
VLTPA	♂	-	-	-	-	15	100%	0%	0%	11	64%	36%	0%	9	33%	67%	0%	8	88%	13%	0%	13	77%	23%	0%
	♀	-	-	-	-	13	92%	8%	0%	12	67%	33%	0%	10	40%	60%	0%	8	88%	13%	0%	11	100%	0%	0%
	all	**-**	**-**	**-**	**-**	**28**	**96%**	**4%**	**0%**	**23**	**65%**	**35%**	**0%**	**19**	**37%**	**63%**	**0%**	**16**	**88%**	**13%**	**0%**	**24**	**88%**	**13%**	**0%**
AT	♂	1	100%	0%	0%	7	29%	14%	57%	6	33%	17%	50%	-	-	-	-	6	50%	33%	17%	6	17%	67%	17%
	♀	1	100%	0%	0%	5	40%	20%	40%	6	33%	17%	50%	-	-	-	-	6	50%	33%	17%	4	25%	50%	25%
	all	**2**	**100%**	**0%**	**0%**	**12**	**33%**	**17%**	**50%**	**12**	**33%**	**17%**	**50%**	**-**	**-**	**-**	**-**	**12**	**50%**	**33%**	**17%**	**10**	**20%**	**60%**	**20%**

[a] SEP = socioeconomic position, PA = physical activity

[b] TPA = Total Physical Activity, OPA = Occupational Physical Activity, TLTPA = Total Leisure-time Physical Activity, VLTPA = Vigorous Leisure-time Physical Activity, AT = Active Transport.

[c] The symbol '+' indicates the positive associations (a high SEP is associated with a high PA), the symbol '-' indicates negative associations (a high SEP is associated with a low PA), and '0' indicates the neutral associations (no association found).

[d] ♂ = males, ♀ = females, all = genders combined.

Occupational physical activity

There were 10 studies, with a total of 19 unique associations, which reported on the association between SEP and occupational PA (Appendix, Table 3-A2). The majority of the associations (68%) were negative, indicating that persons in lower socioeconomic groups did more occupational PA (Table 3-2). Patterns were similar for men and women. Almost all associations based on social class showed a negative relationship, while mixed patterns were found for education and income (Table 3-2). In studies in Eastern Europe, four out of six associations were non significant, while mainly negative associations were found in other regions of Europe (Table 3-3).

Leisure-time physical activity

Leisure-time PA was the most frequent domain of PA assessed in relation to SEP. A total of 112 studies reported 310 unique associations. The results are presented for total leisure-time PA and vigorous leisure-time PA separately.

Total leisure-time physical activity

A total of 75 studies reported 200 unique associations (Appendix, Table 3-A3) on the association between TLTPA and SEP. Most studies (68% of associations) showed that people with a higher SEP were more likely to be physically active in their leisure-time, whereas one study reported that a higher SEP was associated with less TLTPA (Table 3-2). The association between education and TLTPA was reported most frequently and most studies found a positive association (74%) (Table 3-2). Men and women differed slightly by the SEP indicator used. For women, the associations between education and TLTPA were mostly positive (78% in women versus 68% in men), and for men the associations between social class and TLTPA were mostly positive (79% in men versus 68% in women). Income showed a more consistent positive association with TLTPA among men (71% positive) compared with women (47% positive). There were also geographical differences (Table 3-3). In Scandinavia and the Western European countries, predominantly positive associations were observed (84% and 81% respectively). In Eastern Europe and in the Anglo-Saxon region, only half of the associations were positive (46% and 48% respectively), with the remaining being null associations.

Vigorous leisure-time physical activity

The results from the 37 included studies reporting about VLTPA and SEP showed clear socioeconomic inequalities in VLTPA (Appendix, Table 3-A4). A total of 84 out of the 110 associations (76%) were positive, indicating that higher socioeconomic groups were more vigorously physically active during leisure-time than lower socioeconomic groups (Table 3-2). No studies found a significant inverse association. Income was found to be positively associated with VLTPA more frequently among men (83%) than among women (67%) (Table 3-2). Regarding the other SEP indicators, the results were slightly more pronounced in women.

Nearly all studies (96%) conducted in the Western European region reported that VLTPA was more prevalent among people with a higher SEP (Table 3-3). In both Scandinavia and in the Anglo-Saxon countries, the positive associations also dominated (both 88% positive), whereas in Southern Europe about a third of the associations were positive (37%), the other 63% being non significant.

Active transport

There were 11 studies that examined socioeconomic differences in active transport (Appendix, Table 3-A5). Two studies distinguished between engaging in active transport (yes/no) and the amount of active transport in a week [129, 56]. This resulted in a total of 48 associations of which 18 (38%) were positive, 14 (29%) were neutral, and 16 (33%) were negative (Table 3-2). There were no clear differences by gender, SEP indicator, or geographic region (Tables 3-2 and 3-3).

Quality sensitivity analyses

After excluding all studies that did not report a percentage of response or that did not have a response of at least 50% (n = 40), a total of 91 studies remained in the sensitivity analysis. The number of associations decreased from 447 to 313, though patterns remained similar (Appendix, Table 3-A6 and Table 3-A7). The main difference was that now all associations between OPA and SEP were negative, compared with 63% in the main analysis.

Excluding associations that were not at least adjusted for age and gender from the analysis resulted in a total of 342 unique associations (Appendix, Table 3-A6 and Table 3-A7). In this restricted set of studies, all associations between OPA and SEP were negative thus accentuating the negative pattern found in the main analysis. All other patterns remained similar.

Finally, excluding the studies with less than 2000 participants (n = 31) resulted in an analysis with the remaining 100 studies (Appendix, Table 3-A6 and Table 3-A7). The patterns became somewhat more pronounced, since larger studies in general produce more significant associations. In this restricted set of studies, half of the associations for TPA were positive, compared with 40% in the main analysis. Also the associations in TLTPA and VLTPA were more often positive (77% and 82% relatively compared with 68% and 76%). The associations between OPA and SEP were more often negative (77% compared with 63%). The pattern for active transport remained similar.

DISCUSSION

Patterns of socioeconomic inequalities in PA are perhaps more complex than often thought. The direction of socioeconomic inequalities in PA in Europe differs considerably by domain of PA and to some degree by European region and socioeconomic indicator. Since only few studies reported men and women separately, no conclusions about gender differences are warranted.

Domains of physical activity

Different domains of PA demonstrated different socioeconomic patterns. The most consistent socioeconomic inequalities were found for vigorous leisure-time PA, with the lower SEP groups participating less in vigorous activities like sports than higher SEP groups. For overall leisure-time PA a similar pattern was observed although less articulated. In contrast to PA during leisure time, Occupational PA was more frequently reported by lower SEP groups. For total PA and active transport, many studies found a significant association, but they differed considerably in direction.

The absence of a consistent direction in the socioeconomic inequalities in total PA might be caused by the contrasting socioeconomic patterns found for leisure-time PA and occupational PA, that both may make up a large part of total PA. This was nicely illustrated by a study by Lissner and colleagues [155]. They studied leisure-time PA, occupational PA, and PA index (total PA) which was a combined measure of occupational and leisure-time PA. Their results showed that education was positively associated with leisure-time PA and inversely associated with occupational PA. Education and the PA index were not associated since the association between leisure-time PA and occupational PA evened each other out. This mechanism may partly explain the contradictory results with as much negative as positive associations between SEP and total PA, since the association will be determined by the relative influence of leisure-time PA and occupational PA on total PA.

Another question that rises is whether occupational physical activity compensates for not being active during leisure time. A few included studies [51, 54] examined socio-economic differences in leisure-time PA while correcting for occupational PA. In the multivariable models, both income and education, and occupational PA were significantly associated with leisure-time PA. These studies indicated that although respondents who were more occupationally active were less active in leisure time, people from lower socio-economic backgrounds were still less physically active compared with high socio-economic people, even after correcting for occupational PA.

Also, by including occupational PA as an indicator of healthy PA, it is assumed that occupational PA is beneficial to health, however this may not be the case [156]. The few studies that look at associations between occupational PA and mortality or morbidity show no clear pattern. There are studies that report a beneficial effect [157, 90, 158-159, 126], no effect [160], or a detrimental effect [161-163, 123] of occupational PA on cardiovascular diseases and mortality. The health benefits of leisure-time PA and sports are more consistent [164, 157, 90, 158, 165, 123, 126]. The different types of activity carried out at work might partly explain these inconsistent findings. For example, Fransson et al. [166] found that walking and standing at work, both aerobic activities, decreases the risk of myocardial infarction, while lifting or carrying at work increases the risk of myocardial infarction. The relation between all aspects of occupational PA and health should be investigated further.

Active transport was studied considerably less often than the other domains of PA and no clear pattern was detected. There were almost equal amounts of studies showing a positive, a null, or a negative association between SEP and active transport. It could be that whether or not one engages in active transport and time spent doing so have different determinants. The two studies that distinguished between participation and time spent in active transport showed for example that participation was not or inversely associated with education while, among the participators, the higher educated spent more time in active transport [129, 56]. The contradictory results may also be explained by factors that influence the association between SEP and active transport. A Dutch and a Belgium study both looked at neighbourhood SEP as an indicator of active transport and found negative associations [38, 47]. This could either be an indication that people with a lower SEP are more likely to engage in transport PA or for example, that neighbourhoods with a low SEP are more likely to make people engage in transport PA for example because of a higher density or more connectivity [167]. External factors such as connectivity, density and the availability of public transport might be especially important for active transport PA and more research should be conducted to get a better insight into determinants of active transport.

Types of SEP indicator

Income, education and occupation reflect different aspects of SEP [17-18]. Occupational class appears to be the SEP indicator most sensitive for studying SEP differences in occupational PA. However, the consistent associations found for this indicator may also be due to the definitions used to describe social classes. Because manual jobs are in general considered to be of lower social class, the social class definition is often partly based on having a manual or a non-manual job. This already implies a difference in activities at work.

Inequalities in leisure-time PA and vigorous activity are often thought to be caused by either an educational effect on knowledge about the positive health consequences of PA, or

financial possibilities to engage in leisure-time PA, for example to buy PA equipment or to afford memberships or admission rates for sports and PA facilities. The fact that the patterns in inequalities in PA were roughly similar for the different indicators of SEP, including education and income, suggest that it is not one or the other but both may indeed be important. Other factors related to chance and choice of lifestyle [168], such as SEP differences in social or cultural capital [169] or differences in physical environmental opportunities for PA [37, 36], may be additional determinants of SEP inequalities in PA. Also, some factors, such as intrapersonal factors, may act as intermediary in the process between SES and PA [36]. In a previous review, Gidlow and colleagues [170] reported that education was stronger associated with PA than income. Although in the present review education was the most frequent studied SEP indicator, we could not confirm that the associations of education with PA were also stronger than the associations with the other SEP indicators.

European regions

A recent study showed that the largest inequalities in obesity prevalence were found in Southern Europe, especially among women, and the smallest in Eastern Europe [8]. In concordance with these findings, we found that the socioeconomic inequalities in PA were less consistent in Eastern Europe for both occupational PA and leisure-time PA. Opposite to what would be expected from the inequalities found in obesity, the inequalities in vigorous leisure-time PA were least pronounced in Southern Europe. This was also found in the few pan-European studies that were included in this review [23, 27, 29] and by a recent pan-European study by Mäkinen et al. [171]. A possible explanation could be that general levels of PA are low in these countries [171, 23] which would make it harder to detect SEP differences in PA.

Strengths & limitations

The main strength of this review is the systematic exploration of different domains of physical activity, different SEP indicators, and geographic regions of Europe. Also, the inclusion of a quality sensitivity analyses strengthens the results. There are, however, also some limitations to be taken into account when interpreting the results.

Like any review of the published literature, the present review may suffer from publication bias [172]. The fact that a substantial numbers of null findings were reported in the reviewed studies may indicate that publication bias may not be severe. Also, some relevant studies may have been missed because only English-language studies that were available in electronic databases and that were published in peer-reviewed journals were included. Moreover, by analyzing the data on the level of the associations instead of the level of studies, more weight was given to studies that reported more than one association. Although this may have influenced conclusions based on all reported associations, this influence was expected

to be smaller when subgroups of associations, such as by PA domain and SEP indicator, are considered.

Methodological differences between the included studies, such as the assessment of PA [173], the selection of participants, and the adjustment for confounders, could have influenced the reported associations. Although this probably introduced some noise, the sensitivity analysis showed that the overall patterns seem to be quite stable.

CONCLUSION

This review showed that leisure-time PA, and specifically vigorous leisure-time PA, is less prevalent while occupational PA is more prevalent among people with lower SEP. Although there were some regional differences, these inequalities were visible throughout Europe. The contradictory inequalities for total PA may partly be explained by the contrasting socioeconomic patterns found for leisure-time PA and occupational PA. These inconsistent results in total PA indicate that total PA may not be a suitable summary measure when investigating inequalities in PA and their effects on morbidity and mortality.

The found inequalities indicate that leisure-time PA should be an important focus in improving physical activity levels and reducing inequalities. However, interventions aimed at improving leisure-time PA in lower socioeconomic groups needs to acknowledge their potential higher levels of occupational PA.

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Table 3-A1: Summary of study findings examining associations between total or usual physical activity (TPA) and SEP[‡]

	Direction of the associations between the socioeconomic indicator and physical activity								
	Men				Women				
Author (Date)	**Income**	**Education**	**Social class**	**Other**	**Income**	**Education**	**Social class**	**Other**	**Adjustment**
EU wide studies									
Ståhl *et al*, 2001[24]		+				+			age, gender, country, several cognitive factors
Western European region									
de Vries *et al*, 2008[49]		**(0)**				**(0)**			-
Eastern European region									
Frömel *et al*, 2009[52]				**0**[1]				-[1]	age, gender[s], BMI, smoking, # residents in town, living status, dog ownership, participating in organized PA
Jurakić *et al*, 2009[53]	**0**	-			**0**	-			-
Zaletel-Kragelj *et al*, 2006[65]		+	+			+	+		age, gender, education, kind of work, social class, residence community, geographical region
Southern European region									
Borrel *et al*, 2000b[69] [a]			-				**0**		age, gender[s]
Gal *et al*, 2005[71]		-	-			-	-		age, gender[s]
Panagiotakos *et al*, 2008[75] [b]		+				+			-
Santos *et al*, 2009[79]	-	-			-	-			gender[s]
Scandinavian region									
Barengo *et al*, 2006[83] [†]		-				**0**			age, gender[s]
Bergman *et al*, 2008[84]	**0**	-			**0**	-			age, gender, education, income, employment status, BMI, residential community size, marital status, smoking, self-perceived health
Kivimäki *et al*, 2007[91]				**(+)**[1]				**(+)**[1]	-
Lagerros *et al*, 2009[95]		-				-			-
Leijon *et al*, 2010[96]		+		+[3]		+		+[3]	survey design, non-response
Norman *et al*, 2002[106]		-							age, gender[s], BMI, smoking, marital status, self-rated health
Novak *et al*, 2006[107]		+				**0**			age[t], gender[s]
Orsini *et al*, 2007[108]						-			age, gender[s], BMI, postmenopausal status, alcohol consumption, smoking, employment status, urban/rural place in childhood
Pudaric *et al*, 2000[114]	+				**0**				gender[s]

Table 3-A1: Summary of study findings examining associations between total or usual physical activity (TPA) and SEP[‡] *(Continued)*

	Direction of the associations between the socioeconomic indicator and physical activity								
	Men				Women				
Author (Date)	**Income**	**Education**	**Social class**	**Other**	**Income**	**Education**	**Social class**	**Other**	**Adjustment**
Anglo-Saxon region									
Adams, 2009[128]		+				+			age, gender, self-reported health
Allender *et al*, 2008[15]		+	-			**0**	-		age, gender[s], education, social status, employment status
Amuzu *et al*, 2009[130] [c]								+[1], +[2]	gender[s], individual SEP, neighb. SEP
Chaudhury & Shelton, 2010[133] [d]	**0**		**0**	**0**	**0**		**0**	**0**[2]	age, gender[s], income, social class, employment status, long-term illness, BMI, waist circumference, waist-hip ratio, smoking status, alcohol consumption, region, deprivation index
Harrison *et al*, 2006[135]				+[4], +[2]				+[4], +[2]	age, gender
Mullineaux *et al*, 2001[142]		+				+			age, self perception of being active, motivation to be active, self perception of doing adequate exercise, lifestyle problems
Myint *et al*, 2006[28] [e]			-				-		age, gender[s]
Popham & Mitchell, 2007[16]				**0**				+[1]	age, gender[s], health status, employment status

‡ The symbols in the table should be read as follows: '+' means that a high SEP is associated with a high TPA, a '-' means that a high SEP is associated with a low TPA. A '0' means that there was no association found. When the symbol is between brackets, no tests of significance were done.

† Results from most recent year (1997) reported. Associations in previous years were different.

a. Similar results found in the same sample population by Borrel *et al*, 2000a[94].

b. Similar results found in the same sample population by Panagiotakos *et al*, 2008a[100].

c. Similar results found in the same sample population by Hillsdon *et al*, 2008[159] and by Watt *et al*, 2009[173].

d. The association between social class and TPA was also reported by Allender *et al*, 2008[15] but since Chaudhury and Shelton[155] report about an older subsample (age 60-69), the results were different and therefore reported here as well.

e. Only the results for people under 65 are presented here.

s. Results were stratified according to gender.

t. All respondents were the same age.

1. Individual SEP (composite measure).

2. Neighbourhood SEP.

3. Self-reported economy.

4. Home ownership.

Table 3-A2: Summary of study findings examining associations between occupational physical activity (OPA) and SEP[‡]

	Direction of the associations between the socioeconomic indicator and physical activity								
	Men				Women				
Author (Date)	**Income**	**Education**	**Social class**	**Other**	**Income**	**Education**	**Social class**	**Other**	**Adjustment**
EU wide studies									
Van Tuyckom & Scheerder, 2010b[27]		+				+			-
Eastern European region									
Jurakić *et al*, 2009[53]	**0**	**0**			**0**	**0**			-
Mišigoj-Durakoviæ *et al*, 2000[58]		-				-			gender[s]
Scandinavian region									
Mäkinen *et al*, 2010a[101]			-				-		age, gender[s]
Suadicani *et al*, 2001[123]			-						age, gender[s]
Wang *et al*, 2010[126] [a]		-				-			age, gender[s], study year
Anglo-Saxon region									
Mutrie & Hannah, 2004[143]			-				**0**		gender[s]
Poortinga, 2007[144]			-				-		-
Popham & Mitchell, 2007[16]				-[1]				-[1]	age, gender[s], health status, employment status

‡ The symbols in the table should be read as follows: '+' means that a high SEP is associated with a high OPA, a '-' means that a high SEP is associated with a low OPA. A '0' means that there was no association found. When the symbol is between brackets, no tests of significance were done.

a. Similar results found in the same sample population by Hu et al, 2003[90].

s. Results were stratified according to gender.

1. Composite individual SEP measure.

Table 3-A3: Summary of study findings examining associations between total leisure-time physical activity (TLTPA) and SEP[‡]

	Direction of the associations between the socioeconomic indicator and physical activity								
	Men				Women				
Author (Date)	Income	Education	Social class	Other	Income	Education	Social class	Other	Adjustment
EU wide studies									
Van Tuyckom & Scheerder, 2010a[26] [a]			+				+		age, gender, marital status, geographical status
Van Tuyckom & Scheerder, 2010b[27] [a]		+				+			-
Varo , 2003[29] [b]		+				+			age, gender[c], education, marital status, smoking, weight change
Western European region									
Bertrais , 2004[31]		**0**				+			age, gender[c], smoking, urban/rural location, TV viewing
Chaix & Chauvin, 2003[32]	+	+			+	+			age, gender, education, income, occupation, employment, marital status
Dragano , 2007[33] - DEU		+		+[5]		+		+[5]	age, gender, education, economic activity, social isolation, neighbourhood unemployment
Drieskens , 2010[34]		(+)				(+)			gender[c]
Kamphuis *et al*, 2009[37]	**0**	+			**0**	+			age, gender
van Lenthe *et al*, 2005[38]				+[2]				+[2]	age, gender, educational level
van Oort *et al*, 2004[41]		(+)				(+)			age, gender
Rathmann *et al*, 2005[42]	+	**0**	+		+	+	+		age, gender[c]
Ribet *et al*, 2001[43] – GAZEL			+				+		age, gender[c], own and spouses occupation
Ribet *et al*, 2001[43] – MONICA			+				+		age, gender[c], own and spouses occupation
Van Dyck *et al*, 2010[47]		+		**0**[2]		+		**0**[2]	age, gender, education, employment status, BMI, walkability of neighbourhood, neighbourhood SEP, walkability*neighbourhood SEP
Verdaet *et al*, 2004[48]		+							gender[c]
Wagner *et al*, 2003[50] - FRA		**0**		+[3]					age, gender[c], marital status, obesity, reported disease, centre
Eastern European region									
Dragano *et al*, 2007[33] – CZE		+		**0**[5]		+		**0**[5]	age, gender, education, economic activity, social isolation, neighbourhood unemployment

Table 3-A3: Summary of study findings examining associations between total leisure-time physical activity (TLTPA) and SEP[‡] *(Continued)*

	Direction of the associations between the socioeconomic indicator and physical activity								
	Men				Women				
Author (Date)	**Income**	**Education**	**Social class**	**Other**	**Income**	**Education**	**Social class**	**Other**	**Adjustment**
Drygas *et al*, 2009[51]	**0**	+			+	+			age, gender[c], place of residence, education, income, marital status, active commuting, occupational PA
Jurakić *et al*, 2009[53]	+	**0**			+	**0**			-
Kaleta & Jegier, 2005[54] [m]	+	+			**0**	+			age, gender[c], education, income, job characteristics (mental/ physical work), occupational PA
Kaleta & Jegier, 2007[55] [m]	**0**	+			+	+			age, gender[c], education, income, job characteristics (mental/ physical work), occupational PA
Mišigoj-Durakoviæ *et al*, 2000[58]<45 years		**0**				**0**			gender[c]
Mišigoj-Durakoviæ *et al*, 2000[58] >45 years		-				**0**			gender[c]
Pomerleau *et al*, 2000[61] – EST	+	+			**0**	+			age, gender[c], education, income, nationality, area of residence
Pomerleau *et al*, 2000[61] – LTU	+	**0**			**0**	+			age, gender[c], education, income, nationality, area of residence
Pomerleau *et al*, 2000[61] – LVA	+	+			**0**	+			age, gender[c], education, income, nationality, area of residence
Puska *et al*, 2003[62] – EST		**0**				**0**			age, gender[c], place of residence, year of measurement
Puska *et al*, 2003[62] – LTU		**0**				**0**			age, gender[c], place of residence, year of measurement
Shapo *et al*, 2004[63]	**0**	**0**			**0**	**0**			age, gender[c], education, income, smoking, vegetable intake, alcohol intake, # unhealthy behaviours
Stelmach *et al*, 2004[64]	+	**0**			**0**	**0**			age, gender[c], education, income, marital status, chronic illnesses, self-rated health
Southern European region									
Bolívar *et al*, 2010[67]				**0**[6]				**0**[6]	age, gender[c], unemployment in municipality, illiteracy in municipality
Bolívar *et al*, 2010[67]		+	**0**	**0**[5],+[7]		+	+	**0**[5],+[7]	age, gender[c], education, occupational class, employment, children <15yrs, status, obesity, smoking status, self-rated health, sufficient green spaces in neighbourhood, unemployment in municipality, illiteracy in municipality

Table 3-A3: Summary of study findings examining associations between total leisure-time physical activity (TLTPA) and SEP‡ *(Continued)*

	Direction of the associations between the socioeconomic indicator and physical activity								
	Men				Women				
Author (Date)	**Income**	**Education**	**Social class**	**Other**	**Income**	**Education**	**Social class**	**Other**	**Adjustment**
De Vogli *et al*, 2005[70]			+				+		gender[a]
Gal *et al*, 2005[71]		+	+			+	+		age, gender[a]
Meseguer *et al*, 2009[73]		+				+			age, gender, occupational physical activity
Pascual *et al*, 2007[76]	+	+	+	+[2]	**0**	+	+	+[2]	age, gender[a], education, social class, income, neighbourhood income, # sports facilities/1000 inhabitants, rurality, density
Schröder *et al*, 2004[80]		**0**				**0**			gender[a]
Scandinavian region									
Henriksson *et al*, 2003[89]		+							gender[a]
Korniloff *et al*, 2010[92]	+	+			+	+			age, gender, education, income, marital status, smoking, presence of metabolic syndrome or depressive symptoms
Lahelma *et al*, 2010[138] – FIN			+				**0**		age, gender[a], job strain, working overtime, work-family conflicts, marital status, social relations
Lindström *et al*, 2001[97]			+				+		age, gender[a], country of origin, previous/current diseases, social participation
Lindström *et al*, 2003a[98] [c]		+				+			-
Mäkinen *et al*, 2009[100] [d, e]	+	+	**0**		+	+	**0**		Age, gender[a], income, education, occupation
Mäkinen *et al*, 2010b[102] [f]	+	+	+		+	+	+		age, gender[a]
Molarius, 2003[104]		(+)				(+)			gender[a]
Nielsen *et al*, 2006[105]		+							age, gender[a]
Norman *et al*, 2002[106]		**0**							age, gender[a], BMI, smoking, marital status, self-rated health
Osler *et al*, 2001[110]		**0**				**0**			age, gender[a], own and parent's education, occupational physical activity, smoking status
Osler *et al*, 2000[109]		**0**				+			age, gender[a], height, weight, BMI, SPB, DPB, Total cholesterol, HDL cholesterol, smoking, heavy smoking, healthy eating, multiple risk index
Osler *et al*, 2008[111]		+							age[1], gender[a], father's social class, cognitive function, labour market participation, divorce
Petersen *et al*, 2010[112]		+				+			age, gender[a]
Pulkki *et al*, 2003a[115]				**0**[1]				+[1]	age, gender[a],

Table 3-A3: Summary of study findings examining associations between total leisure-time physical activity (TLTPA) and SEP[‡] *(Continued)*

	Direction of the associations between the socioeconomic indicator and physical activity								
	Men				Women				
Author (Date)	**Income**	**Education**	**Social class**	**Other**	**Income**	**Education**	**Social class**	**Other**	**Adjustment**
Pulkki *et al*, 2003b[116]		**0**				+			age, gender[c], parental education
Puska *et al*, 2003[62] – FIN		+				**0**			age, gender[c], place of residence, year of measurement
Salonen *et al*, 2010[117]		+	+				**0**		age, gender[c]
Schnohr *et al*, 2004[118] [g]		+				+			gender[e]
Sjögren & Stjernberg, 2010[120]		**0**				+			age, gender[c], being able to bath or shower independently, age*having access to areas for country walks
Strand & Tverdal, 2004[121]		+				+			gender[e]
Strandhagen *et al*, 2010[122]		+				+			age, gender[c]
Suadicani *et al*, 2005[124] [h]			+						gender[e]
Tammelin *et al*, 2003[125] [i]		+				+			age[t] gender[c], children, education, employment status, place of residence, several sports related factors at age 14
Wang *et al*, 2010[126] [j]		+				+			age, gender[c], study year
Wemme & Rosvall, 2005[127] [k]		+	+			+	+		age, gender[c]
Anglo-Saxon region									
Allender *et al*, 2008[15]		+	**0**			+	**0**		age, gender[c], education, work activity status, social status
Heslop *et al*, 2001[136]						**0**	**0**	**0**[2]	age, gender[c]
Mein *et al*, 2005[141] [l]			+				+		age, gender[c], marital status, month of questionnaire completion
Mutrie & Hannah, 2004[143]			+				+		gender[e]
Popham & Mitchell, 2006[145]	**0**	**0**	**0**	**0**[4]	**0**	+	**0**	+[4]	age, gender[c], income, education, occupation, school type, marital status, self-rated health, general health questionnaire, health limits daily activities, GP consultations, smoking, year, housework hours, employment status, children
Wagner *et al*, 2003[50] - IRE		+		+[3]					age, gender[c], marital status, obesity, reported disease

‡ The symbols in the table should be read as follows: '+' means that a high SEP is associated with a high TLTPA, a '-' means that a high SEP is associated with a low TLTPA. A '0' means that there was no association found. When the symbol is between brackets, no tests of significance were done.

a. Similar results found in the same sample population by Van Tuyckom & Scheerder, 2008[25].

b. Similar results found in the same sample population by Martinez-Gonzalez et al, 2001[23].

c. Similar results found in the same sample population by Lindström et al, 2003b[99].

d. Results from the most recent data were reported (1998-2002).

e. Similar results found in the same sample population by Laaksonen et al, 2002[93] and Laaksonen et al, 2008[94].

f. Similar results found in the same sample population by Mäkinen et al, 2010a[101].

g. Similar results found in the same sample population by Andersen et al, 2000[82].

h. Similar results found in the same sample population by Suadicani et al, 2001[123].

i. Similar results found in the same sample population by Häkinnen et al, 2006[88].

j. Similar results found in the same sample population by Borodulin et al, 2008[85], Mäkinen et al, 2010c[103], and Hu et al, 2003[90].

k. Similar results found in the same sample population by Ali & Lindström, 2006[81].

l. Similar results found in the same sample population by Stringhini et al, 2010[3], Bartley et al, 2004[132], and Lahelma et al, 2010[138] (data from Great-Britain).

m. Both studies of Kaleta & Jegier[54-55] are reported here. Although they report the same association in a similar dataset, they provide different results with respect to the association between income and TLTPA in the adjusted model.

s. Results were stratified according to gender.

t. All respondents were the same age.

1. Composite individual SEP measure.

2. Neighbourhood SEP.

3. Household wealth (material conditions).

4. Fee paying versus public school.

5. % unemployment in neighbourhood/municipality.

6. Economic level of municipality.

7. Illiteracy in municipality.

Table 3-A4: Summary of study findings examining associations between vigorous leisure-time physical activity (VLTPA) and SEP[‡]

	Direction of the associations between the socioeconomic indicator and physical activity								
	Men				Women				
Author (Date)	**Income**	**Education**	**Social class**	**Other**	**Income**	**Education**	**Social class**	**Other**	**Adjustment**
Western European region									
Addor *et al*, 2003[30] – <45 years		+				**0**			gender[c]
Addor *et al*, 2003[30] – 45+ years		+				+			gender[c]
Galobardes *et al*, 2003[35]			+				+		age, gender[s]
Kamphuis *et al*, 2008[36]	+	+			+	+			age, gender
van Lenthe *et al*, 2005[38]				+[2]				+[2]	age, gender, educational level
Meyer *et al*, 2005[39]	+	+			+	+			age, gender, education, income, size of household, urban/rural residence, language
Nocon *et al*, 2008[40] [a]	+	+	+		+	+	+		age, gender, income, education, occupation
Scheerder *et al*, 2005[45] [b]		+	+			+	+		gender[c]
Wagner *et al*, 2003[50] - FRA		+		+[3]					age, gender[s], marital status, obesity, reported disease, centre
Eastern European region									
Frömel *et al*, 2009[52]				**0**[1]				**0**	age, gender[s], BMI, smoking, # residents in town, living status, dog ownership, participating in organized PA
Leskosek *et al*, 2002[57]		+				+			age, gender, employment, marital status/family status
Mišigoj-Durakoviæ *et al*, 2000[58]		+				+			age[†], gender[c],
Nowak, 2010[59]						+			gender[c]
Paulik *et al*, 2010[60]		+		+[3]		+		+[3]	-
Pomerleau *et al*, 2000[61] – EST	+	**0**			+	+			age, gender[s], nationality (native, Russian, other), area of residence (rural, urban), education, income
Pomerleau *et al*, 2000[61] – LTU	+	**0**			**0**	+			age, gender[s], nationality (native, Russian, other), area of residence (rural, urban), education, income
Pomerleau *et al*, 2000[61] – LVA	+	**0**			**0**	**0**			age, gender[s], nationality (native, Russian, other), area of residence (rural, urban), education, income

Table 3-A4: Summary of study findings examining associations between vigorous leisure-time physical activity (VLTPA) and SEP[‡] *(Continued)*

	Direction of the associations between the socioeconomic indicator and physical activity								
	Men				Women				
Author (Date)	**Income**	**Education**	**Social class**	**Other**	**Income**	**Education**	**Social class**	**Other**	**Adjustment**
Southern European region									
Artazcoz *et al*, 2004[66]						(+)			gender[a]
Borrel *et al*, 2000a[68]			**0**				**0**		age, gender[a], employment status, family structure
Lera-López & Rapún-Gárate, 2005[72]	**0**	**0**			**0**	**0**			age, gender, education, size of household, income, degree of urbanization, employment status
Pascual *et al*, 2009[77]	+	+			+	+			age, gender[a]
Pitsavos *et al*, 2005[78]	**0**	**0**	+		**0**	**0**	+		age, gender[a]
Schröder *et al*, 2004[80]		**0**				**0**			gender[a]
Scandinavian region									
Andersen *et al*, 2000[82]		(+)				(+)			gender[a]
Cubbin *et al*, 2006[86]				+[1], +[2]				+[1], +[2]	age, gender, urbanization, deprivation, marital status, immigration status, individual SEP
Engström, 2008[87]		+				+			age[t]
Piro *et al*, 2007[113]	+	+		+[2]	+	+		+[2]	age, gender, marital status, education, employment status, income
Simonen *et al*, 2003[119]		**0**				**0**			-
Anglo-Saxon region									
Bartley *et al*, 2000[131] [c]			+				+		age
Ecob & Macintyre, 2000[134]				+[2]				+[2]	age, gender, social class, education, marital status, whether recently moved, household material deprivation
Livingstone *et al*, 2001[139]			**0**				+		gender[a]
Lunn, 2010[140]	+	+			+	+			gender, cohort, parent's participation in sports, education, income, occupation, occupation*gender
Popham & Mitchell, 2007[16]				+[1]				+[1]	age, gender[s], health status, employment status
Popham, 2010[146]			(+)				(+)		age, gender
Stamatakis & Chaudhury, 2008[147] [d]	+	+	+		+	+	+		-
Wagner *et al*, 2003[50] - IRE		**0**		**0**[3]					age, gender[s], marital status, obesity, reported disease
Wardle & Steptoe, 2003[149] [e]			+				+		age, gender, self-rated health

‡ The symbols in the table should be read as follows: '+' means that a high SEP is associated with a high VLTPA, a '-' means that a high SEP is associated with a low VLTPA. A '0' means that there was no association found. When the symbol is between brackets, no tests of significance were done.

† Reported for age group <45 and >45. They found the same association in both age samples.

a. Similar results found in the same sample population (employed subsample) by Schneider & Becker, 2005[46].

b. Similar results found in the same sample population by Scheerder et al, 2002[44].

c. The results reported here are from the sample from HALS 1984.

d. Similar results found in the same sample population by Poortinga, 2007[144] and Bartley et al, 2000[131] (sample HSfE 1993).

e. Similar results found in the same sample population by Wardle & Griffith, 2001[148].

s. Results were stratified according to gender.

t. All respondents were the same age.

1. Composite individual SEP measure

2. Neighbourhood SEP.

3. Household wealth (material conditions).

Table 3-A5: Summary of study findings examining associations between active transport (AT) and SEP‡

	Direction of the associations between the socioeconomic indicator and physical activity								
	Men				Women				
Author (Date)	**Income**	**Education**	**Social class**	**Other**	**Income**	**Education**	**Social class**	**Other**	**Adjustment**
EU wide studies									
Van Tuyckom & Scheerder, 2010b[27]		+				+			-
Western European region									
van Lenthe *et al*, 2005[38]				-[2]				-[2]	age, gender, educational level
Van Dyck *et al*, 2010[47] – walking		+		-[2]		+		-[2]	age, gender, education, employment status, BMI, walkability of neighbourhood, neighb. SEP, walkability*neighb. SEP
Van Dyck *et al*, 2010[47] – cycling		+		-[2]		+		0[2]	age, gender, education, employment status, BMI, walkability of neighbourhood, neighb. SEP, walkability*neighb. SEP
Wagner *et al*, 2003[50] - FRA		0		-[3]					age, gender[s], marital status, obesity, reported disease, centre

Table 3-A5: Summary of study findings examining associations between active transport (AT) and SEP‡ *(Continued)*

	Direction of the associations between the socioeconomic indicator and physical activity								
	Men				Women				
Author (Date)	**Income**	**Education**	**Social class**	**Other**	**Income**	**Education**	**Social class**	**Other**	**Adjustment**
Eastern European region									
Jurakić *et al*, 2009[53]	-	**0**			-	**0**			-
Kwaśniewska *et al*, 2010[56] – participation [b]	-	-			-	-			age, gender[s], education, income, marital status, smoking, place of residence, LTPA, OPA
Kwaśniewska *et al*, 2010[56] –minutes [b]	+	+			+	+			age, gender[s], education, income, marital status, smoking, place of residence, LTPA, OPA
Scandinavian region									
Andersen *et al*, 2000[82]		**(-)**				**(-)**			gender
Hu *et al*, 2003[90]		+				+			age, gender[s], study year
Mäkinen *et al*, 2009[100] [a]	**0**	**0**	+		+	**0**	**0**		age, gender[s], income, education, occupation
Wang *et al*, 2010[126]		+				+			age, gender[s], study year
Anglo-Saxon region									
Adams, 2010 – participation[129] [b]		**0**	**0**			**0**	**0**		age, gender, education, social class, employment status, car access
Adams, 2010 – minutes[129] [b]		+	-			+	-		age, gender, education, social class, employment status, car access
Wagner *et al*, 2003[50] - IRE		**0**		**0**[3]					age, gender[s], marital status, obesity, reported disease

‡ The symbols in the table should be read as follows: '+' means that a high SEP is associated with a high AT, a '-' means that a high SEP is associated with a low AT. A '0' means that there was no association found. When the symbol is between brackets, no tests of significance were done.

a. The results from the most recent data (1998-2002) are reported here.

b. The outcome was split up according to whether someone participates in active commuting and among those who participate, how many minutes they were active.

s. Results were stratified according to gender.

1. Composite individual SEP measure.

2. Neighbourhood SEP.

3. Household wealth (material conditions).

Table 3-A6: Distribution of positive, negative, and null associations by SEP indicator and PA domains in subsets of the reviewed associations.[a]

			Socioeconomic indicator																			
Physical activity[b,c]		**Total**				Income				Education				Social class				Other				
			+	**0**	-		+	0	-		+	0	-		+	0	-		+	0	-	
	Subset[d]	**n**	**%**	**%**	**%**	n	%	%	%	n	%	%	%	n	%	%	%	n	%	%	%	
TPA	**all**	**70**	**40%**	**27%**	**33%**	10	10%	70%	20%	32	44%	16%	41%	12	17%	25%	58%	16	69%	25%	6%	
	response	**47**	**47%**	**19%**	**34%**	6	17%	50%	33%	21	48%	14%	38%	8	25%	13%	63%	12	75%	17%	8%	
	adjusted	**46**	**37%**	**30%**	**33%**	4	0%	100%	0%	20	50%	15%	35%	12	17%	25%	58%	10	50%	40%	10%	
	s-size[e]	**54**	**50%**	**15%**	**35%**	4	25%	25%	50%	26	50%	15%	35%	10	20%	10%	70%	14	79%	14%	7%	
OPA	**all**	**19**	**11%**	**26%**	**63%**	2	0%	100%	0%	8	25%	25%	50%	7	0%	14%	86%	2	0%	0%	100%	
	response	**7**	**0%**	**0%**	**100%**	-	-	-	-	2	0%	0%	100%	3	0%	0%	100%	2	0%	0%	100%	
	adjusted	**7**	**0%**	**0%**	**100%**	-	-	-	-	2	0%	0%	100%	3	0%	0%	100%	2	0%	0%	100%	
	s-size[e]	**13**	**15%**	**8%**	**77%**	-	-	-	-	4	50%	0%	50%	7	0%	14%	86%	2	0%	0%	100%	
TLTPA	**all**	**200**	**68%**	**32%**	**1%**	34	59%	41%	0%	105	72%	27%	1%	38	74%	26%	0%	23	52%	48%	0%	
	response	**147**	**70%**	**30%**	**0%**	26	58%	42%	0%	78	77%	23%	0%	28	71%	29%	0%	15	53%	47%	0%	
	adjusted	**171**	**67%**	**33%**	**0%**	32	56%	44%	0%	83	75%	25%	0%	33	70%	30%	0%	23	52%	48%	0%	
	s-size[e]	**141**	**77%**	**23%**	**0%**	20	65%	35%	0%	72	85%	15%	0%	31	74%	26%	0%	18	61%	39%	0%	
VLTPA	**all**	**110**	**76%**	**24%**	**0%**	24	75%	25%	0%	48	71%	29%	0%	20	85%	15%	0%	18	83%	17%	0%	
	response	**82**	**77%**	**23%**	**0%**	18	78%	22%	0%	36	69%	31%	0%	16	88%	13%	0%	12	83%	17%	0%	
	adjusted	**78**	**74%**	**26%**	**0%**	22	73%	27%	0%	28	68%	32%	0%	12	83%	17%	0%	16	81%	19%	0%	
	s-size[e]	**88**	**82%**	**18%**	**0%**	22	82%	17%	0%	32	78%	22%	0%	16	88%	13%	0%	18	83%	17%	0%	
AT	**all**	**48**	**38%**	**29%**	**33%**	8	38%	13%	50%	26	54%	31%	15%	6	17%	50%	33%	8	0%	25%	75%	
	response	**30**	**47%**	**17%**	**37%**	6	50%	17%	33%	16	63%	13%	25%	2	50%	50%	0%	6	0%	17%	83%	
	adjusted	**40**	**40%**	**30%**	**30%**	6	50%	17%	33%	20	60%	30%	10%	6	17%	50%	33%	8	0%	25%	75%	
	s-size[e]	**36**	**39%**	**31%**	**31%**	6	50%	17%	33%	20	50%	30%	20%	6	17%	50%	33%	4	0%	25%	75%	

[a] SEP = socioeconomic position, PA = physical activity.

[b] TPA = Total Physical Activity, OPA = Occupational Physical Activity, TLTPA = Total Leisure-time Physical Activity, VLTPA = Vigorous Leisure-time Physical Activity, AT = Active Transport.

[c] The symbol '+' indicates the positive associations (a high SEP is associated with a high PA), the symbol '-' indicates negative associations (a high SEP is associated with a low PA), and '0' indicates the neutral associations (no association found).

[d] All=Total set of studies and associations included in the review, Response=Subset of associations from studies with a reported response of 50% or higher, Adjusted=Subset of associations that were at least adjusted for age and gender, Sample size=Subset of associations from studies with a sample size of 2000 participants or higher.

[e] s-size = sample size

Table 3-A7: Distribution of positive, negative, and null associations by European region and PA domain in subsets of the reviewed associations.[a]

		European Region																							
Physical activity[b,c]		EU wide studies				Western European region				Eastern European region				Southern European region				Scandinavian region				Anglo-Saxon region			
			+	0	-		+	0	-		+	0	-		+	0	-		+	0	-		+	0	-
	Subset[d]	n	%	%	%	n	%	%	%	n	%	%	%	n	%	%	%	n	%	%	%	n	%	%	%
TPA	**all**	2	100%	0%	0%	2	0%	100%	0%	10	40%	30%	30%	12	17%	8%	75%	20	40%	25%	35%	24	50%	33%	17%
	response	2	100%	0%	0%	-	-	-	-	6	67%	17%	17%	12	17%	8%	75%	17	47%	29%	24%	10	60%	20%	20%
	adjusted	2	100%	0%	0%	-	-	-	-	6	67%	17%	17%	6	0%	17%	83%	10	10%	40%	50%	22	45%	36%	18%
	s-size[e]	2	100%	0%	0%	2	0%	100%	0%	6	67%	17%	17%	12	17%	8%	75%	14	50%	14%	36%	18	67%	11%	22%
OPA	**all**	2	100%	0%	0%	-	-	-	-	6	0%	67%	33%	-	-	-	-	5	0%	0%	100%	6	0%	17%	83%
	response	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	0%	0%	100%	2	0%	0%	100%
	adjusted	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	0%	0%	100%	2	0%	0%	100%
	s-size[e]	2	100%	0%	0%	-	-	-	-	-	-	-	-	-	-	-	-	5	0%	0%	100%	6	0%	17%	83%
TLTPA	**all**	6	100%	0%	0%	37	81%	19%	0%	48	46%	52%	2%	28	71%	29%	0%	60	80%	20%	0%	21	48%	52%	0%
	response	-	-	-	-	32	84%	16%	0%	28	46%	54%	0%	18	83%	17%	0%	52	81%	19%	0%	17	35%	65%	0%
	adjusted	4	100%	0%	0%	34	79%	21%	0%	40	50%	50%	0%	24	75%	25%	0%	50	76%	24%	0%	19	42%	58%	0%
	s-size[e]	6	100%	0%	0%	20	90%	10%	0%	24	54%	46%	0%	26	77%	23%	0%	47	87%	13%	0%	18	56%	44%	0%
VLTPA	**all**	-	-	-	-	28	96%	4%	0%	23	65%	35%	0%	19	37%	63%	0%	16	88%	13%	0%	24	88%	13%	0%
	response	-	-	-	-	22	95%	5%	0%	20	60%	40%	0%	14	42%	57%	0%	10	80%	20%	0%	16	100%	0%	0%
	adjusted	-	-	-	-	20	100%	0%	0%	18	56%	44%	0%	16	38%	63%	0%	10	100%	0%	0%	14	86%	14%	0%
	s-size[e]	-	-	-	-	24	100%	0%	0%	19	58%	42%	0%	13	54%	46%	0%	12	100%	0%	0%	20	90%	10%	0%

Table 3-A7: Distribution of positive, negative, and null associations by European region and PA domain in subsets of the reviewed associations.[a] *(Continued)*

		European Region																							
Physical activity[b,c]		EU wide studies				Western European region				Eastern European region				Southern European region				Scandinavian region				Anglo-Saxon region			
			+	0	-		+	0	-		+	0	-		+	0	-		+	0	-		+	0	-
	Subset[d]	n	%	%	%	n	%	%	%	n	%	%	%	n	%	%	%	n	%	%	%	n	%	%	%
AT	**all**	2	100%	0%	0%	12	33%	17%	50%	12	33%	17%	50%	-	-	-	-	12	50%	33%	17%	10	20%	60%	20%
	response	-	-	-	-	10	40%	10%	50%	8	50%	0%	50%	-	-	-	-	12	50%	33%	17%	-	-	-	-
	adjusted	-	-	-	-	12	33%	17%	50%	8	50%	0%	50%	-	-	-	-	10	60%	40%	0%	10	20%	60%	20%
	s-size[e]	2	100%	0%	0%	4	0%	25%	75%	8	50%	0%	50%	-	-	-	-	12	50%	33%	17%	10	20%	60%	20%

[a] PA = physical activity.

[b] TPA = Total Physical Activity, OPA = Occupational Physical Activity, TLTPA = Total Leisure-time Physical Activity, VLTPA = Vigorous Leisure-time Physical Activity, AT = Active Transport.

[c] The symbol '+' indicates the positive associations (a high SEP is associated with a high PA), the symbol '-' indicates negative associations (a high SEP is associated with a low PA), and '0' indicates the neutral associations (no association found).

[d] All=Total set of studies and associations included in the review, Response=Subset of associations from studies with a reported response of 50% or higher, Adjusted=Subset of associations that were at least adjusted for age and gender, Sample size=Subset of associations from studies with a sample size of 2000 participants or higher.

[e] s-size = sample size

4

Sports participation, perceived neighbourhood safety, and individual cognitions: how do they interact?

Mariëlle A. Beenackers
Carlijn B.M. Kamphuis
Alex Burdorf
Johan P. Mackenbach
Frank J. van Lenthe

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ABSTRACT

Background: Little is known about the interaction between individual and environmental determinants of physical activity, although this may be important information for the development of effective interventions. The goal of this paper is to investigate whether perceived neighbourhood safety modifies associations between individual cognitions and sports participation.

Methods: Cross-sectional data were obtained from residents (age 25-75) of 87 neighbourhoods in the city of Eindhoven, who participated in the Dutch GLOBE study in 2004 (N = 2,474). We used multilevel logistic regression to analyze the interactions between perceived neighbourhood safety and individual cognitions (attitude, self-efficacy, social influence, and intention) on sports participation (yes/no).

Results: In its association with sports participation, perceived neighbourhood safety interacted significantly with self-efficacy and attitude ($p < 0.05$). Among persons who perceived their neighbourhood as safe, a positive attitude was strongly associated with sports participation (OR 2.00, 95%CI 1.48-2 71). In contrast, attitude was not associated with sports participation in persons who perceived their neighbourhood as unsafe (OR 0.65, 95%CI 0.34-1.24). Further, self-efficacy was significantly stronger associated with sports participation in persons who perceived their neighbourhood as unsafe (OR 1.85, 95%CI 1.31-2.60) than in those who perceived their neighbourhood as safe (OR 1.19, 95%CI 1.05-1.36). Social influence and intention did not interact with perceived neighbourhood safety.

Conclusions: Associations between individual cognitions and sports participation depend on neighbourhood circumstances, such as perceived neighbourhood safety. Interventions to promote sports participation in adults should take the interaction between environmental and individual characteristics into account. More research is needed to find out the causal pathways in individual-environment interactions.

INTRODUCTION

Regular physical activity (PA) prevents major chronic diseases such as diabetes, cardiovascular disease, mental illness, obesity, and various types of cancer [1-2]. Although the health benefits of regular exercise and a physically active lifestyle are well known, many people are still not active. In the Dutch population, over 40% does not meet the national recommendation of being moderately active for at least half an hour on at least five days a week [3-4]. In the US, the percentage of people not reaching the recommended level of PA is over 50% [5]. Therefore, increasing PA comprises a large potential public health gain [1, 6].

Previously, the promotion of PA has focused mainly on changing individual cognitions towards PA, such as attitude and self-efficacy [7-8]. Over the past decade, the focus of research has shifted more to environmental determinants of health and health behaviour [9]. In addition, ecological models suggest that health behaviour is determined by individual as well as environmental factors, and that they are interrelated [10-11]. So far, little is known about these individual-environment interactions.

Sports participation is an important element of PA. Persons who participate in sports have a lower mortality than those who do not participate in sports [12]. In Europe, only 40% of the adult population participates in sports with some regularity, ranging from 72% in Finland, to only 13% in Bulgaria [13]. In the US, 24% of the population is regularly vigorously physically active [5]. An environmental factor that has been suggested to be related to PA and sports participation is neighbourhood safety [14-15]. In the US, higher levels of perceived neighbourhood safety were associated with lower levels of physical inactivity [16]. A study by McGinn and colleagues reported that both perceived as objectively measured crime were related to physical activity [17].

Why does neighbourhood safety influence physical activity? Macintyre suggests that the importance of environmental factors related to health roughly follows the order of human needs as defined by Maslow [18-19]. In this order of human needs, safety is one of the main needs, just after air, water, food, and shelter [19]. When a basic need like safety is unfulfilled, higher ranked needs, like sport participation, are less relevant.

Another explanation for the association between neighbourhood safety and physical activity is that people most often have to leave their house when they want to exercise. An unsafe environment might act as a barrier for sports participation. Especially since, in the Netherlands, adults are most involved in sports activities in the evenings and weekends due to other responsibilities during the day. For types of sports that start from the doorstep (like running and cycling), this association is rather obvious, as these sports completely or partly

take place in the neighbourhood. For sports that are played at a sports club outside the own neighbourhood, neighbourhood safety may also act as an important perceived barrier, as one has to travel through his or her own neighbourhood to get there.

A large pan-European study showed that perception of safety was associated with an increase in the likelihood to engage in occasional exercise of 22% in women and 39% in men [20]. Sallis and colleagues [21] showed that women who reported low levels of crime in their neighbourhood reported about an hour more moderate and vigorous physical activity compared with women who reported high levels of crime in their neighbourhood. In a previous study by Kamphuis et al [22], it was demonstrated that people who perceived their neighbourhood as safe were almost twice as likely to participate in sports as those who perceived their neighbourhood as unsafe.

However, not all studies find a positive association between perceived safety and PA [23-24]. Whether perceived neighbourhood safety is a barrier for sports participation is likely to depend on individual cognitions. It seems plausible that positive cognitions towards PA might help people to deal with environmental barriers. The exact nature of this interdependency is largely unknown. Although previous studies have focused on the association between perceived neighbourhood safety or individual cognitions and sports participation, very few investigated their interaction. For example, Deforche and colleagues [25] found that feelings of unsafety were only associated with the likelihood of active transportation in youth who had low self-efficacy and not in youth who had a strong self-efficacy. Thus, the aim of this study is to investigate whether perceived neighbourhood safety modifies the associations between individual cognitions and sports participation.

METHODS

Study population

Data were obtained in a large-scale postal survey, a component of the most recent wave of data collection for the longitudinal Dutch GLOBE study (October 2004). The cross-sectional data originated from a stratified sample of the adult population of Eindhoven and its surrounding municipalities (N=4,785; response 64.4%). More detailed information on the objectives, study design, and data collection of the Dutch GLOBE study can be found in Chapter 2 and elsewhere [26-27]. The use of personal data in the GLOBE study is in compliance with the Dutch Personal Data Protection Act and the Municipal Database Act, and has been registered with the Dutch Data Protection Authority (number 1248943).

Since we suspect that safety concerns are different in a city environment compared with a rural environment, only participants residing in the city of Eindhoven (N=2,917) were selected. Eindhoven is the fifth largest city in the Netherlands with over 200,000 inhabitants. Respondents lived spread throughout the whole city. Individuals with missing data on the outcome measure or on one of the confounding variables, i.e. age, sex, education, or country of origin, were omitted (N=356). Respondents who had missing values on more than 25% of the items of individual cognition and neighbourhood safety were also omitted (N=87). A total number of 2,474 respondents were analyzed. These respondents resided in 87 of Eindhoven's administrative neighbourhoods (mean number of respondents per neighbourhood = 28, range 1 to 103).

Measures

All measures used in this study were derived from self-reported data from the GLOBE postal survey of 2004.

Sports participation

Sports participation was measured using the SQUASH questionnaire, which is a validated questionnaire for measuring different types of PA among an adult population [28]. Respondents could record up to four different sport activities they had done in an average week over the past few months (open question, no defined list given). For each sport activity, they had to report the frequency (times per week), the average duration (minutes per day) and the intensity (low, average, high). In combination with the respondent's age and the activity-specific metabolic equivalent of task (MET) values, the self-reported intensity was used to calculate intensity scores. The total number of minutes per week with at least moderate intensity (moderate intensity = 4-6 MET for 18-55 yrs-old; 3-5 MET for 55+ yrs-old) was calculated. Since about half of the respondents did not do any sports, sports participation was dichotomized into 'yes' for respondents who participated in sports with moderate or high intensity at least once a week for at least 30 minutes versus 'no' for those who did not participate in sports weekly.

Individual cognitions

The individual cognition items were formulated as individual cognitions towards 'sufficient PA' (see Appendix, Table 4-A1). The cognitions used in this study were derived from commonly employed health behaviour theories such as the Social Cognitive Theory and the Theory of Planned Behaviour [7-8]. Attitude (eleven items, Cronbach's alpha=0.77), self-efficacy (two items, Cronbach's alpha=0.75), and intention (one item) were measured on a five-point ordinal scale, and social influence (three items, Cronbach's alpha=0.72) was measured on a three-point ordinal scale. The percentage of missing observations varied between 1.7% and 4.9% for the items for attitude, self-efficacy and social influence, while there were 9.5% miss-

ing observations for the item 'intention'. Missing values were imputed by using the expectation maximization (EM) algorithm [29] from SPSS version 15.0. For all individual cognitions (except intention) a mean score was calculated from the relevant items within each cognition. A higher score on each of the individual cognition scales represented a more positive cognition. Individual cognitions were mean-centred for analytical purposes. All individual cognitions were treated in the analyses as continuous variables.

Perceived safety of the neighbourhood

Perceived safety of the neighbourhood was assessed with four items. The first three items assessed people's fear of being home alone or of going out on the streets in their neighbourhood in the daytime or at night. The items were dichotomized into 'no, never feeling afraid' (0) and 'neutral/yes, sometimes feeling afraid' (1). The fourth item asked the respondents whether they thought their neighbourhood was unsafe (no=0, yes=1). These four dichotomous items were summed up to form a scale (Cronbach's alpha=0.67).

The first three items about fear had just over one percent (1.3 – 1.4%) missing observations. These missing values were imputed using the EM algorithm. The fourth item about neighbourhood safety had 5.9% missing observations. The missing values of this (dichotomous) item were imputed using the predicted group membership from a logistic regression with the other three safety items and several social disorganization items from the survey as predictor variables ("How frequent do the following adverse events occur in your neighbourhood?" Items referred to examples such as litter, graffiti, vandalism, and violence.).

Respondents who did not agree with any of the items indicating an unsafe neighbourhood were regarded as 'high' on perceived neighbourhood safety. Respondents who agreed once or twice to a measure indicating an unsafe neighbourhood were considered 'medium' on perceived neighbourhood safety. Respondents who agreed to three or four of the items indicative of an unsafe surrounding were considered 'low' on perceived neighbourhood safety.

Demographics

Possible confounders were age, sex, country of origin (the Netherlands, other country), and educational level ((1) no education or primary education; (2) lower professional and intermediate general education; (3) intermediate professional and higher general education; (4) higher professional education and university). Educational level was included as an indicator for socio-economic status (SES) and has proven to be a good measure for SES in the Netherlands [30].

Statistical analyses

Crude and multivariable logistic regressions were used to explore the associations between individual cognitions and sport participation, and between perceived neighbourhood safety and sport participation. All multivariable models were adjusted for age, sex, educational level, and country of origin. To assess interactions between individual cognitions and perceived neighbourhood safety, a backward logistic regression was performed in which all possible interaction terms between perceived neighbourhood safety and the individual cognitions were included. These analyses were carried out in SPSS version 15.0.

Because of the hierarchical structure of the data, a multilevel analyses was performed using MLwiN (version 2.02) using the logit-link function and 2nd order PQL estimation methods [31]. In the multilevel models, all the significant variables ($p<0.05$) from the crude analyses (Model 1) and all the significant interactions ($p<0.05$) from the backward logistic regression (Model 2) were included.

Parameters in logistic regression models that include an interaction are difficult to interpret. To clarify this, a simplified interactive logistic regression model (Equation 1) was formulated which was reduced to only one quantitative variable (X), one categorical variable with three levels (Z), and the interaction between these two variables (XZ). In this study, X represents an individual cognition (e.g. attitude) and Z represents perceived neighbourhood safety with three levels: high, medium, and low.

$$\ln\left(\frac{P}{1-P}\right) = \ln(odds) = \alpha + \beta_1 X + \beta_2 Z_{high} + \beta_3 Z_{medium} + \beta_4 Z_{low} + \beta_5 XZ_{high} + \beta_6 XZ_{medium} + \beta_7 XZ_{low} \quad [1]$$

In this equation, P is the probability of participating in sports, α is the constant and β1 is the coefficient that reflects how much the log odds will change when the individual cognition increases with one unit. However, because of the interaction term in the model, the association of X on the outcome is conditional on the reference level of perceived neighbourhood safety (Z_{high}) (Equation 2).

To obtain the coefficient of the individual cognition (X) for the second category of perceived neighbourhood safety (Z_{medium}), the coefficient of X (β1) should be added to the coefficient of the interaction term XZ_{medium} (β6) (Equation 3). Because of the logarithmic scale, the odds ratio of an interaction term can be interpreted as a multiplicative factor. To obtain the odds ratio of the individual cognition (X) for the second category of perceived neighbourhood

safety (Z_{medium}), the odds ratio of X (EXPβ1) should be multiplied by to the odds ratio of the interaction term XZ_{medium} (EXPβ6).

To obtain the coefficient of the individual cognition (X) for the last category of perceived neighborhood safety (Z_{low}), the coefficient of X (β1) should be added to the coefficient of the interaction term XZ_{low} (β7) (Equation 4). Again, to obtain the odds ratio of the individual cognition (X) for the last category of perceived neighbourhood safety (Z_{low}), the odds ratio of X (EXPβ1) should be multiplied by to the odds ratio of the interaction term XZ_{low} (EXPβ7).

$$\beta_{1\_conditional\_on\_Z_{high}} = \beta_1 \quad [2]$$

$$\beta_{1\_conditional\_on\_Z_{medium}} = \beta_1 + \beta_6 \quad [3]$$

$$\beta_{1\_conditional\_on\_Z_{low}} = \beta_1 + \beta_7 \quad [4]$$

The other coefficients of the variables that are part of the interaction term should also be interpreted carefully. Because Z_{high} is the reference category, its value is zero. Therefore, coefficients β2 and β5 are zero. The coefficients β3 and β4 are the coefficients for the medium and low levels of perceived neighbourhood safety, which are conditional on the 0-value of the individual cognition (X). Since the individual cognitions were mean-centred, the coefficients can be interpreted as the typical effect of the perceived neighbourhood safety when the individual cognition is at its mean.

The analyses were carried out for both the imputed and non-imputed datasets and they provided similar results. We present the data of the imputed dataset.

RESULTS

Table 4-1 shows the characteristics of the sample. Almost half of the sample participated in sports with moderate or high intensity at least once a week for at least 30 minutes.

In the crude and the adjusted models, all individual cognitions were strongly positively associated with sports participation (Table 4-2). Those who perceived their neighbourhood as safe were twice as likely to participate in sports as those perceiving their neighbourhood as unsafe. The associations remained similar when adjusted for age, sex, education, and country of origin.

Table 4-1: Characteristics of the GLOBE study respondents living in the city of Eindhoven.

	Sample[a]	
Characteristics	**N**	**%**
Total sample	2474	100
Sex		
Male	1168	47.2
Female	1306	52.8
Age mean (range)	53.1 (25-75)	
25-34	340	13.7
35-44	409	16.5
45-54	413	16.7
55-64	668	27.0
65-75	644	26.0
Education		
1 Low	243	9.8
2	890	36.0
3	571	23.1
4 High	770	31.1
Country of birth		
Netherlands	2253	91.1
Other	221	8.9
Sports participation		
Yes	1308	47.1
No	1166	52.9

a. The numbers and percentages presented are unweighted and are therefore a representation of the actual numbers in the dataset.

In the multivariable model without interactions (Model 1, Table 4-3), attitude and intention were the strongest predictors of sports participation. When attitude increased by one unit (on a 5-unit scale), the odds of participating in sports increased by approximately 60% relative to the odds when attitude was at its mean value. When intention increased by one unit (on a 5-unit scale), the likelihood of sports participation increased by just over 50% relative to the odds when intention was at its mean value.

Multilevel multivariable analyses showed significant interactions between attitude and perceived neighbourhood safety and between self-efficacy and perceived neighbourhood safety (Model 2, Table 4-3). Social influence and intention did not interact with perceived neighbourhood safety.

These interactions are visualized in Figure 4-1. It shows that among persons who perceived their neighbourhood as safe, a positive attitude increased the likelihood of sports participation (OR 2.00, 95%CI 1.48-2.71). The association between attitude and sports participation became weaker when the neighbourhood was perceived as less safe. Among those who perceived their neighbourhood to be unsafe, the association with attitude was no longer significant (OR 0.65, 95%CI 0.34-1.24). For self-efficacy, the interaction was the other way around: a strong self-efficacy increased the probability of sports participation significantly more in persons who perceived their neighbourhood as unsafe (OR 1.85, 95%CI 1.31-2.60) relative to those who perceived their neighbourhood as safe (OR 1.19, 95%CI 1.05-1.36).

Table 4-2: Crude and adjusted logistic regression analyses for sports participation.

		Crude		Adjusted [a]	
Variables		**OR [b]**	**95% CI**	**OR [a, b]**	**95% CI [a]**
Individual cognitions	**Mean (SD)**				
Attitude (1-5)	3.76 (0.54)	**3.71** ***	**3.12-4.40**	**3.50** ***	**2.94-4.18**
Self-efficacy (1-5)	3.82 (0.91)	**1.92** ***	**1.74-2.11**	**1.91** ***	**1.72-2.11**
Social influence (1-3)	2.28 (0.59)	**1.63** ***	**1.42-1.87**	**1.63** ***	**1.41-1.88**
Intention (1-5)	4.04 (1.02)	**2.20** ***	**2.01-2.42**	**2.10** ***	**1.91-2.31**
Perceived neighbourhood safety	**%**				
Safety high (safe)	60.6 %	1.00		1.00	
Safety medium	31.8 %	**0.75** **	**0.63-0.89**	**0.81** *	**0.67-0.98**
Safety low (unsafe)	7.6 %	**0.36** ***	**0.26-0.50**	**0.45** ***	**0.32-0.64**

a. Models were adjusted for age, sex, educational level and country of origin.

b. * = p<.050, ** = p<.010, *** = p<.001

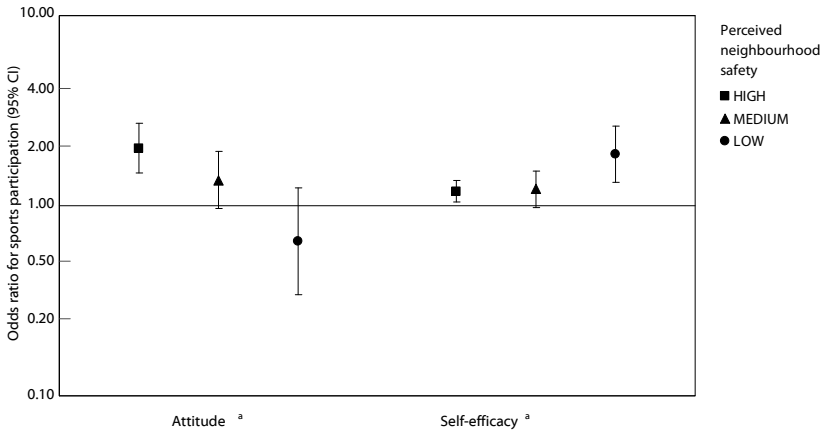

Figure 4-1: OR and 95% CI for attitude and self-efficacy for three levels of perceived neighbourhood safety.

Note: The ORs were calculated by multiplying the OR of the individual cognition by the OR of the relevant interaction term (both derived from Model 2 in Table 4-3 which is adjusted for age, sex, educational level, country of origin, and all other individual cognitions).

Table 4-3: Multilevel multivariable logistic regression models with OR and 95% CI for sports participation.

	Model 1[a]		Model 2[a]	
Variables	**OR [b]**	**95% CI**	**OR [b]**	**95% CI**
Perceived neighbourhood safety				
Safety high (safe)	1.00		1.00	
Safety medium	0.90	0.74-1.09	0.90	0.74-1.09
Safety low (unsafe)	**0.60** **	**0.43-0.84**	**0.57** ***	**0.42-0.77**
Individual cognitions				
Attitude (1-5) [c]	**1.60** ***	**1.27-2.01**	**2.00** *** [d]	**1.48-2.71**
Self-efficacy (1-5) [c]	**1.25** ***	**1.13-1.39**	**1.19** ** [d]	**1.05-1.36**
Social influence (1-3) [c]	**1.24** **	**1.07-1.43**	**1.25** **	**1.08-1.44**
Intention (1-5) [c]	**1.51** ***	**1.35-1.68**	**1.51** ***	**1.35-1.69**
Interactions				
Safety * attitude				
Safety high * attitude			1.00 [e]	
Safety medium * attitude			0.69 [e]	0.44-1.07
Safety low * attitude			**0.33** *** [e]	**0.17-0.63**
Safety * self-efficacy				
Safety high * self-efficacy			1.00 [e]	
Safety medium * self-efficacy			1.03 [e]	0.79-1.33
Safety low * self-efficacy			**1.55** * [e]	**1.07-2.24**

a. Models were adjusted for age, sex, educational level and country of origin

b. * = p<.050, ** = p<.010, *** = p<.001

c. The individual cognitions were centred around it's mean for analytical and interpretational purposes.

d. The OR of attitude and self-efficacy in model 2 represent the ORs of these two variables in a neighbourhood perceived as safe (the reference category).

e. The parameters of the interaction terms should be interpreted as multiplicative factors. E.g.: to obtain the OR for self-efficacy for people who perceive their neighbourhood as unsafe, one has to multiply the OR for the relevant interaction term (OR=1.55) with the OR of self-efficacy (OR=1.19). The calculated ORs for attitude and self-efficacy for each of the safety categories can be found in Figure 4-1. More information on the interpretation of these parameters can be found in the method section.

DISCUSSION

This study is among the first to explore environment-individual interactions in sports participation. It showed that perceived neighbourhood safety moderated the associations between attitude and sports participation, and between self-efficacy and sports participation. The associations between social influence and sports participation, and between intention and sports participation did not differ according to perceived neighbourhood safety.

Similar with many other studies [32], attitude, self-efficacy, social influence, and intention were all important correlates of sports participation in this study. Our finding that perceived neighbourhood safety was strongly associated with the likelihood of sports participation is

in line with some, though not all studies [16, 23, 33, 20]. To check whether this relationship was different for different types of sports, we compared respondents who participated in organized sports like tennis and basketball with non-participators, and respondents who participated in more "neighbourhood oriented" sports like cycling, jogging, and walking with non-participators (results not shown). Although the association between perceived neighbourhood safety and sports participation was stronger in those who participated in "neighbourhood oriented" sports, the association was also significant for those participating in organized sports. This strengthens the assumption that perceived neighbourhood safety might be an important factor for all sports participation either because the activity is carried out within the neighbourhood or because people have to travel through their neighbourhood. The interaction found in this study indicated that associations of self-efficacy and attitude with sports participation were modified by the environmental barrier of an unsafe neighbourhood environment; where a strong self-efficacy may help people to overcome this barrier, having a positive attitude may not be enough to participate in sports when living in an unsafe neighbourhood. In a safely perceived environment, on the other hand, attitude was more important for explaining sports participation than self-efficacy, since a strong self-efficacy may be less relevant for this situation. Similar to our study, Deforche and colleagues [25] also looked at the interaction between perceived safety and self-efficacy and found that, perceived safety was associated with active transportation in youth with low-self-efficacy only.

Since this study is cross-sectional, the interactions as observed can also be interpreted differently, that is, that individual cognitions moderate the association between perceived neighbourhood safety and sports participation. In this interpretation, sports participation of those who have a strong self-efficacy is possibly less influenced by an unsafe environment. On the other hand, people who have a positive attitude might be more inhibited by an unsafe environment compared with those who have a negative attitude. This difference could be explained by the different nature of the two cognitions. A positive attitude is more related to whether someone wants to be physically active, while a strong self-efficacy is more related to whether someone feels he can be active. When someone wants to be active, but lives in an unsafe environment, he or she could perceive this as a barrier to become active. When someone has a negative attitude, and therefore, does not want to be active, he or she might also be less likely to perceive any barriers.

Methodological considerations

An important limitation is the cross-sectional design. Therefore, no conclusions about causalities or the direction of the interactions can be drawn; the investigated associations of individual cognitions and neighbourhood factors with sports participation can be bi-directional. The neighbourhood can influence whether someone participates in sports, but,

just as likely, participating in sports may influence the way people perceive their neighbourhoods; as by participating in sports or travelling to the sports facility, they get exposed to their neighbourhood. The same counts for individual cognitions. A mechanism that may be involved in this process is 'cognitive dissonance' [34], which describes the cognitive process in which people adjust their beliefs to match their actions; persons who are not active may adjust their cognitions or even their perceptions of the neighbourhood to match their behaviour. The interactions can also be interpreted both ways: It can be interpreted as if the perceived neighbourhood safety moderates the associations between cognitions and sports participation, but another explanation could be that the cognitions moderate the association between perceived neighbourhood safety and sports participation.

When interpreting the results, one should be aware that only perceptions about the safety of the neighbourhood are considered in this study. From the results we can infer that feeling unsafe in the neighbourhood is associated with a lower probability of sports participation. However, we cannot determine why people are feeling unsafe because this was not stated in the question posed. Another reason is that there are many factors, apart from the real safety in a neighbourhood, which can affect perceived neighbourhood safety [23]. It would therefore be interesting to see if these interactions can also be found in a study that includes objective measures of neighbourhood safety.

Moreover, self-reported data were used, which may have led to an over-reporting of PA [35-36] or an overestimation of strength of associations between determinants and sports participation due to same-source bias. Lastly, individual cognitions were not measured specifically regarding sports participation but for PA in general.

Implications for research and practice

This study is a first exploration of interactions between individual and environmental correlates of sports participation and it suggests that these are important for understanding health behaviour. Further research should incorporate both objective and subjective measures of safety when investigating interactions regarding PA behaviours. Moreover, studies need to explore interactions with other important environmental determinants such as neighbourhood aesthetics. Although cross-sectional designs are helpful in exploring the possible relations, stronger designs are needed to confirm causal pathways. It is also important to explore interactions for other types of health behaviours.

This study implies that when developing interventions to promote PA, the specific individual cognitions that should be targeted may differ by how persons perceive their neighbourhood. It may also imply that whether an improvement of neighbourhood safety results in more sports participation depends on the specific individual cognitions people hold.

CONCLUSION

Associations between individual cognitions and sport participation depend on neighbourhood circumstances such as perceived neighbourhood safety. More research is needed to find out the causal pathways in individual-environment interactions with regard to health behaviours.

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APPENDIX

Table 4-A1: Measurement of individual cognitions in the GLOBE postal survey 2004.

Variable	Item	Response categories
Attitude	Negative outcome expectancy of physical activity: It requires too much time	(1)Very important – – – (5)Not important at all
	Negative outcome expectancy of physical activity: It requires too much discipline	(1)Very important – – – (5)Not important at all
	Negative outcome expectancy of physical activity: It requires too much energy	(1)Very important – – – (5)Not important at all
	Negative outcome expectancy of physical activity: I am afraid to get injured	(1)Very important – – – (5)Not important at all
	Negative outcome expectancy of physical activity: I feel uncomfortable when exercising	(1)Very important – – – (5)Not important at all
	Positive outcome expectancy of physical activity: It makes me feel less stressed	(1)Not important at all – – – (5)Very important
	Positive outcome expectancy of physical activity: It gets me into a good mood	(1)Not important at all – – – (5)Very important
	Positive outcome expectancy of physical activity: I like being active	(1)Not important at all – – – (5)Very important
	Positive outcome expectancy of physical activity: I am more confident with my body	(1)Not important at all – – – (5)Very important
	Positive outcome expectancy of physical activity: It is good for fitness/condition	(1)Not important at all – – – (5)Very important
	Positive outcome expectancy of physical activity: I feel energized	(1)Not important at all – – – (5)Very important
Social influence	Most people who are important to me think I should be sufficiently physically active [a]	(1)No, not true – (3)Yes, true
	Most people who are important to me stimulate me to be sufficiently physically active	(1)No, not true – (3)Yes, true
	Most people who are important to me are sufficiently physically active	(1)No, not true – (3)Yes, true
Self-efficacy	Do you think it is easy or difficult to be sufficiently physically active?	(1)Very difficult – – – (5)Very easy
	How sure are you that you can be sufficiently physically active?	(1)Not sure at all – – – (5)Very sure
Intention	Do you plan to be sufficiently physically active?	(1)No, for sure not – – – (5)Yes, for sure

[a] Sufficient physical activity was defined in the questionnaire as being active for at least half an hour a day (e.g. gardening, sports participation, bicycling)

5

Why some walk and others don't: exploring interactions of perceived safety and social neighbourhood factors with psychosocial cognitions

Mariëlle A. Beenackers
Carlijn B.M. Kamphuis
Johan P. Mackenbach
Alex Burdorf
Frank J. van Lenthe

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ABSTRACT

Objective: While physical activity is often believed to be influenced by both environmental and individual factors, little is known about their interaction. This study explores interactions of perceived safety and social neighbourhood factors with psychosocial cognitions for leisure-time walking.

Method: Cross-sectional data were obtained from residents (age 25-75) of 212 neighbourhoods in the South-East of the Netherlands, who participated in the Dutch GLOBE study in 2004 (N=4,395, survey response 64.4%). Direct associations of, and interactions between perceived neighbourhood safety, social neighbourhood factors (social cohesion, social network, feeling at home), and psychosocial cognitions (attitude, self-efficacy, social influence, intention) on two outcomes of leisure-time walking (yes vs. no (binary), and among walkers: minutes/week (continuous)) were analyzed in multilevel regression models.

Results: The association between attitude and participating in leisure-time walking was stronger in those who felt less at home in their neighbourhood. Social influence and attitude were stronger associated with participation in leisure-time walking in those who sometimes felt unsafe in their neighbourhood. A positive intention was associated with more minutes walked in those who perceived their neighbourhood as unsafe among those who walked.

Conclusion: Only limited support was found for interactions between neighbourhood perceptions and psychosocial cognitions for leisure-time walking.

INTRODUCTION

Physical inactivity is among the most important and prevalent risk factors of many major diseases [1-4]. Understanding why people are physically inactive is therefore of key importance in developing strategies to reduce these major diseases. Walking is a relatively easy way to be physically active; it is accessible to most people because it does not require any financial means and it can be continued into old age. Known determinants of walking are individual psychosocial cognitions, such as attitude and self-efficacy [5-6]. In the past decade, many studies also investigated possible environmental determinants of walking, such as safety, population density, and access to facilities [7-11].

Thus far, many studies have looked at the relation between psychosocial cognitions and environmental factors with walking separately or have explored to what extent psychosocial cognitions mediated the influence of environmental factors on walking [12-16]. However, a social-ecological perspective suggests that there is interplay between the individual and the environment. According to Emmons [17], improving the understanding of health behaviours in their social context implies that the role of individual factors for health behaviours may depend on the environmental context. One of the core principles of ecological models is that influences interact across levels [18]. So, although such interactions are implied in ecological models [19-20, 18], these models do not provide specific hypotheses, and perhaps as a consequence, empirical studies into interaction effects are still scarce.

The few studies that did investigate environment-individual interactions for walking have mainly focused on built environmental factors including connectivity of streets, availability of shopping and sports facilities and neighbourhood aesthetics [21-23]. Other factors, such as social environmental factors [24-27] and safety concerns [28-29], are also suggested to be of importance for walking behaviour. Rhodes et al. studied the interactions between safety and psychosocial cognitions with respect to walking behaviour [23] and found that low levels of perceived crime resulted in a larger influence of attitude on the intention to walk compared with people who perceived high levels of crime. To date, there are no studies that have looked at interactions of psychosocial cognitions with social neighbourhood factors such as social cohesion and social network for walking. Therefore, it is the aim of this article to explore interactions of safety and social neighbourhood perceptions (neighbourhood social cohesion, neighbourhood social network, and feeling at home within your neighbourhood) with psychosocial cognitions (attitude, self-efficacy, intention, and social influence) for leisure-time walking.

In general, two possible interaction mechanisms can be at play. The first mechanism proposes that the environment is less important for the decision to walk for those who have

more positive psychosocial cognitions towards physical activity. When this interaction exists, people with less positive psychosocial cognitions would benefit more from a supportive environment. The other mechanism assumes a synergy between environmental factors and psychosocial cognitions; the environment is more important in the decision to walk for people with more positive cognitions. This means that the beneficial effects of having positive psychosocial cognitions and living in a stimulating environment on walking would strengthen each other. For example, among those who report to have a small social network in their neighbourhood, one may expect that having a positive intention towards physical activity results in less walking than among those with a large social network, as having a smaller social network may be a barrier to putting one's positive intentions into action. The aim of this article is to investigate interactions of perceived safety and social neighbourhood perceptions (neighbourhood social cohesion, neighbourhood social network, and feeling at home within your neighbourhood) with psychosocial cognitions (attitude, self-efficacy, intention, and social influence) for two outcomes of leisure-time walking; any versus no leisure-time walking and among walkers: minutes per week spent on leisure-time walking.

METHODS

Data collection

Data for this study were collected among a stratified sample of the adult population of the city of Eindhoven and its surrounding municipalities in the Netherlands in 2004, as part of the Dutch GLOBE study. The baseline sample was stratified by age, degree of urbanization, and socioeconomic status (SES). More detailed information on the objectives, study design and data collection of the Dutch GLOBE study can be found in Chapter 2 and elsewhere [30-31]. In short, the study started with a baseline survey in 1991. This baseline sample was stratified by age, degree of urbanization, and SES. In 2004, a new subsample was added to the original cohort to restore population representativeness of the study sample. In this study, questionnaires from the cross-sectional sample of the fourth wave (October 2004) were used (N=4,785; response 64.4%). The fourth wave was chosen because of its particular focus on neighbourhood factors. The use of personal data in the GLOBE study is in compliance with the Dutch Personal Data Protection Act and the Municipal Database Act and has been registered with the Dutch Data Protection Authority (number 1248943).

Respondents with a missing outcome (n=182) or who had more than 25% missing values on the variables used in the analyses (n=149) were omitted from the analyses. Respondents with a missing neighbourhood identifier (n=59) were also excluded. Thus, a total of 4,395 respondents were included. Remaining missing values were imputed (see Statistical Analyses section). The respondents resided in 212 administrative neighbourhoods of Eindhoven and

its surrounding municipalities (mean number of respondents per neighbourhood n=21, interquartile range = 6-27).

Measures

Leisure-time walking

Leisure-time walking was assessed by the SQUASH, a validated Dutch questionnaire that measures different types of physical activity [32]. Within SQUASH, leisure-time walking (i.e. walking for recreational purposes, no transportation walking) was measured by asking the respondent how many days they walked during leisure-time in a usual week (frequency) and how much time they spend on this on those days (duration). Because many respondents did not walk at all during leisure time, the first outcome variable we analyzed was binary, namely any versus no leisure-time walking ('yes, does walk during leisure-time' versus 'no, does not walk during leisure-time'). For those who indicated to do any leisure-time walking, total minutes of leisure-time walking per week were calculated using information on frequency and duration.

Psychosocial cognitions

Psychosocial cognitions were based on the Theory of Planned Behaviour [33] and the Social Cognitive Theory [34]. All items were formulated towards 'sufficient physical activity in line with recommended levels' [35]. Attitude was measured with 11 items (Cronbach's alpha=0.79) with a 5-point ordinal answering scale (1, very important to 5, not important at all). An example question was whether respondents found the argument 'it takes too much time' important in their decision to be sufficiently active. Self-efficacy was measured with two items (Cronbach's alpha=0.77). The first item asked whether respondents thought it was easy or difficult to be sufficiently physically active (1, very difficult to 5, very easy). The second item asked how sure they could be sufficiently physically active when they would want to (1, not sure at all to 5, very sure). Intention was measured with one item ('do you plan to be sufficiently physically active?'; 1, no, not sure at all to 5, yes, for sure). Social influence was measured with three items (Cronbach's alpha=0.73) that addressed whether persons important to the respondent would (i) think the respondent should be sufficiently active, (ii) stimulate the respondent to be physically active, and (iii) are sufficiently active themselves. Answering categories ranged from 1, 'not true' to 3, 'yes, true'. For all psychosocial cognitions (except intention), a mean score was calculated from the relevant items within each cognition. A higher score on each scale represented a more positive cognition. All items used to construct the scales can be found in the appendix (Table 5-A1).

Neighbourhood perceptions – social

Elements of the neighbourhood social environment were measured using a 13 item scale (Cronbach's alpha=0.87). All items were measured on a 5-point ordinal scale (1, totally disagree to 5, totally agree). A principal component analyses with Varimax rotation and Kaiser Normalization distinguished three factors. The first factor was labelled 'social cohesion', defined as 'the extend of connectedness and solidarity among groups in society' [36]. An item that had a high factor loading on this factor was 'most people in this neighbourhood can be trusted'. The second factor was labelled 'social network', defined as 'the presence and nature of interpersonal relationships and interactions; extend to which one is interconnected and embedded in a community' [27]. An item stat had a high factor loading on this factor was 'I often visit my neighbours in their home'. The third factor was labelled 'feeling at home in this neighbourhood'. An item that had a high factor loading on this factor was 'I move out of this neighbourhood if I get the chance (recoded)'. For all three factors, a standardized factor score (mean=0, standard deviation of 1) was constructed using the factor loadings. The individual social neighbourhood items, their means and standard deviations, and the factor loadings can be found in the appendix (Table 5-A2).

Neighbourhood perceptions - safety

Perceived safety of the neighbourhood was assessed with four items. The first three items assessed people's fear of being home alone or of going out on the streets in their neighbourhood in the daytime or at night. The items were dichotomized into 'no, never feeling afraid' (0) and 'neutral/yes, sometimes feeling afraid' (1). The fourth item asked the respondents whether they thought their neighbourhood was unsafe (no=0, yes=1). These four dichotomous items were summed up to form a scale (Cronbach's alpha=0.68). Respondents who did not agree with any of the items indicating an unsafe neighbourhood were regarded as 'high' on perceived neighbourhood safety; they felt safe. Respondents who agreed once or twice to a measure indicating an unsafe neighbourhood were considered 'medium' on perceived neighbourhood safety; they sometimes felt unsafe. Respondents who agreed to three or four of the items indicative of an unsafe surrounding were considered 'low' on perceived neighbourhood safety; they often felt unsafe.

Demographics

Potential confounders included were gender, age, country of origin (the Netherlands, other country), and educational level ((1) no education or primary education; (2) lower professional and intermediate general education; (3) intermediate professional and higher general education; (4) higher professional education and university or missing). Educational level was included as an indicator for SES and has proven to be a good measure for SES in the Netherlands [37].

Statistical analyses

Overall, missing values of questionnaire items varied from <1% to 3% per item, with only intention having 7% missing values. Because complete case analyses would result in a loss of 25% of the respondents, missing values for the predictors were imputed using the Expectation Maximization method [38] from PASW version 18.0. All the variables described in the method (psychosocial cognitions, neighbourhood perceptions, demographics, and leisure-time walking) were used in the imputation model.

Weighted multilevel logistic regression (for participation in leisure-time walking) and linear regression (for total minutes walked in a usual week, within those who walked) models were used to explore the associations between the predictors and leisure-time walking of respondents (Level 1) nested within neighbourhoods (Level 2). Associations among all neighbourhood predictors and between the neighbourhood predictors and the psychosocial cognitions were at best modest (correlation coefficients <0.3). Associations between the psychosocial cognitions were as expected somewhat higher (correlation coefficients 0.1; 0.5). Although multicollinearity is not expected to be a problem because of these modest correlations, all continuous variables were mean centred to prevent multicollinearity in the interaction models and to ease interpretation. All models were weighted (Level 1 weight) to reflect the source population in terms of gender, age, and educational level. Model 1 contained all neighbourhood perceptions. Model 2 contained all psychosocial cognitions. Model 3 combined neighbourhood perceptions with psychosocial cognitions. Subsequently, interactions were explored whereby each neighbourhood-individual interaction term was added separately to Model 3 (Model 4a-p). Interactions in a logistic regression model are tested for their departure from multiplicativity (the combined 'effect' of the two factors is larger or smaller that the *product* of the individual 'effects'). Interactions in a linear regression model are tested for their departure from additivity (the combined 'effect' of the two factors is larger or smaller that the *sum* of the individual 'effects'). Because additive interactions are considered more intuitive and more relevant to public health [39], and to increase comparability of the results for the two outcomes, the Relative Risk due to Interaction (RERI), a measure to quantify interaction on an additive scale, was also calculated for all interactions departing from multiplicativity [40-41]. The RERI is a measure of interaction between two parameters with a value further away from zero indicating a stronger interaction. The tool created by Knol and coworkers [40-41] was used to calculate the RERI and the accompanying 95% confidence interval (CI).

All multivariable models were adjusted for age, gender, educational level, and country of origin. Significance was interpreted by using the 95%CI. All regression analyses were carried out in STATA 12 using GLLAMM [42] for the logistic regression analysis to study participation in leisure-time walking and using XTMIXED to study the amount of leisure-time walking within those who walked. Significant interactions have been visualized by simple slope analyses.

RESULTS

Table 5-1 shows the characteristics of the sample. Approximately one-third (32.7%) of the respondents reported no leisure-time walking at all. Those who did walk spent on average 212 minutes per week on leisure-time walking. Crude analyses as presented in Table 5-2 show that females, higher educated, and older respondents were more likely to participate in leisure-time walking. Among the walkers, minutes spent per week on leisure-time walking increased with age, but decreased with educational level.

Crude analyses also showed that a positive attitude (OR 1.67, 95%CI 1.42- 1.95), a strong self-efficacy (OR 1.20, 95%CI 1.11-1.29), a positive social influence (OR 1.39, 95%CI 1.22-1.57) and a strong intention towards physical activity (OR 1.37, 95%CI 1.27-1.47) were positively associated with participating in leisure-time walking (Table 5-2). Those with a larger social network in the neighbourhood (OR 1.16, 95%CI 1.08-1.24) were also more likely to walk in leisure time. A positive attitude (β 33.77, 95%CI 14.19-53.34), strong self-efficacy (β 39.12, 95%CI 29.05-49.20), and a positive intention towards physical activity (β 16.06, 95%CI 7.40-24.73) were also associated with more walking in those who walked during leisure time (Table 5-2). None of the neighbourhood perceptions were significantly associated with minutes walked.

Adjusted for potential demographic confounders and the other neighbourhood perceptions, individuals with a larger social network (OR 1.14, 95% CI 1.07-1.22) were more likely to engage in walking in leisure time (Model 1, Table 5-3). The association remained significant after additional adjustment for the psychosocial cognitions (Model 3, Table 5-3). Of the psychosocial cognitions, all but self-efficacy remained a significant predictor of leisure-time walking after adjusting for the potential demographic confounders and the other psychosocial cognitions (Model 2, Table 5-3). After additional adjustment for the neighbourhood perceptions, the associations between social influence and leisure-time walking were no longer significant (although there was only little change in the point estimate (Model 3, Table 5-3)), whereas attitude and intention remained significant.

Table 5-1: Characteristics of the GLOBE study respondents (n=4395).

Characteristics	N [a]	%[b]
Total sample	4395	100%
Leisure-time walking		
No	1438	32.7%
Yes	2957	67.3%
Minutes walking/week within those who walk (mean (SD))	2957	212 (200)
Gender		
Male	2054	46.7%
Female	2341	53.3%
Age		
25-34	672	15.3%
35-44	816	18.6%
45-54	780	17.8%
55-64	1117	25.4%
65-75	1010	23.0%
Education		
1 Low	398	9.1%
2	1432	32.6%
3	1033	23.5%
4 High	1297	29.5%
missing	235	5.4%
Country of origin		
Netherlands	3994	90.9%
Other	401	9.1%
Neighborhood factors [c]		
Perceived safety		
Safe	2734	62.2%
Medium safe	1311	29.8%
Unsafe	350	8.0%
Psychosocial cognitions (mean (SD))		
Attitude (1-5)		3.7 (0.6)
Self-efficacy (1-5)		3.8 (1.0)
Social influence (1-3)		2.3 (0.6)
Intention (1-5)		4.0 (1.1)

a. The numbers and percentages presented are unweighted and are therefore a representation of the actual numbers in the dataset.

b. Percentages are presented, unless otherwise stated.

c. Social neighbourhood factors ('social cohesion', 'social network', and 'feeling at home') were not included in this table because they were standardized factor scores (mean=0, standard deviation of 1). The mean and standard deviations for the individual items that were used to construct the factor scores can be found in the appendix (Table 5-A2).

Table 5-2: Crude associations between participating in leisure-time walking and minutes of walking among those who walk with all individual and neighbourhood predictors.

	Participation in recreation walking (n=4395)		**Minutes/week of walking – in walkers (n=2975)**	
	Crude[a]		**Crude[a]**	
Predictors	**OR**	**95% CI[b]**	**β**	**95% CI[b]**
Demographics				
Age (in years)	**1.01**	**1.00; 1.01 ****	**1.28**	**0.63; 1.94 *****
Female gender (male is ref.)	**1.35**	**1.18; 1.55 *****	7.33	-6.46; 21.11
Education				
1 Low	1.00			
2	1.29	0.97; 1.70	-0.20	-40.37; 39.96
3	**1.57**	**1.20; 2.04 ****	-22.60	-66.00; 20.80
4 High	**1.35**	**1.04; 1.75 ***	**-50.26**	**-90.65; -9.88 ***
missing	**1.58**	**1.05; 2.36 ***	-22.60	-78.26; 33.07
Non-Dutch origin (Dutch is ref.)	0.88	0.70; 1.12	-5.68	-29.60; 18.24
Neighborhood factors				
Perceived safety				
Safe	1.00			
Medium safe	1.18	0.99; 1.40	-0.97	-21.13; 19.20
Unsafe	1.13	0.86; 1.50	43.31	-0.23; 86.86
Social cohesion (factor score)	1.04	0.96; 1.13	-7.27	-17.07; 2.54
Social network (factor score)	**1.16**	**1.08; 1.24 *****	4.17	-5.18; 13.51
Feeling at home (factor score)	1.06	0.98; 1.14	-2.88	-12.49; 6.74
Psychosocial cognitions				
Attitude (1-5)	**1.67**	**1.42; 1.95 *****	**33.77**	**14.19; 53.34 *****
Self-efficacy (1-5)	**1.20**	**1.11; 1.29 *****	**39.12**	**29.05; 49.20 *****
Social influence (1-3)	**1.39**	**1.22; 1.57 *****	-4.94	-20.14; 10.27
Intention (1-5)	**1.37**	**1.27; 1.47 *****	**16.06**	**7.40; 24.73 *****

a. Bold figures indicate statistical significance (p<.05), * = p<.05, ** = p<.01, *** = p<.001

b. CI= Confidence Interval

In those who walked during leisure time, a strong self-efficacy was associated with longer total duration of walking during leisure time, also in the fully adjusted model (β 38.31, 95%CI 27.37-49.25) (Model 3, Table 5-4). In Model 3, there was also a significant inverse association between perceived social cohesion in the neighbourhood and minutes walked (β -11.69, 95%CI -21.00 to -2.38) (Model 3, Table 5-4).

Interactions

Additional inclusion of the interaction terms resulted in three significant interactions for participation in leisure-time walking in the regression models. The calculated RERIs basically followed the results of the multiplicative interactions. Safety interacted significantly with both attitude and social influence. The association between attitude and participation in leisure-time walking in people who sometimes felt unsafe was 1.59 times as high compared with those who never felt unsafe (95%CI 1.10-2.31) (as visualized in Figure 5-1). This pattern was not observed for those who often felt unsafe in their neighbourhood (OR 1.04, 95%CI 0.59-1.83).

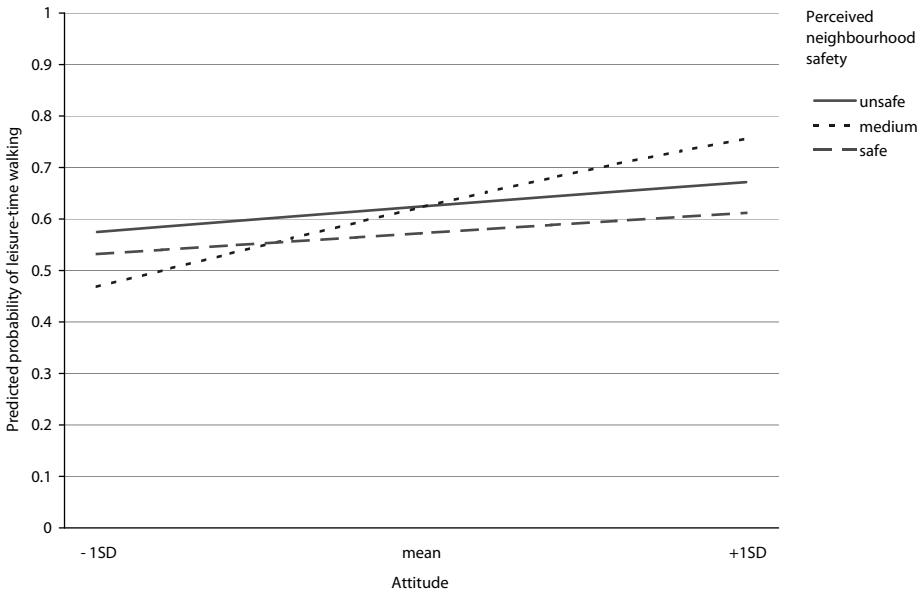

Figure 5-1: Interaction between perceived neighbourhood safety and attitude for leisure-time walking participation.

Table 5-3: Multilevel multivariable interaction models for participating in leisure-time walking (n=4395).

	Model 1[a, b, c]		Model 2[a, b, c]		Model 3[a, b, c]		Model 4a-p[a, b, c, d, e]			
Predictors	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**RERI**	**95% CI**
Neighbourhood factors										
Perceived safety (safe is ref.)										
medium safe	1.14	0.96; 1.36			1.19	0.99; 1.42	1.19	0.99; 1.42		
unsafe	1.22	0.92; 1.64			1.26	0.93; 1.71	1.26	0.93; 1.71		
Social cohesion	1.02	0.95; 1.11			0.99	0.92; 1.08	0.99	0.92; 1.08		
Social network	**1.14**	**1.07; 1.22** ***			**1.10**	**1.03; 1.18** *	**1.10**	**1.03; 1.18** *		
Feeling at home	1.05	0.98; 1.13			1.05	0.97; 1.13	1.05	0.97; 1.13		
Psychosocial cognitions										
Attitude (1-5) [d]			**1.27**	**1.05; 1.55** *	**1.27**	**1.05; 1.55** *	**1.27**	**1.05; 1.55** *		
Self-efficacy (1-5) [d]			1.00	0.91; 1.09	1.00	0.91; 1.10	1.00	0.91; 1.10		
Social influence (1-3) [d]			**1.20**	**1.06; 1.36** **	**1.19**	**1.04; 1.35** *	**1.19**	**1.04; 1.35** *		
Intention (1-5) [d]			**1.26**	**1.15; 1.37** ***	**1.25**	**1.15; 1.37** ***	**1.25**	**1.15; 1.37** ***		
Model 4 a-p: model 3+interaction										
4a. +safety*attitude (safe=ref)										
medium safe							**1.59**	**1.10; 2.31** *	**0.87**	**-0.11; 1.63** *
unsafe							1.04	0.59; 1.83	0.10	-0.74; 0.94
4b. +safety*self-efficacy (safe=ref)										
medium safe							1.11	0.92; 1.33	0.12	-0.13; 0.36
unsafe							1.17	0.84; 1.64	0.21	-0.28; 0.69
4c. + safety*social infl. (safe=ref)										
medium safe							**1.36**	**1.01; 1.84** *	0.51	-0.04; 1.06
unsafe							0.85	0.53; 1.35	-0.18	-0.73; 0.37
4d. + safety * intention (safe=ref)										
medium safe							1.09	0.91; 1.29	0.17	-0.10; 0.45
unsafe							0.94	0.69; 1.28	-0.03	-0.48; 0.41
4e. +cohesion*attitude							0.95	0.82; 1.09	-0.07	-0.24; 0.10
4f. +cohesion*self-efficacy							0.99	0.92; 1.07	-0.01	-0.08; 0.06

Table 5-3: Multilevel multivariable interaction models for participating in leisure-time walking (n=4395). *(continued)*

	Model 1[a, b, c]		Model 2[a, b, c]		Model 3[a, b, c]		Model 4a-p[a, b, c, d, e]			
Predictors	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**RERI**	**95% CI**
4g. +cohesion*social infl.							1.04	0.91; 1.20	0.05	-0.12; 0.22
4h. +cohesion*intention							1.02	0.95; 1.09	0.02	-0.07; 0.11
4i. +network*attitude							1.08	0.95; 1.23	0.14	-0.06; 0.35
4j. +network*self-efficacy							0.99	0.92; 1.06	-0.01	-0.09; 0.06
4k. +network*social infl.							1.04	0.92; 1.18	0.07	-0.10; 0.25
4l. +network*intention							1.04	0.97; 1.12	0.08	-0.03; 0.19
4m. +feel home*attitude							**0.87**	**0.75; 1.00 ***	**-0.17**	**-0.33; -0.00 ***
4n. +feel home*self-efficacy							1.03	0.95; 1.13	0.03	-0.06; 0.13
4o. +feel home*social infl.							0.91	0.80; 1.03	-0.10	-0.24; 0.04
4p. +feel home*intention							0.96	0.89; 1.03	-0.04	-0.13; 0.05

a. All models were adjusted for age, gender, educational class, and country of origin.

b. Bold figures indicate statistical significance (p<.05), * = p<.05, ** = p<.01, *** = p<.001

c. OR = Odds Ratio, CI = Confidence Interval, RERI = Relative Excess Risk due to Interaction

d. Most of the ORs for the predictors already in model 3 (in grey) can vary slightly with each version of model 4. However, these changes are only minimal. Only in the interaction models with perceived neighbourhood safety (4a-d), the ORs for the cognition in the interaction term will be notably different than those represented here (in grey). When an interaction term is added to the model, the ORs for the cognition involved will change to the OR for that cognition in the reference situation (people who perceive their neighbourhood as safe).

e. The parameters of the interaction terms should be interpreted as multiplicative factors.

Table 5-4: Multilevel multivariable interaction models for minutes/week of recreational walking among those who reported to walk (n=2957).

	Model 1[a, b, c]		Model 2[a, b, c]		Model 3[a, b, c]		Model 4a-p[a, b, c,]	
Predictors	**β**	**95% CI**	**β**	**95% CI**	**β**	**95% CI**	**β**	**95% CI**
Neighbourhood factors								
Perceived safety (safe is ref.)								
medium safe	-9.99	-32.77; 12.79			3.07	-25.55; 19.41	3.07	-25.55; 19.41
unsafe	20.24	-26.10; 66.57			27.24	-17.86; 72.34	27.24	-17.86; 72.34
Social cohesion	-8.76	-18.29; 0.77			**-11.69**	**-21.00; -2.38** *	**-11.69**	**-21.00; -2.38** *
Social network	2.53	-6.65; 11.70			2.20	-7.22; 11.62	2.20	-7.22; 11.62
Feeling at home	-4.03	-13.93; 5.86			-8.07	-17.91; 1.76	-8.07	-17.91; 1.76
Psychosocial cognitions								
Attitude (1-5) [d]			2.36	-20.06; 24.78	4.87	-17.31; 27.05	4.87	-17.31; 27.05
Self-efficacy (1-5) [d]			**36.20**	**25.26; 47.14** ***	**38.31**	**27.37; 49.25** ***	**38.31**	**27.37; 49.25** ***
Social influence (1-3) [d]			-14.91	-29.94; 0.12	-15.08	-30.27; 0.11	-15.08	-30.27; 0.11
Intention (1-5) [d]			5.30	-5.06; 15.68	4.44	-5.97; 14.85	4.44	-5.97; 14.85
Model 4 a-p: model 3+interaction								
4a. +safety*attitude (safe=ref)								
medium safe							-20.77	-55.74; 14.20
unsafe							6.36	-73.44; 86.15
4b. +safety*self-efficacy (safe=ref)								
medium safe							-14.56	-39.16; 10.03
unsafe							-8.71	-52.06; 34.64
4c. + safety*social infl. (safe=ref)								
medium safe							15.61	-21.28; 52.50
unsafe							11.86	-38.98; 62.69
4d. + safety * intention (safe=ref)								
medium safe							-1.71	-25.95; 22.54
unsafe							**31.92**	**7.98; 55.86** **
4e. +cohesion*attitude							-4.05	-23.69; 15.60
4f. +cohesion*self-efficacy							3.26	-7.57; 14.09

Table 5-4: Multilevel multivariable interaction models for minutes/week of recreational walking among those who reported to walk (n=2957). (Continued)

	Model 1[a, b, c]		Model 2[a, b, c]		Model 3[a, b, c]		Model 4a-p[a, b, c, d, e]	
Predictors	**β**	**95% CI**	**β**	**95% CI**	**β**	**95% CI**	**β**	**95% CI**
4g. +cohesion*social infl.							2.77	-14.17; 19.72
4h. +cohesion*intention							1.67	-8.02; 11.36
4i. +network*attitude							7.36	-9.61; 24.33
4j. +network*self-efficacy							-1.30	-11.28; 8.68
4k. +network*social infl.							12.54	-1.87; 26.94
4l. +network*intention							5.57	-4.01; 15.14
4m. +feel home*attitude							2.57	-17.06; 22.19
4n. +feel home*self-efficacy							3.55	-6.74; 13.85
4o. +feel home*social infl.							10.43	-7.93; 28.79
4p. +feel home*intention							-6.41	-15.43; 2.61

a. All models were adjusted for age, gender, educational class, and country of origin.

b. Bold figures indicate statistical significance (p<.05), * = p<.05, ** = p<.01, *** = p<.001

c. CI = Confidence Interval

d. Most of the betas for the predictors already in model 3 (in grey) can vary slightly with each version of model 4. However, these changes are only minimal. Only in the interaction models with perceived neighbourhood safety (4a-d), the betas for the cognition in the interaction term will be notably different than those represented here (in grey). When an interaction term is added to the model, the betas for the cognition involved will change to the betas for that cognition in the reference situation (people who perceive their neighbourhood as safe).

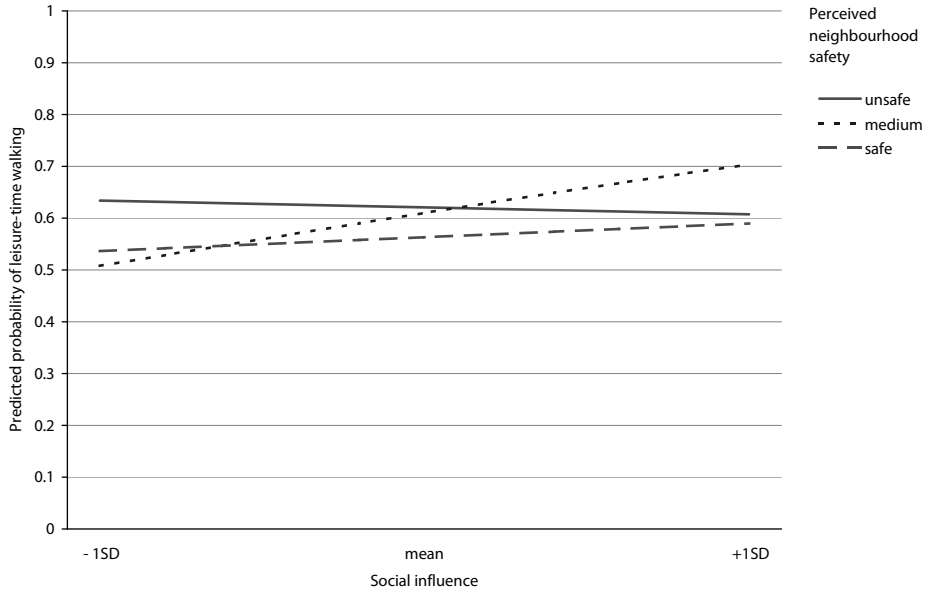

Figure 5-2: Interaction between perceived neighbourhood safety and social influence for leisure-time walking participation.

The interaction between social influence and safety was similar in such a way that the association between social influence and participation in leisure-time walking was 1.36 as high in those who felt sometimes unsafe compared with those who never felt unsafe in their neighbourhood (as visualized in Figure 5-2). This pattern was not observed for those who often felt unsafe (OR 0.85, 95%CI 0.53-1.35). The third interaction was between feeling at home in your neighbourhood and attitude (OR 0.87, 95%CI 0.75-1.00); among those feeling more at home, attitude had a weaker association with participation in leisure-time walking, than among those feeling less at home in their neighbourhood (visualized in Figure 5-3).

Among those who walked during leisure time, one significant interaction was observed for total minutes walked per week. In those who felt unsafe, a positive intention was associated with over 30 minutes more walking during leisure time compared with those who did not feel unsafe and had a positive intention towards physical activity. This interaction has been visualized in Figure 5-4.

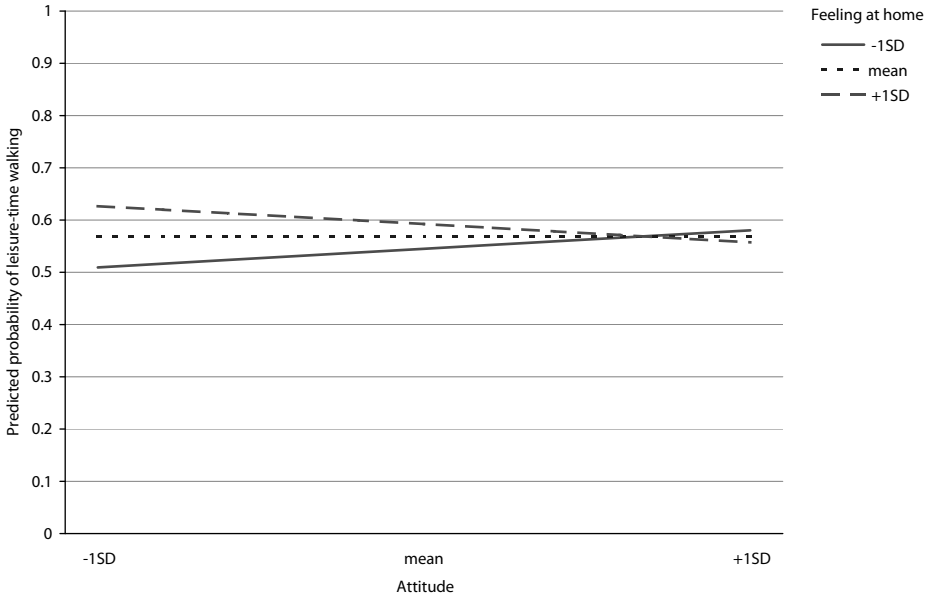

Figure 5-3: Interaction between feeling at home and attitude for leisure-time walking participation.

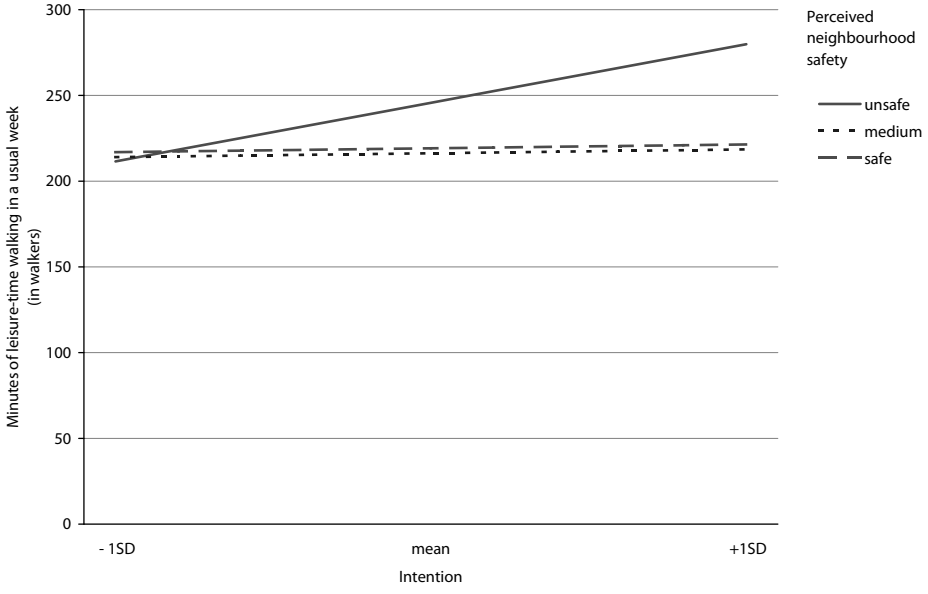

Figure 5-4: Interaction between perceived neighbourhood safety and intention for minutes walked during leisure-time.

DISCUSSION

This study is among the first to evaluate interactions between elements of the social environmental and safety in neighbourhoods and psychosocial cognitions towards leisure-time walking. Several interactions were found but no clear pattern could be detected.

Our finding of an association between attitudes, self-efficacy, social influence, intention and leisure-time walking is in line with both theory and previous empirical research [5-6]. Interestingly, a positive social influence was associated with participating in leisure-time walking but not with minutes walked. Also, our finding that a large social network was positively related to participating in leisure-time walking has been found in previous studies [24-27]. The negative association between neighbourhood social cohesion and minutes walked among the walkers was unexpectedly and without a plausible explanation.

This study extends on previous research by exploring environment-individual interactions. Three interactions were found with perceived neighbourhood safety. For participation in leisure-time walking, perceived neighbourhood safety interacted with attitude and social influence: in those who sometimes felt unsafe, a positive attitude and a positive social influence were significantly stronger associated with any leisure-time walking. This pattern was not observed for those who often felt unsafe. This finding was different from findings by Rhodes et al. [23] who found that low levels of perceived crime resulted in a larger influence of attitude on the intention to walk compared with people who perceived high levels of crime. For our second outcome, minutes walked among those persons who engaged in leisure-time walking, also an interaction with safety was found: those who perceived feelings of unsafety but had a positive intention to walk in leisure time walked ~30 minutes per week more than persons who felt safe in their neighbourhood and persons who lacked intention to walk. Although these unexpected interactions with safety are hard to interpret, a possible explanation may be found in the association between safety and walking itself. Although we were primarily interested in the influence of neighbourhood safety on leisure-time walking, the cross-sectional nature of this study cannot preclude the direction of association. Therefore, it is possible that those who walk in their neighbourhood are more likely to report feelings of unsafety because they are more exposed to their neighbourhood. This inverse association between neighbourhood safety and physical activity has been observed before [43-44].

The final interaction observed was between feeling at home and attitude, whereby feeling at home in your neighbourhood was stronger associated with engaging in leisure-time walking in those with a below average attitude. This interaction could indicate the existence of the first mechanism proposed in the Introduction: those who have negative psychosocial cognitions benefit more from a positive neighbourhood environment than those with more

positive psychosocial cognitions towards physical activity. Or, stated the other way around, not feeling at home in your neighbourhood may not be a barrier for walking among those with a positive attitude towards physical activity, as this positive attitude makes them more likely to be active anyway.

Overall, we found limited empirical support for interactions, and neither of the proposed mechanisms was clearly favoured in our results although the interaction between feeling at home and attitude hints at the first mechanism in which those with negative psychosocial cognitions benefit most from a positive neighbourhood environment. The recent study by Carlson et al. also found a limited number of interactions [21]. In their article, they studied the interactions between walkability, parks and recreation facilities, aesthetics, and walking facilities within the neighbourhood with social support, self-efficacy, and perceived barriers on leisure-time walking. They found one significant interaction between walking facilities and self-efficacy in which self-efficacy was only associated with leisure-time walking in neighbourhoods with few walking facilities. This interaction also supports the first proposed mechanism in which positive psychosocial cognitions can help to overcome neighbourhood barriers. Although methodological reasons, including lack of statistical power and measurement error in environmental and (to a lesser extent) individual factors may have contributed to this finding, it is also possible that walking behaviour mainly is a result of a combination of environmental and individual factors, in which only few interactions are involved which have little implications for public health practice. However, the strong theoretical support for environment-individual interactions in ecological models prompts for more research that indentifies and quantifies these interactions.

Study limitations and strengths

Several limitations need to be considered in the interpretation of the findings of this study. First, the cross-sectional design restricts interpretation on causality and direction of the associations. This is particularly relevant because of the increasing recognition of a dynamic interrelation in which individuals change places and places change people [45]. Second, our psychosocial cognitions were measured with regard to 'sufficient physical activity in line with recommended levels' where it would have better preferred to ask this specifically for leisure-time walking. This may have resulted in an underestimation of associations with leisure-time walking. Third, self-reported physical activity data are known for overestimations. In addition, the SQUASH questionnaire was validated for total physical activity but not for the underlying specific activities such as leisure-time walking. Because this study used a robust dichotomous measure it is expected to be of little influence although we can not exclude some bias in the associations. Finally, the results of this study should be interpreted in the context of a medium-sized city in the Netherlands. The situation in Dutch urban areas may not be representative for other urban areas in the world.

CONCLUSION

This study explored interactions between neighbourhood factors and psychosocial cognitions for explaining leisure-time walking in adults and found limited evidence for these interactions. The relationship between neighbourhood and individual determinants of walking and environment-individual interactions remains complex and more studies are needed that incorporate these interactions to strengthen these results.

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APPENDIX

Table 5-A1: Measurement of individual cognitions in the GLOBE postal survey 2004.

Variable	Item	Response categories
Attitude	Negative outcome expectancy of physical activity: It requires too much time	(1)Very important – – – (5)Not important at all
	Negative outcome expectancy of physical activity: It requires too much discipline	(1)Very important – – – (5)Not important at all
	Negative outcome expectancy of physical activity: It requires too much energy	(1)Very important – – – (5)Not important at all
	Negative outcome expectancy of physical activity: I am afraid to get injured	(1)Very important – – – (5)Not important at all
	Negative outcome expectancy of physical activity: I feel uncomfortable when exercising	(1)Very important – – – (5)Not important at all
	Positive outcome expectancy of physical activity: It makes me feel less stressed	(1)Not important at all – – – (5)Very important
	Positive outcome expectancy of physical activity: It gets me into a good mood	(1)Not important at all – – – (5)Very important
	Positive outcome expectancy of physical activity: I like being active	(1)Not important at all – – – (5)Very important
	Positive outcome expectancy of physical activity: I am more confident with my body	(1)Not important at all – – – (5)Very important
	Positive outcome expectancy of physical activity: It is good for fitness/condition	(1)Not important at all – – – (5)Very important
	Positive outcome expectancy of physical activity: I feel energized	(1)Not important at all – – – (5)Very important
Social influence	Most people who are important to me think I should be sufficiently physically active [a]	(1)No, not true – (3)Yes, true
	Most people who are important to me stimulate me to be sufficiently physically active	(1)No, not true – (3)Yes, true
	Most people who are important to me are sufficiently physically active	(1)No, not true – (3)Yes, true
Self-efficacy	Do you think it is easy or difficult to be sufficiently physically active?	(1)Very difficult – – – (5)Very easy
	How sure are you that you can be sufficiently physically active?	(1)Not sure at all – – – (5)Very sure
Intention	Do you plan to be sufficiently physically active?	(1)No, for sure not – – – (5)Yes, for sure

[a] Sufficient physical activity was defined in the questionnaire as being active for at least half an hour a day (e.g. gardening, sports participation, bicycling)

Table 5-A2: Measurement of social neighbourhood in the Dutch GLOBE postal survey 2004 and rotated factor loadings.

		Factor loadings [b]		
Items [a]	**Mean (SD)**	**Social cohesion**	**Social network**	**Feeling at home**
Most people in this neighbourhood can be trusted	3.85 (0.83)	**0.7976**	0.0614	0.1944
Most people in this neighbourhood get on with each other pleasantly	3.75 (0.82)	**0.7966**	0.2059	0.2427
Most people in this neighbourhood are willing to help each other	3.76 (0.80)	**0.7556**	0.3128	0.1747
People in this neighbourhood have the same norms and values	3.47 (1.01)	**0.6466**	0.1339	0.2542
My neighbours help each other in case of emergency	4.04 (0.84)	**0.5696**	0.4620	0.0794
I often visit my neighbours in their home	2.56 (1.17)	0.0796	**0.8111**	0.1171
My neighbours visit me on my birthday	2.66 (1.41)	0.0756	**0.8026**	0.1292
I borrow things from my neighbours	3.15 (1.22)	0.3196	**0.6700**	0.0545
I can always ask my neighbours if I need advice	3.48 (1.08)	**0.5284**	**0.6172**	0.0629
I move out of this neighbourhood if I get the chance [c]	4.03 (1.14)	0.2282	0.0598	**0.7680**
I often feel alone in this neighbourhood [c]	4.04 (0.95)	0.0641	0.1541	**0.7416**
I feel at home in this neighbourhood	4.06 (0.85)	0.4388	0.0818	**0.6725**
People in this neighbourhood hardly know each other [c]	3.27 (1.09)	0.2302	0.4523	0.3963

[a] Answering categories ranged from (1) Totally disagree to (5) Totally agree.

[b] Bold factor loadings are the ones above .5 to indicate the most important items within the factors.

[c] Recoded so 5 means 'Totally disagree'.

6

Urban form characteristics and psychosocial cognitions: do they interact for leisure-time walking?

Mariëlle A. Beenackers
Carlijn B.M. Kamphuis
Richard G. Prins
Johan P. Mackenbach
Alex Burdorf
Frank J. van Lenthe

Submitted

7

Taking up cycling after residential relocation: built environment factors

Mariëlle A. Beenackers
Sarah Foster
Carlijn B.M. Kamphuis
Sylvia Titze
Mark Divitini
Matthew Knuiman
Frank J. van Lenthe
Billie Giles-Corti

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ABSTRACT

Background: To successfully stimulate cycling, it is necessary to understand the factors that facilitate or inhibit cycling. Little is known about how changes in the neighbourhood environment are related to changes in cycling behaviour.

Purpose: This study aimed to identify environmental determinants of the uptake of cycling after relocation.

Methods: The RESIDential Environment Project (RESIDE) is a longitudinal natural experiment of people moving into new housing developments in Perth (Western Australia). Self-reported usual transport and recreational cycling behaviour, as well as self-reported and objective built environmental factors were measured before and after residential relocation. Participants who did not usually cycle at baseline in 2003–2004 were included in the study. Logistic regression models were used to relate changes in built environmental determinants to the probability of taking up cycling after relocation (2005–2006). Analyses were carried out in 2010–2011.

Results: At baseline, 90% (n = 1,289) of the participants did not cycle for transport and 86% (n = 1,232) did not cycle for recreation. After relocation, 5% of the non-cyclists took up transport-related cycling, and 7% took up recreational cycling. After full adjustment, the uptake of transport-related cycling was determined by an increase in objective residential density (OR 1.54, 95%CI 1.04-2.26) and self-reported better access to parks (OR 2.60, 95%CI 1.58-4.27) and other recreation destinations (OR 1.57, 95%CI 1.12-2.22). Commencing recreational cycling mostly was determined by an increase in objective street connectivity (OR 1.20, 95%CI 1.06-1.35).

Conclusions: Changes in the built environment may support the uptake of cycling among formerly non-cycling adults.

INTRODUCTION

Cycling is a moderate-to-vigorous intensity form of physical activity, [1-3] and therefore a good way to achieve recommended levels of physical activity [4-6]. Apart from the health effects of cycling for recreation and transport [7], cycling for transport has beneficial effects including reductions in air pollution, CO_2 gas emissions, and traffic congestion [8-9, 5, 10]. To successfully stimulate cycling within a population, it is necessary to understand the factors that facilitate or inhibit cycling.

In the past decade, many studies related environmental factors to physical activity in general and to walking specifically [11-13]. Studies on the association between the environment and cycling behaviour are less common and mostly cross-sectional [14-19]. Important limitations of cross-sectional studies are that environments may change in response to residents' preferences and that residents may choose to live in locations consistent with their preferred lifestyles.

Natural experiments of changes to the built environment that take personal preferences towards cycling into account could help determine how environmental changes are related to behavioural change. RESIDE is a longitudinal study of people moving into new neighbourhoods in metropolitan Perth, Western Australia. The aim of this natural experiment was to identify how changes in objective and perceived environmental characteristics determine the uptake of cycling among formerly non cycling adults, independent of previous preferences towards cycling.

METHODS

Study Design

The RESIDE study is a quasi-experimental longitudinal study of people moving into 74 new housing developments in Perth, Western Australia (details are described elsewhere) [20]. Data about self-reported cycling, individual factors, and self-reported and objective environment factors were collected before people moved to their new neighbourhoods (T1: 2003–2004) and after relocation (T2: 2005–2006). The total longitudinal study sample consisted of 1,427 participants. All participants in the study provided written consent and the study protocol was approved by the Human Research Ethics Committee at the University of Western Australia.

Variables

Cycling

Cycling was measured using the Neighbourhood Physical Activity Questionnaire (NPAQ) [21]. Total minutes of cycling for transport and cycling for recreation were calculated. Because this study focuses on the uptake of cycling, only people who did not cycle at T1 were included in the analyses. Cycling at T2 was dichotomized into "yes," participant does cycle for transport/recreation at least once within a usual week, and "no," participant does not cycle for transport/recreation within a usual week.

Neighbourhood environment

The perceived neighbourhood variables examined in this study were based on the Neighbourhood Environment Walkability Scale (NEWS) [22-24]. Objective neighbourhood variables were constructed using GIS. For all study participants, a 1,600-m network service area buffer was mapped around the residential address. Within this buffer, measures for connectivity, residential density, land-use mix, and number of destinations relevant for transport or recreation were calculated [25-26]. Connectivity, residential density, and land-use mix measures at T1 and T2 were converted to z-scores using the mean and SD at T1.

Changes in perceived and objective neighbourhood variables were calculated by subtracting the T1 value from the value at T2. Details about the measurement and data sources for the neighbourhood environment variables can be found in the appendix (Table 7-A1).

Intrapersonal and interpersonal factors

These factors, measured at T1, were derived from the Theory of Planned Behaviour [27] and the Social Cognitive Theory [28] and formulated specifically for application to cycling. Details about these measures can be found in the appendix (Table 7-A1).

Statistical Analyses

Statistical analyses were conducted in 2010–2011 in SAS, version 9.2. Logistic regression models (with generalized estimating equations) were used to estimate the ORs for taking up cycling while accounting for clustering within neighbourhoods (PROC GENMOD, repeated). All models were adjusted for the covariates age, gender, educational level, marital status, children aged 18 years living at home, and whether a participant has access to a car (all measured at T1). No changes in the covariates between T1 and T2 were related to changes in cycling behaviour.

Changes in each of the objective and self-reported neighbourhood factors were related to the uptake of recreational and transport-related cycling in separate logistic regression

models, adjusted for the covariates and the baseline value of the neighbourhood factor (see Appendix, Table 7-A2). Tests of multi-collinearity statistics between the neighbourhood factors were non-significant (results not shown). All neighbourhood factors that were associated with taking up cycling ($p<0.20$) were then included in multivariable models. In the first multivariable model, all objective neighbourhood factors were included; in Model 2, all perceived neighbourhood factors were added; and Model 3 additionally was adjusted for the baseline values of the intrapersonal and interpersonal factors to control for the possibility that changes in cycling behaviour were caused by prior differences in individual cognitions towards cycling rather than neighbourhood changes.

Table 7-1: Baseline characteristics of non-cycling study participants, and their cycling behaviour at follow-up (T2).

Characteristic	Not cycling for transport at baseline (n=1289)	Not cycling for recreation at baseline (n=1232)
Age *(Mean (SD))*	40.69 (11.69)	40.50 (11.66)
Gender		
Male	37.78%	37.42%
Female	62.22%	62.58%
Education		
Secondary or less	40.50%	40.18%
Trade/apprentice/certificate	36.07%	35.88%
Bachelor or higher	23.43%	23.94%
Marital status		
Married / defacto	83.24%	83.36%
Separated / divorced / widowed	7.99%	8.04%
Single	8.77%	8.60%
Car availability		
Always	93.56%	93.59%
Other	6.44%	6.41%
Children under 18 living at household		
Yes	70.13%	70.29%
No	27.46%	27.44%
No response	2.40%	2.27%
Started cycling for transport at T2	4.89% (n=63)	-
Started cycling for recreation at T2	-	7.31% (n=90)

RESULTS

Table 7-1 shows the baseline characteristics of respondents who usually did not cycle at baseline and the percentage of non-cyclists who reported cycling at follow- up. Multivariable regression analyses on the uptake of transport-related cycling (Table 7-2) showed that greater objective residential density, increased access to a park, and more recreation-related destinations were positively associated with an increase in transport-related cycling after relocation in the fully adjusted model. A decrease in objective connectivity, increased access to services, and more pedestrian crossings were marginally associated (p<0.10) with the uptake of transport-related cycling. Higher baseline self-efficacy and more social support regarding cycling also were associated with cycling at follow-up. Multivariable regression analyses on

Table 7-2: Multivariable logistic regression models for taking up cycling for transport. [a]

Independent variable	Model 1: Objective environment [b, d]		Model 2: Model 1 + perceptions [b, d]		Model 3: Model 2 + baseline intrapersonal and interpersonal factors [b, d]	
	OR (95% CI) [c]	p	OR (95% CI) [c]	p	OR (95% CI) [c]	p
Objective environment						
Δ Connectivity	0.99 (0.88; 1.12)	.87	0.90 (0.80; 1.01)	.08	0.88 (0.77; 1.01)	0.06
Δ Residential density	**1.51 (1.12; 2.02)**	**<.01**	1.36 (0.93; 1.98)	.11	**1.54 (1.04; 2.26)**	**0.03**
Neighbourhood perceptions						
Δ Access to mixed services – scale			**1.52 (1.08; 2.14)**	**.02**	1.42 (0.96; 2.11)	0.08
Δ Neighbourhood aesthetics – scale			0.82 (0.52; 1.31)	.41	0.86 (0.53; 1.41)	0.55
Δ Traffic hazards – scale			0.85 (0.49; 1.46)	.55	0.98 (0.54; 1.77)	0.94
Δ Major barriers present			0.96 (0.65; 1.41)	.84	0.98 (0.66; 1.46)	0.93
Δ Parking local services difficult			0.99 (0.74; 1.31)	.92	0.96 (0.72; 1.28)	0.78
Δ Access to park			**2.28 (1.49; 3.50)**	**<.001**	**2.60 (1.58; 4.27)**	**<.001**
Δ Access to cycling paths			1.08 (0.82; 1.42)	.59	1.07 (0.81; 1.41)	.62
Δ Pedestrian crossings present			**1.37 (1.02; 1.83)**	**.04**	1.33 (0.97; 1.81)	.07
Δ Number of transport destinations			0.95 (0.89; 1.02)	.16	0.96 (0.89; 1.04)	.29
Δ Number of recreation destinations			**1.53 (1.07; 2.20)**	**.02**	**1.57 (1.12; 2.22)**	**<.01**
Intrapersonal and interpersonal factors (baseline)						
Attitude					1.07 (0.99; 1.17)	0.10
Self-efficacy					**1.07 (1.03; 1.12)**	**<.01**
Social influence					**1.15 (1.07 1.23)**	**<.001**
Intention					0.99 (0.81; 1.22)	0.92

a. Outcome is cycling for transport at T2. The sample consists of people who did not cycle for transport at T1.

b. All the models are adjusted for age, gender, educational level, marital status, children under 18 living at home, and whether a participant has access to a car. All measured at T1. The models were also adjusted for the baseline variable of the neighbourhood measures included in the model and change in access to a car.

c. OR=odds ratio, CI=confidence interval.

d. Bold results are significant at p<.05.

Table 7-3: Multivariable logistic regression models for taking up cycling for recreation. [a]

Independent variable	Model 1: Objective environment [b, d]		Model 2: Model 1 + perceptions [b, d]		Model 3: Model 2 + baseline intrapersonal and interpersonal factors [b, d]	
	OR (95% CI) [c]	p	OR (95% CI) [c]	p	OR (95% CI) [c]	p
Objective environment						
Δ Connectivity	**1.14 (1.05; 1.25)**	**<.01**	**1.16 (1.03; 1.30)**	**.01**	**1.20 (1.06; 1.35)**	**<.01**
Δ Residential density	1.05 (0.73; 1.53)	0.79	0.97 (0.62; 1.53)	.90	0.86 (0.49; 1.48)	.58
Δ Transport destinations	0.94 (0.85; 1.03)	0.19	0.95 (0.86; 1.04)	.27	0.95 (0.87; 1.05)	.34
Neighbourhood perceptions						
Δ Neighbourhood aesthetics – scale			1.18 (0.76; 1.84)	.45	1.06 (0.69; 1.62)	.79
Δ Crime hazards – scale			1.02 (0.71; 1.46)	.93	0.95 (0.64; 1.42)	.80
Δ Hilly streets			0.76 (0.55; 1.05)	.09	0.79 (0.58; 1.06)	.11
Δ Major barriers present			0.97 (0.77; 1.24)	.83	0.97 (0.77; 1.23)	.82
Δ Access to park			1.16 (0.84; 1.61)	.37	1.14 (0.82; 1.59)	.45
Δ Access to cycling paths			1.02 (0.77; 1.35)	.89	1.03 (0.79; 1.34)	.83
Δ Many alternative routes			1.06 (0.82; 1.38)	.66	1.08 (0.83; 1.40)	.56
Δ Number of recreation destinations			1.10 (0.87; 1.39)	.42	1.12 (0.88; 1.41)	.35
Intrapersonal and interpersonal (baseline)						
Attitude					1.05 (1.00; 1.11)	.07
Self-efficacy					1.02 (0.99; 1.05)	.14
Social influence					**1.11 (1.04; 1.18)**	**<.001**
Intention					**1.17 (1.01; 1.35)**	**.03**

a. Outcome is cycling for recreation at T2. The sample consists of people who did not cycle for recreation at T1.

b. All the models are adjusted for age, gender, educational level, marital status, children under 18 living at home, and whether a participant has access to a car. All measured at T1. The models were also adjusted for the baseline variable of the neighbourhood measures included in the model.

c. OR=odds ratio, CI=confidence interval.

d. Bold results are significant at p<.05.

the uptake of recreational cycling (Table 7-3) showed that an increase in objective connectivity was associated with the uptake of recreational cycling in the fully adjusted model, along with higher baseline social support and intention regarding cycling.

DISCUSSION

Predictors of transport-related cycling and recreational cycling differed. The determinants of transport-related cycling were mostly functional: In areas with a high residential density and easy access to proximate facilities, residents were more likely to travel by bike. This is likely due to shorter distances between home and potential destinations. For recreational

cycling, on the other hand, the neighbourhood's physical layout appeared to be important, as indicated by determinants such as street connectivity. Also, the results from the multiple logistic regressions (Appendix, Table 7-A2) indicate that perceived neighbourhood aesthetics, the absence of barriers for cycling such as hills, and the availability of cycling paths and parks, encouraged residents to cycle for recreation. The finding that determinants of transport- versus recreation-related cycling differ, confirms that these two behaviours should be studied separately, as the motives for differing types of cycling are likely to be different and may require different interventions to increase cycling behaviour [29-30].

Strengths and Limitations

This natural experiment demonstrated that changes in both objective and self-reported neighbourhood characteristics are associated with transport-related and recreational cycling, and strengthens previous cross-sectional findings [31, 17]. To our knowledge, this is the first natural experiment to show such findings. The major strength of this study is its longitudinal quasi-experimental design, which makes it possible to study the effects of neighbourhood design on cycling, while taking into account individual cognitions towards cycling before relocation.

Several study limitations also need to be considered when interpreting these results. First, measures of cycling were self-reported and may therefore be biased. However, because a dichotomous variable was used, it is expected to be less of a problem. Second, Perth is a low-density city, and very few people cycle, which restricted the analyses. However, taking up cycling is the first step towards developing a healthy lifestyle that incorporates cycling. Especially in countries lacking a strong cycling culture, such as Australia and the U.S., it might be more important to help people initiate cycling rather than to focus on the amount of cycling required per week.

Third, this study used environmental measures based on the NEWS, the Neighbourhood Environment Walkability Scale [24], which focuses on environmental characteristics relevant to walking. Although there have been some recent improvements to the NEWS because of the inclusion of more cycling-specific measures [32], it would be beneficial to even further develop this tool so it fully assesses both the walking and cycling environments, ideally with differentiation between transport and recreational behaviours. Also, because larger distances can be covered by cycling, a larger service area buffer could be relevant (e.g., 3.0 km) although variation in the number of destinations within reach may decline sharply when such a large area is considered.

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APPENDIX

Table 7-A1: Measurement details of the neighbourhood factors and of the intrapersonal and interpersonal factors.

Variable		
Objective neighbourhood environment	**Variable construction**	**Data source**
Connectivity	Connectivity was calculated by taking the ratio of the count of three-way or more-way intersections to the 1600-m network service area.[1] *Z*-scores based on the M and SD of T1 were calculated.	Road network
Residential density	Residential density represents the number of residential dwellings within the census count area divided by the area in residential use within that area.[1] *Z*-scores based on the M and SD of T1 were calculated.	The number of residential dwellings was obtained from the Austral an Bureau of Statistics. The area in residential use was calculated using information on properties in residential use by the Department of Planning/Western Australian Land Information Authority and land parcel cadastre information
Land-use mix	The measure land-use mix (LUM) represents the heterogeneity or homogeneity of the land uses within the participant's 1600-m network service area and was calculated according to the method of Frank et al.[1,2]: $LUM = -\sum_{i=1}^{n} (p_i^* \ln p_i) / \ln n, \quad (1)$ in which p_i is the proportion of estimated building square footage attributed to land use *i*, and *n* is the number of land uses. The area of land uses assessed for each participant in the RESIDE study includes the following: Shop/retail Other retail Office/business Health/welfare and community services Entertainment/recreation and cultural These classes are derived from the Department of Planning's Planning Land Use Categories (PLUCs) and are meant to represent destinations that are attractive to walk/cycle to. *Z*-scores based on the M and SD of T1 were calculated.	The distribution of land uses (cadastral polygons of land parcels) was based on classifications from two data sources: Valuer General's Office (VGO) taxation/rating records with classification of features; and reserve use and vesting reports maintained by Landgate.
# of transport destinations	The number of destinations relevant for transport-related cycling was calculated by counting the different transport destinations present within the 1600-m network service area, namely supermarkets, hardware stores, green grocers, laundromats/dry cleaners, post offices, bookstores, cafés/restaurants, video stores, gas stations, CD/DVD stores, delis, general stores, markets, libraries, pharmacies, bus stops, and train stations (0–17).	Commercial destinations: Sensis data (Yellow Pages) Transit destinations: Department of Planning/Perth Transport Authority
# of recreation destinations	The number of destinations relevant for recreational cycling was calculated by counting the recreational destinations present within the 1600-m network service area, namely parks, beach access points, fitness and recreational centres, and sports fields (0–4).	Parks: extensive field survey (>2 acres) Beach access points: aerial photography Recreational centers and sports fields: Sensis data (Yellow Pages)

Table 7-A1: Measurement details of the neighbourhood factors and of the intrapersonal and interpersonal factors. *(continued)*

Variable		
Neighbourhood perceptions[3,4]	**Questions**	**Answer categories[a] and scale information[5]**
Access to mixed services	I can do most of my shopping in my local area. There are many shops within easy walking distance of my home. There are many places to go within easy walking distance of my home. It is easy to walk to a public transport stop (bus, train) from my home.	Scale: M score T1: α=0.745 T2: α=0.734
Neighbourhood aesthetics	There is lots of greenery around my local area (trees, bushes, household gardens). There are many interesting things to look at while walking in my local area. There are attractive buildings and homes in my local area. There are pleasant natural features in my local area (for example, nature reserves, beach, lakes).	Scale: M score T1: α=0.769 T2: α=0.705
Traffic hazards	There is so much traffic along most nearby streets that it makes it difficult or unpleasant to walk in my local area. I live on or near a main arterial road or busy throughway for motor vehicles. When walking in my local area there are a lot of exhaust fumes (such as from cars, buses).	Scale: M score T1: α=0.606 T2: α=0.539
Crime hazards	There is a lot of petty crime in my local area (such as vandalism, shoplifting). There is a lot of major crime in my local area (such as armed robberies, break-ins, attacks). The level of crime in my local area makes it unsafe to go on walks during the day. The level of crime in my local area makes it unsafe to go on walks at night.	Scale: M score T1: α=0.819 T2: α=0.822
Hilly streets	The streets in my local area are hilly, making it difficult to walk in.	
Major barriers present	There are major barriers to walking in my local area that make it hard to get from place to place (for example, freeways, major roads).	
Local parking difficult	Car parking is difficult in local shopping areas.	
Access to park	There is a park or nature reserve in my local area that is easily accessible.	
Access to cycling paths	There are bicycle or walking paths in or near my local area that are easily accessible.	
Traffic speed usually slow	The speed of traffic on most nearby streets is usually slow (≤50 km/hour).	
Traffic-slowing devices	There are many traffic-slowing devices in my local area (such as speed bumps, roundabouts, traffic islands).	
Pedestrian crossings present	Busy streets in my local area have pedestrian crossings and traffic signals to help walkers cross.	
Streets are well lit at night	Streets in my local area are well lit at night.	
Few cul-de-sacs	The streets in my local area do not have many, or any, cul-de-sacs.	
Intersection distance short	The distance between intersections in my local area is usually short (≤100 meters).	
Many four-way intersections	There are many four-way intersections in my local area.	
Many alternative routes	There are many alternative routes for getting from place to place when walking in my local area (I don't have to go the same way every time).	

Table 7-A1: Measurement details of the neighbourhood factors and of the intrapersonal and interpersonal factors. *(continued)*

Variable		
Neighbourhood perceptions[3,4]	**Questions**	**Answer categories[a] and scale information[5]**
Number of transport destinations	Number of facilities within a 10–15 minute walk: local shops, supermarkets, hardware stores, green grocers , laundromats/dry cleaners, post offices, libraries, elementary schools, other schools, bookstores, cafés/restaurants, video outlets, pharmacies, job, bus or train stops, gas station shops	count, 0–16
Number of recreation destinations	Number of facilities within a 10–15 minute walk: park, natural open space, fitness/recreation centre, sports field, beach, river	count, 0–6
Intrapersonal and interpersonal factors	**Questions**	**Answer categories and scale information[5]**
Intention	How likely or unlikely is it that in the next month, you will try to cycle for a total of 30 minutes on 5 or more days a week?	1. very unlikely – 7. very likely
Attitude	Trying to cycle for recreation or transport on most days in your neighbourhood in the next month would be:	1. very unpleasant – 7. very pleasant 1. very difficult – 7. very easy 1. very negative – 7. very positive Scale: M score T1: α=0.906
Self-efficacy	How confident are you that you could stick to cycling for recreation or transport on most days in your neighbourhood in the next months, in each of the following situations: – you are tired – you are in a bad mood – you have to cycle alone – you have work commitments – you have social commitments – you have family commitments	1. sure I could not do it – 5. sure I could do it Scale: M score T1: α=0.949
Social support	During the past month my family /friends: – went cycling with me – offered to go cycling with me – gave me encouragement to go cycling	1. never – 5. very often Scale: M score T1: α=0.807

Note: α is Cronbach's alpha for the scale.

[a] Answer categories for all neighbourhood perceptions variables are: 1. strongly disagree – 5. strongly agree.

Table 7-A2: Multiple logistic regression models for taking up cycling for either transport or recreation.

	Cycling for transport [a,c]			Cycling for recreation [b,c]		
Independent change variable	**M (SD)**	**OR (95%CI)**	***p*-value**	**M (SD)**	**OR (95%CI)**	***p*-value**
Objective environment						
Connectivity, *z*-score	0.71 (1.50)	1.09 (0.97, 1.22)	0.14	0.75 (1.55)	**1.17 (1.11, 1.23)**	**0.04**
Residential density, *z*-score	−0.35 (1.04)	**1.49 (1.17, 1.91)**	**<0.01**	−0.35 (1.05)	**1.52 (1.19, 1.94)**	**<0.001[d]**
Land-use mix score, *z*-score	−0.20 (1.35)	1.16 (0.89, 1.51)	0.30	−0.20 (1.36)	0.88 (0.71, 1.08)	0.36
Number of transport destinations	−2.59 (4.14)	1.04 (0.96, 1.14)	0.40	−2.66 (4.13)	0.92 (0.83, 1.03)	0.14
Number of recreation destinations	−0.31 (0.86)	0.98 (0.58, 1.68)	0.95	−0.32 (0.86)	0.85 (0.61, 1.18)	0.33
Neighbourhood perceptions						
Access to mixed services, scale	−0.62 (1.19)	**1.70 (1.25, 2.31)**	**<0.001**	−0.62 (1.19)	0.94 (0.77, 1.14)	0.51
Neighbourhood aesthetics, scale	0.35 (0.94)	**1.55 (1.04, 2.29)**	**0.03**	0.36 (0.96)	**1.42 (1.04, 1.93)**	**0.03**
Traffic hazards, scale	−0.43 (0.91)	0.72 (0.46, 1.13)	0.15	−0.44 (0.91)	1.03 (0.71, 1.51)	0.86
Crime hazards, scale	−0.44 (0.82)	1.01 (0.66, 1.54)	0.97	−0.45 (0.82)	**0.73 (0.54, 0.99)**	**0.04**
Hilly streets	−0.27 (1.24)	0.93 (0.73, 1.19)	0.56	−0.28 (1.25)	**0.74 (0.56, 0.97)**	**0.03**
Major barriers present	−0.07 (1.24)	0.76 (0.52, 1.10)	0.14	−0.08 (1.26)	0.80 (0.64, 1.01)	0.06
Local parking difficult	−0.08 (1.20)	0.83 (0.65, 1.08)	0.16	−0.07 (1.19)	0.91 (0.74, 1.13)	0.42
Access to park	0.22 (0.97)	**2.56 (1.77, 3.72)**	**<0.001**	0.23 (0.96)	**1.54 (1.16, 2.05)**	**<0.01**
Access to cycling paths	0.18 (1.24)	**1.46 (1.13, 1.89)**	**<0.01**	0.20 (1.25)	**1.26 (1.02, 1.56)**	**0.03**
Traffic speed usually slow	0.31 (1.25)	1.12 (0.81, 1.54)	0.49	0.29 (1.25)	1.01 (0.78, 1.32)	0.91
Traffic-slowing devices	0.19 (1.43)	1.04 (0.80, 1.34)	0.79	0.19 (1.42)	0.96 (0.76, 1.22)	0.76
Pedestrian crossings present	−0.21 (1.22)	**1.53 (1.18, 1.99)**	**<0.01**	−0.21 (1.22)	1.05 (0.83, 1.34)	0.68
Streets are well lit at night	0.45 (1.14)	1.01 (0.76, 1.34)	0.95	0.47 (1.15)	0.91 (0.74, 1.12)	0.37
Few cul-de-sacs	0.64 (1.49)	1.04 (0.80, 1.35)	0.80	0.63 (1.49)	1.03 (0.84, 1.28)	0.75
Intersection distance short	0.20 (1.11)	0.99 (0.69, 1.43)	0.96	0.20 (1.12)	0.87 (0.66, 1.14)	0.31
Many four-way intersections	0.04 (1.24)	0.91 (0.71, 1.16)	0.44	0.05 (1.24)	0.89 (0.73, 1.08)	0.22
Many alternative routes	0.16 (1.13)	1.24 (0.84, 1.83)	0.28	0.16 (1.14)	1.23 (0.96, 1.56)	0.10
Number of transport destinations	−2.64 (4.92)	**1.08 (1.02, 1.13)**	**<0.01**	−2.62 (4.88)	0.99 (0.94, 1.05)	0.83
Number of recreation destinations	−0.14 (1.28)	**1.75 (1.25, 2.45)**	**<0.01**	−0.12 (1.27)	**1.23 (1.01, 1.50)**	**0.04**

Note: Values shown in bold are significant at $p<0.05$.

[a] Outcome is cycling for transport at T2. The sample consists of people who did not cycle for transport at T1.

[b] Outcome is cycling for recreation at T2. The sample consists of people who did not cycle for recreation at T1.

[c] The models tested one independent change variable at a time. All models were adjusted for age, gender, educational level, marital status, children aged <18 years living at home, and whether a participant has access to a car. All were measured at T1. The models were also adjusted for the baseline variable of the neighbourhood measure included in the model.

[d] The general estimating equation model did not converge. The results of the last iteration are presented.

8

Discussion

INTRODUCTION

In this thesis, associations of individual and neighbourhood factors with physical activity (PA) were studied with a particular focus on the interplay between individual and neighbourhood factors.

The first aim was to study socioeconomic differences in different domains of PA and in different European regions. A review of literature was conducted to gain insight in these inequalities (**chapter 3**). The second aim was to gain insight in how individual psychosocial cognitions and neighbourhood factors interact in explaining PA. Three cross-sectional studies were carried out to explore the interaction between these psychosocial cognitions and different neighbourhood factors for sport participation (**chapter 4**) and walking (**chapter 5 and 6**). The third aim was to investigate how changes in the environment can change PA. This was investigated using data from a longitudinal study in Australia (**chapter 7**).

In this chapter, the main findings are summarized. Furthermore, the findings are presented in light of several methodological considerations and discussed in reference to previous research to highlight new insights. Finally, implications of these findings for theory and practice will be discussed.

MAIN FINDINGS

Are there socioeconomic inequalities in physical activity and are these inequalities similar for different domains of physical activity, and for different European regions?

A systematic review of the literature on socioeconomic inequalities in occupational, leisure-time, and transport-related PA in Europe (**chapter 3**) showed that different domains of PA demonstrated different socioeconomic patterns. The most consistent socioeconomic inequalities were found for vigorous leisure-time PA, with the lower socioeconomic groups participating less in vigorous activities than higher socioeconomic groups. For overall leisure-time PA, similar inequalities were observed although less articulated. In contrast to PA during leisure time, PA at work was more frequently reported by lower socioeconomic groups. Many studies found significant associations of socioeconomic position with total PA and active transport, but the directions of these associations differed considerably between studies.

We also studied whether socioeconomic patterns in PA differed by European region, socioeconomic indicator (education, income, social class), or gender. The socioeconomic patterns for the different PA types were quite consistent throughout Europe although they seem less

pronounced in Eastern Europe for both occupational and leisure-time PA, and in Southern Europe for vigorous leisure-time PA. The socioeconomic inequalities were consistently observed for different socioeconomic indicators. Differences in inequalities between men and women could not be identified because most studies did not differentiate by gender.

How do psychosocial cognitions and neighbourhood factors interact in explaining physical activity?

Three cross-sectional studies on leisure-time PA were used to explore the interactions between neighbourhood factors and psychosocial cognitions in explaining PA. In **chapter 4**, the direct associations of, and the interactions between perceived neighbourhood safety and individual psychosocial cognitions with sports participation were studied. First of all, people perceiving their neighbourhood as unsafe were less likely to participate in sports. In addition, people with a positive intention to be active, a strong self-efficacy, a positive attitude towards PA, and positive social influences regarding PA were more likely to participate in sports activities. Perceived neighbourhood safety interacted significantly with self-efficacy and attitude in explaining sports participation. Self-efficacy was stronger associated with sports participation in those who perceived their neighbourhood to be unsafe. Attitude was only associated with sports participation in those perceiving their neighbourhood as safe. Social influence and intention did not interact with perceived neighbourhood safety in explaining sports participation.

In **chapter 5**, the associations of perceived social neighbourhood factors (social network, social cohesion, feeling at home), perceived neighbourhood safety, and psychosocial cognitions with leisure-time walking were studied, as well as their interactions. Both the associations and interactions were explored for any leisure-time walking (yes versus no) and for minutes walked among those who engaged in any leisure-time walking. Those who perceived a larger social network within their neighbourhood were more likely to participate in leisure-time walking. Similar to sports participation, the psychosocial cognitions towards PA were also positively associated with leisure-time walking. We observed several interactions with perceived neighbourhood safety. For participation in leisure-time walking, perceived neighbourhood safety interacted with attitude and social influence: in those who sometimes felt unsafe, a positive attitude and a positive social influence were significantly stronger associated with any leisure-time walking compared with those who never felt unsafe. This pattern was not observed for those who often felt unsafe. Additionally, those who perceived feelings of unsafety but had a positive intention to walk in leisure-time walked about 30 minutes per week more than persons who felt safe in their neighbourhood (regardless of intention) and persons who lacked intention to walk. The final interaction observed was between feeling at home and attitude, whereby feeling at home in your neighbourhood was stronger associated with engaging in leisure time walking in those with a below average attitude.

Chapter 6 describes leisure-time walking as well, but in this chapter the focus was on objectively measured neighbourhood factors. This cross-sectional study used an adaptation of a social-ecological model on the hierarchy of walking needs in order to evaluate how urban form characteristics and psychosocial cognitions were associated with leisure-time walking (any leisure-time walking and sufficient leisure-time walking according to the Dutch PA norm [1]). Also interactions between psychosocial cognitions and urban form in relation to leisure-time walking were studied. The psychosocial cognitions (attitude, self-efficacy, social influence, intention) were again associated with leisure-time walking. For sufficient leisure-time walking, interactions between attitude and several urban form characteristics were found that indicated that positive urban form characteristics contributed towards leisure-time walking only in residents with a less positive attitude towards PA. Contrary, a good accessibility of the neighbourhood was more important for sufficient leisure-time walking in those residents who experienced a more positive social influence to engage in PA compared with those who reported less social influence. None of the urban form characteristics (accessibility, safety, comfort, pleasurability) were associated directly with leisure-time walking and no evidence for an urban form hierarchy was found.

Can neighbourhood changes cause changes in physical activity?

Chapter 7 describes the results of a natural experiment of people moving into new housing developments in Perth, Australia. The uptake of cycling after residential relocation was studied among those that did not cycle in their old neighbourhood. The results indicated that changes in the neighbourhood were associated with the uptake of cycling among formerly non-cycling adults, although the results were different for transport-related cycling and recreational cycling. The uptake of transport-related cycling occurred more often in those who moved to a neighbourhood with a higher residential density. Also, a perceived increase in access to parks, and an increase in access to other recreation destinations such as sports fields and the beach resulted in an increased likelihood of transport-related cycling. People were more likely to start cycling for recreational purposes when they moved to a neighbourhood with an increased street connectivity compared with their old neighbourhood. These results were independent of the psychosocial cognitions (e.g. attitude) that residents had towards cycling before they moved to their new neighbourhood.

METHODOLOGICAL CONSIDERATIONS

The results of this thesis should be interpreted in light of some methodological considerations. First, some issues with regard to the internal validity of the results will be examined. Secondly, the external validity of the results will be discussed.

Internal validity

Study design

The studies described in chapters 4, 5, and 6 had a cross-sectional design, which cannot be used to draw conclusions about causality or the direction of interactions studied. The most likely explanation for the association between a neighbourhood factor and PA is that certain characteristics of neighbourhoods influence the activity patterns of the neighbourhood residents, which was also confirmed in the natural experiment described in chapter 7. However, in cross-sectional studies, other interpretations of the observed associations cannot be excluded.

First, if perceptions of the neighbourhood are studied, it is important to realize that how people perceive their neighbourhood may be different for those who are active compared with the inactive. For example, those who frequently go for a walk in their neighbourhood will be more exposed to their neighbourhood compared with those who do not walk which in turn could influence their perception of the neighbourhood. Measuring neighbourhood characteristics objectively can prevent this type of bias, as we did in the studies described in chapters 6 and 7.

Second, the associations between the psychosocial cognitions and PA may be bi-directional. Although it is hypothesized that people match their actions (PA) according to their psychosocial cognitions, this may also go the other way around, due to a mechanism called 'cognitive dissonance' [2-3]. Due to this cognitive process, people adjust their beliefs to match their actions; persons who are not active may adjust their cognitions or even their perceptions of the neighbourhood to match their behaviour.

Third, a neighbourhood-individual interaction can be interpreted in both directions; the association between the cognition and PA may be moderated by neighbourhood factors but it could also be that the influence between neighbourhood factors and PA varies according to the individual psychosocial cognition a person holds.

Even though firm conclusions about causality cannot be drawn, cross-sectional studies are very efficient to explore new areas in research, such as neighbourhood-individual interactions in PA. This area is still relatively young and in the exploratory phase. Since current hypotheses on the possible mechanisms underlying these interactions are still scarce and solely based on theoretical conceptions, cross-sectional studies can help to strengthen these hypotheses with empirical evidence. When multiple cross-sectional studies provide enough evidence for a possible mechanism, this mechanism should be tested with longitudinal studies with repeated measurements over time and with intervention studies.

Selection

Apart from the direction of association, it is also important to consider the potential confounding effect of selection; a person who wants to be active may have a higher probability to move to a more active friendly neighbourhood. This confounding by selection could not be excluded in the cross-sectional studies. In the natural experiment described in chapter 7, we tried to minimize the risk of selection bias by correcting the analyses for psychosocial cognitions towards cycling at baseline (such as attitude towards cycling). Although confounding by selection cannot fully be excluded, this adjustment did control for the possibility that changes in cycling were caused by prior differences in individual cognitions towards cycling rather than neighbourhood changes.

Measurement of physical activity

PA is a multifaceted behaviour that comprises many activities, such as walking, cycling, going to the gym, walking the stairs, vacuuming the living room, and lifting loads at work. These activities can also be done for different reasons; a person can walk to get some exercise, to walk the dog, to get groceries, or to carry out work. The studies in this thesis show that different domains of PA are influenced by different factors. This need for specificity in studying PA has been emphasized before [4]. A strong point of this thesis is that the studies all investigated specific PA behaviours. To assess these PA activities, validated questionnaires were used that allowed estimating these specific measures [5-6]. The measures used were all self-reported measures which have the disadvantage of a possible recall bias and social desirability [7]. People tend to over-report their PA [8-9]. Objective measurement of PA can prevent such bias. However, we expect that a different measurement method would have resulted in similar results since we mostly used quite robust dichotomous measures that indicated whether someone participates in a specific PA behaviour at all or not.

The most promising technique to measure PA objectively is by means of accelerometry. Accelerometers measure the direction and speed of movements and can therefore classify whether an activity is sedentary, or of light, moderate or vigorous intensity. The objectivity is a large advantage of accelerometry. A disadvantage of accelerometers is that, so far, they are not able to adequately record the type of activity that is carried out. Recent initiatives aim to generate algorithms to identify specific types of behaviour by studying the particular accelerometer patterns for these activities [10-11]. However, even if many activities can be specified in the future, accelerometers are still unable to differentiate *why* people are active; e.g. whether someone cycles for leisure purposes or for commuting purposes. This will require additional tools such as a PA diary. Although the purpose of PA is less important for health reasons, this specificity is important when trying to study environmental determinants. This specific information can provide policy makers with guidance for appropriate interventions. To conclude, accelerometers are a very promising tool to measure PA. However, additional

tools or questionnaires will still be necessary until it is possible to identify the different types of activities or in research when specificity about the reason of the activity is important. When feasible, it is recommended to assess PA by a combination of objective (accelerometer) and self-reported measures.

Measurement of psychosocial cognitions

A limitation of the studies in chapter 4, 5 and 6 was the framing of the psychosocial cognition questions. Although the specificity within the PA measure was warranted, the measurement of psychosocial cognitions in these three cross-sectional studies was not behaviour specific. Because of feasibility reasons, the questions to measure attitude, self-efficacy, social influence, and intention were only asked once and formulated towards 'sufficient PA'. This is not in compliance with the Theory of Planned Behaviour which states that the cognitions should be framed in accordance with the specific outcome under study. This lack of specificity in the measurement of the psychosocial cognitions probably underestimated the association of these cognitions with the specifically measured sub-domains of PA. In the longitudinal RESIDE study (chapter 7) the psychosocial cognitions were formulated specifically towards cycling.

Measurement of the neighbourhood environment

There are several ways to assess a neighbourhood environment; 1) by means of questionnaires or interviews (perceived neighbourhood), 2) by means of observations by researchers when auditing a neighbourhood, or 3) by mapping information on neighbourhood factors as obtained from sources such as a municipal register (presence of shops and facilities) with the use of a Geographic Information System (GIS) (objective neighbourhood). In the studies described in this thesis, all of these different methods were used to assess the neighbourhood environment.

In the studies in chapter 4 and 5, questionnaires were used to assess the perceptions of certain neighbourhood factors among residents. Using only questionnaires to measure the neighbourhood has the potential disadvantage of same source bias and recall bias. People are usually not very aware of what is available in their neighbourhood [12-13] and perceptions might be influenced by other things than actual objective neighbourhood factors [14, 13]. An advantage of using questionnaires to assess neighbourhood circumstances is that perceptions are closer related to a person's behaviour and that it is relatively easy to obtain neighbourhood information for large numbers of respondents living in many different neighbourhoods. Questionnaires are also largely appropriate for measuring social neighbourhood factors such as the ones described in chapter 5.

In the study from chapter 6, an auditing instrument was used by independent researchers to observe the neighbourhood. Independent observations of neighbourhoods are relatively expensive and labour-intensive. A large advantage is that this method can provide detailed information of neighbourhood features and also on the quality of these features.

The Australian study described in chapter 7 used information from GIS in addition to information from questionnaires. Mapping neighbourhood features such as street connectivity and facilities using GIS has the potential to map large areas and can be cost-efficient when data is easily available. However, existing data on neighbourhood features will not provide detailed information on quality issues such as graffiti and litter which can be obtained by observations. Also, specialized knowledge and software is necessary to work with GIS.

All methods provide specific valuable information about the neighbourhood environment and determining the most appropriate method or mix of methods will depend on the research question and the environmental factors studied.

Interactions

Most of the interactions between neighbourhood factors and psychosocial cognitions in this thesis were studied by looking at whether the interaction term between a neighbourhood factor and a psychosocial cognition significantly contributed to describing the pattern of dichotomous PA outcomes in a logistic regression. The interactions tested this way are multiplicative by design [15]. When there is a multiplicative interaction (meaning that the interaction departs from multiplicity), the *relative* influence (difference) of a variable on the outcome varies according to the specific level of a third factor. In chapter 5 we also explored interaction by testing the significance of an interaction effect in a linear model. The interactions in a linear regression model are tested for their departure from additivity; the *absolute* influence (difference) of a variable on the outcome varies according to the specific level of a third factor. Additive interactions are considered more intuitive and more important in determining public health impact [16]. Therefore, in chapter 4 and 5, we additionally calculated a measure that quantifies additive interaction in logistic regressions; the Relative Excess Risk due to Interaction (RERI) [17-18, 16].

In theory, both types of interaction can coincide, but they can also be different from each other. For example, when the likelihood that someone is active when they have a high intention and when they live in an green neighbourhood is *higher* than would be expected from the *sum* of the individual 'effects' of having a high intention and living in a green neighbourhood, *but*, it is *lower* than would have been expected from the *product* of the 'effects' of having a high intention and living in a green neighbourhood, the interpretation of the multiplicative and additive interaction may lead to different conclusions. In this particular case, the additive

interaction would be positive, while the multiplicative interaction would be negative. In this thesis, the existence of multiplicative interaction and additive interactions always coincided although there were small differences in significance. The finding that additive interactions coincided with the multiplicative interactions, strengthens the results of this thesis.

Recently, a guideline has been published on how interactions ideally should be presented which includes core information that allows the calculation of both additive and multiplicative interactions [19]. Calculating both types of interactions, or presenting the result in such a way that readers can calculate it themselves, ensures a complete overview of interaction patterns.

External validity

External validity refers to generalisability of scientific findings to other populations or settings. There are some limitations of the generalisability of the results described in this thesis.

The review about socioeconomic differences in PA only included studies from Europe. In other developed countries such as the US and Australia, inequalities in leisure-time PA have also been reported [20]. For developing regions of the world, such as large parts of Asia, Africa, and Southern America, the presence and magnitude of these inequalities in PA are largely unknown.

The results from the interaction studies described in chapter 4, 5, and 6 were all carried out in one urban area in the Netherlands. Because of large differences between neighbourhood environments in different regions and different countries, neighbourhood influences are likely to be highly contextual and cannot always be generalised to other regions or countries. The Netherlands is a very dense country with very good walking and cycling infrastructure, mild climate, and flat topography [21]. In the city of Eindhoven, the average population density is 2463 persons per square kilometre [22]. To compare, in the US, the average density of cities over 175.000 inhabitants is only 1598 inhabitants per square kilometres [23]. This high density results in no or little urban sprawl in Dutch cities. Also, the Netherlands has been very adapted to cyclists and pedestrians which can be recognized by its many cycling roads, the existence of traffic laws to protect cyclists and pedestrians, 30km/hour zones in living areas, and so called 'woonerven' (parts of a neighbourhood that are dedicated to living and playing where cars are not allowed or only allowed to drive with a maximum speed of 10 km/hour and where the infrastructure is accommodated towards walking with for example many small alleys to connect streets). Finally, because of this high density, good infrastructures, mild climate, and flat topography, the Netherlands has adopted a cycling and walking friendly culture over the years in which pedestrians and cyclists are a common sight in all neighbourhoods and other traffic is used to, and adapted to these vulnerable road users.

This relatively favourable Dutch neighbourhood environment was also shown in chapter 6. To increase variability in neighbourhood factors, we used neighbourhood observations from seven advantaged and seven disadvantaged neighbourhoods in Eindhoven. However, despite these efforts, variability remained low and all neighbourhoods had a relatively favourable profile. These neighbourhood circumstances and this low variability might make it difficult to demonstrate neighbourhood influences of PA in the Netherlands. It is possible that neighbourhood changes have only limited effect on PA when neighbourhoods are in general already favourable. A sort of ceiling effect can take place. Conversely, when the point of departure is less favourable and much improvement (variability) is possible, neighbourhood changes *can* influence PA, as described in chapter 7. This study on recreational and transport-related cycling was carried out in the city of Perth, a very sprawled, low density city (320 persons per square kilometre [24]) with little cycling infrastructure and it showed that an increase in residential density, connectivity, and perceived access to facilities increased the probability of residents to initiate cycling. Replicating the findings of this thesis in other countries, with less favourable neighbourhood circumstances and more variability, could demonstrate the external validity of these results. Cross-national studies may provide more insight into why inhabitants in certain countries are more likely to be physically active than others [25, 21].

THE FUTURE OF EXPLORING INDIVIDUAL NEIGHBOURHOOD INTERACTIONS?

Social-ecological models all propose individual-environment interactions but evidence so far is scarce and inconclusive. To better understand whether these interactions exist, how the mechanisms work, and if these interactions are significant enough that they matter for public health, more studies are needed. Especially research that includes interaction analyses as a complement to existing studies are encouraged since this will be an economic way to further explore this topic.

In addition to survey research, there are relatively new developments and technologies in measuring both PA and the neighbourhood environment that will provide more detailed insight in the environmental determinants of PA. Moreover, they can provide new opportunities to explore individual-neighbourhood interactions for PA.

A challenge in this field of research is to define what a neighbourhood is and therefore, with which aspects in the neighbourhood the person interacts. What people consider to be their neighbourhood is rather individual and depends for example on how people use their neighbourhood and what modes of transportation are available to them. In many studies, including the ones described in chapters 4, 5 and 6, no definition of a neighbourhood was

given to the respondents before they had to answer questions regarding their neighbourhood. An advantage is that the answers will probably match the idea the respondent has of his/her neighbourhood and that they are therefore probably more relevant for the respondent. A disadvantage is that this information will have less value for policy makers since the definition of what the neighbourhood will entail is not defined and therefore it is unclear on what scale to intervene. Also, when observations or GIS are used to map the neighbourhood environment, it is often unclear how large the buffer around a person's home should be to capture all relevant neighbourhood characteristics [26]. So far, a buffer of 1600 meters (1 mile) around a person's home is most often used. This buffer is likely to be most relevant for walking behaviour, since it is the area that can generally be reached within about 15 minutes of walking. For other behaviours, such as cycling, another buffer may be more appropriate since a 15 minute bike ride can cover a much larger distance. In recent studies [27-35], Global Positioning Systems (GPS) are used in combination with pedometers or accelerometers to measure in which parts of the neighbourhood persons are active. This information can help to gain further understanding on how people use their neighbourhood and with what parts of the neighbourhood they interact.

Modern technologies, such as GPS, GIS, and accelerometry, could provide an easy platform to measure neighbourhood-individual interactions more dynamically, compared with the studies described in this thesis. These methods may also allow a more systems approach in which the dynamic interrelation in which individuals change places and places change individuals can be studied [36]. Especially when these technologies are combined with Ecological Momentary Assessments (EMA), a method in which behaviours, states of mind, or experiences are assessed momentary (multiple times a day) in their natural environment which maximizes the ecological validity [37-39]. EMA aims to 'minimize recall bias, maximize ecological validity, and allow study of micro-processes that influence behaviour in real-world contexts' [39]. Because of the multiple measurements, EMA is able to establish the temporal nature of processes allowing the imputation (although not confirmation) of causal mechanisms which cannot be done with cross-sectional studies [40]. Many contemporary smart phones, now widely available and used in many countries, are standard equipped with GPS and an accelerometer that make it possible to continuously assess the respondents' PA and the neighbourhood he or she interacts with.

In addition, prompts can be send out to the phone at regular intervals that ask the respondent certain questions such as how the person feels or what they think. Another addition could be to ask respondents to use their phones to make snapshots of their neighbourhood environment in order to get an idea of the quality of the neighbourhood. This combination of the use of technology with EMA (further referred to as e.EMA) could provide exact information at multiple time points on how much and where exactly a person is physically active, and

what they are thinking at that time. Additionally, e.EMA will produce a high level of detail in the data. This level of detail and the multiple measurements may be able to detect neighbourhood influences and interactions more easily in areas with little neighbourhood variability. However, e.EMA is potentially much more invasive and cumbersome for respondents compared with survey research if multiple questionnaires or prompts are used. Also, there is the risk that the assessment influences the behaviour of the respondents. Finally, the costs and technical feasibility (both for data collection and data cleaning) need to be considered.

To conclude, EMA in combination with modern electronic technologies can provide interesting opportunities to gain in-depth insight in how the neighbourhood characteristics can influence PA and how this neighbourhood interacts with individual factors. Because of the complexity and potential high burden of this method to the respondents, cross-sectional studies as the ones described in this thesis are still very valuable. They can provide hypothesis that can be tested in more elaborate methods such as e.EMA and natural experiments. A recent study by Dunton and colleagues [41] among children combined both e.EMA with a natural experiment. They studied whether children were physically active in different settings when they had recently moved to a so-called smart growth community in comparison to children who lived in a conventional neighbourhood. They found that children who lived in the smart growth communities were more often active accompanied by friends, they more often walked to the location they were physically active, and they were more often active a few blocks from home.

INTERPRETATION AND NEW INSIGHTS

This thesis provides new insights with respect to socioeconomic differences in PA, neighbourhood influences on PA, and the interplay between individual and neighbourhood factors in explaining PA.

The direction of socioeconomic inequalities in physical activity varies by the domain of physical activity

The review described in chapter 3 showed that leisure-time PA was more prevalent in higher socioeconomic groups and occupational PA was more prevalent in the lower socioeconomic groups. The lack of a consistent direction in the socioeconomic inequalities in total PA might be caused by these contrasting socioeconomic patterns found for leisure-time PA and occupational PA, since both types of PA contribute largely to total PA. Because of these contrasting patterns, total PA may not be a suitable summary measure when investigating inequalities in PA and their effects on morbidity and mortality. A question that subsequently arises here is whether all forms of PA can be added up when looking at health–enhancing PA

or whether some types or domains are better for your health than others. The health effects of leisure-time PA and sports are studied most frequently and the benefits of leisure-time PA on health are consistently demonstrated [42-49]. For PA at work, evidence is less consistent [43-45, 50-51, 46, 52-54, 48-49]. It may depend on the type of activity whether PA at work can be considered healthy or not [55-56].

Individual-neighbourhood interactions in physical activity exist in specific combinations and vary across combinations

Many ecological models implicitly or explicitly mention possible interactions between factors from different levels, but only few studies have actually quantitatively explored them [57-62]. Almost all of these studies, including the ones described in this thesis, do find interactions between neighbourhood factors and psychosocial cognitions, although these interactions only seem to exist in very specific combinations and they may differ for each of these combinations. There are two underlying mechanisms that are expected to result in neighbourhood-individual interactions. First, in the synergetic mechanism, positive psychosocial cognitions and a supportive neighbourhood environment reinforce each other in stimulating PA. This mechanism was supported by studies by Carlson et al [57], Rhodes et al [61], and Prins et al [60]. The other mechanism is that people who have less positive psychosocial cognitions towards PA benefit most by a supportive neighbourhood environment. Studies by Cerin [58] and Van Dyck [62] provided evidence for this mechanism. The studies described in this thesis provide evidence for both of these mechanisms. The variety in the findings may indicate that both mechanisms may exist, but that the specific mechanism depends on the specific combination of psychosocial cognition and environmental factor. For example, in this thesis attitude interacted most consistently with neighbourhood factors in describing leisure-time PA (chapter 4, 5, and 6). However, the direction of the interaction differed according to the specific combination of neighbourhood factor and PA outcome. This specificity was also clearly illustrated by Deforche et al [59]; they found that self-efficacy interacted significantly with all included neighbourhood factors in explaining active transportation while just one interaction was found when trying to explain leisure-time sports. The results also differed by neighbourhood factor; better land use diversity, neighbourhood aesthetics, and access to recreational facilities seem to result in more active transport only in those with high self-efficacy towards PA whereas in a neighbourhood that was safe from crime and traffic and had good access to neighbourhood services active transportation seemed only increased in those with low self-efficacy.

This specificity in associations was also demonstrated in the non-interaction studies in this thesis. The longitudinal study described in chapter 7 clearly shows that predictors of transport-related cycling and recreational cycling differed. In chapter 3, different patterns in socioeconomic inequalities in the different domains of PA were observed.

To conclude, the studies in this thesis corroborate evidence in previous studies for the existence of individual-neighbourhood interaction in explaining PA. However, interactions are frequently *not* found as well and the results differ greatly per specific interaction studied. Moreover, the found interactions often had small effect sizes which make it debatable whether they are important for public health purposes. So far there is only very limited evidence available. Because of the complexity and the vast number of potential interactions, more evidence is needed before proper conclusions can be drawn. Since many studies about the determinants of PA have already adapted an ecological approach that includes both neighbourhood factors and psychosocial cognitions, it is recommended that testing for interactions is integrated in the standard analytic procedure for studies on determinants of health-behaviours. This will require no extra data collection while it can provide valuable information for the future.

How safety influences physical activity remains unclear and calls for more comprehensive measures of neighbourhood safety

All original research studies in this thesis have included a measure of neighbourhood safety and the results differed largely among these studies. These inconsistent findings have been reported in literature reviews as well [63] and are difficult to interpret. Since safety is often mentioned as an inhibiting factor in qualitative research [64-67], we think there may be particular factors involved that mask the true effect. One possibility is that the association between safety and PA is confounded by neighbourhood factors. A study by Adams [68] on neighbourhood profiles showed that neighbourhoods that had favourable neighbourhood characteristics such as high residential density and good access to facilities in general were less safe from crime while those neighbourhoods that had less favourable neighbourhood characteristics were in general more safe from crime. Another possibility is that we fail to properly measure the relevant aspects of safety. There is only a weak link between actual crime rates or victimization and safety perceptions. More research is needed on how to properly measure neighbourhood safety.

Neighbourhood changes can stimulate the uptake of cycling

The natural experiment described in chapter 7 showed that improvements in accessibility of facilities and in the physical lay-out of a neighbourhood may encourage non-cycling adults to initiate cycling. After relocation, participants who moved into neighbourhoods with greater residential density and better perceived access to parks and destinations were more likely to take up transport-related cycling. An increase in objectively measured street connectivity was associated with an uptake of recreational cycling. These findings were independent of the psychosocial cognitions of residents before relocation, which indicates that changes in cycling were not caused by a selection effect. The results of this study were in concordance with previous, mostly cross-sectional, findings [69-70] and provide valuable information on

potentially important neighbourhood factors. However, because neighbourhood influences on PA may be highly contextual, it is important to replicate these findings in other countries. In European cities, for example, where cycling is more prevalent and there is more established cycling infrastructure [25, 21], other factors could be important in determining cycling behaviour which could inform countries only beginning to rekindle an interest in cycling such as the US and Australia.

IMPLICATIONS FOR POLICY AND PRACTICE

The studies in this thesis support the ecological nature of influences on PA in adults and they emphasize that there may be interactions between the different levels within the ecological models. This complexity should be reflected in policy and practice. It is nevertheless too early to provide concrete recommendations about these interactions. Recommendations on other issues studied in this thesis are described here.

Tailor intervention and policies to specific physical activity behaviours

Many studies [71-72], including the ones in this thesis, have shown that specific types or domains of PA such as sport, leisure-time walking, or transportation cycling, are influenced by different neighbourhood factors. This finding should be taken into account when developing policies, neighbourhood changes, or other interventions that aim to promote PA. Although the aim is probably to increase overall levels of PA, not all neighbourhood factors are related to every aspect of PA. Therefore, it is important to focus interventions towards the PA behaviour that is most promising for improving population health in a particular population.

Stimulate leisure-time physical activity in people with low socioeconomic status

Socioeconomic health inequalities are well established [73-74] and are thought to be partly caused by inequalities in health behaviours [75]. The review described in this thesis showed that socio-inequalities in PA mainly exist in leisure-time PA, and especially in vigorous leisure-time PA such as sport and exercise. Since the health benefits of leisure-time PA are well recognized [42, 44-49], stimulating this behaviour in groups of low socioeconomic status may decrease socioeconomic inequalities in health. Previous research has shown that differences in neighbourhood factors, such as neighbourhood attractiveness and safety, can partly explain inequalities in leisure-time PA [76-77]. Improving neighbourhood environments in neighbourhoods with low socioeconomic status may therefore help to reduce inequalities in leisure-time PA and possibly health.

New neighbourhoods in sprawled cities should be relatively dense, highly connected, and have accessible facilities.

The Australian study demonstrated that an increased residential density, connectivity and perceived access to facilities such as stores and transit stops stimulates the uptake of cycling in a sprawled city with little cycling infrastructure. This information should be used in new neighbourhood developments or neighbourhood renovations in similarly sprawled cities in order to increase cycling in this type of urban areas. These recommendations cannot be translated to dense urban areas as can be found in the Netherlands.

IMPLICATIONS FOR FUTURE RESEARCH AND THEORY DEVELOPMENT

The complexity of neighbourhood and individual influences on PA, and especially the neighbourhood-individual interplay, warrants the need for more research. Based on the findings and experiences from the studies described in this thesis, some recommendations for future research and theory development are presented here.

Include interaction analyses in all studies on individual and neighbourhood influences on physical activity.

Because of the complexity and the vast number of potential interactions, much more evidence is needed before proper conclusions can be drawn. Testing for interactions should be integrated in the standard analytic procedure for studies on individual and neighbourhood determinants of health-behaviours. This can quickly accumulate evidence on interactions without much extra costs.

Further develop ecological models that incorporate the interplay between individual and neighbourhood factors.

Most ecological models on health behaviours do acknowledge the interplay between individual and environmental factors. However, the majority of these models are very comprehensive and try to catch all aspects that may influence the assumed interplay. There is a need for more focussed models that address specific interaction mechanisms. These specific interactions should be included in studies as recommended, in order to generate concrete hypotheses on how multilevel factors interact in determining health behaviours. This in turn will lead to more focussed theoretical models that can be tested in longitudinal and intervention studies.

Replicate the findings of this thesis in more contrasting neighbourhoods and in other countries

There are large regional and country specific differences between neighbourhood environments. This makes research on neighbourhood influences on PA highly contextual and limits the external validity of the findings. More studies are needed that replicate the findings of the empirical studies in this thesis in other neighbourhood environments. In addition, it is also valuable to increase variability in neighbourhood factors by studying more contrasting and diverse neighbourhoods. A possibility to increase variability is to include neighbourhoods from different cities, neighbourhoods from urban and rural environments, or neighbourhoods in different countries. Especially these cross-national studies could provide valuable information on why PA is more prevalent in certain countries or regions compared with other. In these studies, also higher level neighbourhood factors such as policies and legislation can be studied. For example, Basset et al [78] show that countries with the highest levels of active transportation generally had the lowest obesity rates. Additionally, Pucher et al [21] demonstrate that these differences in active transportation could partly be explained by differences in walking and cycling facilities, traffic calming measures and traffic regulations, a dense urban environment, and restrictions on motor vehicle use.

Evaluate natural experiments

In all urban areas, there are regular neighbourhood renovations or new neighbourhoods being build. Research and practice should work together more often to evaluate these changes as natural experiments, like was done in the study described in chapter 7. These evaluations could yield valuable information for practice since they will show whether choices for creating particular environments have an influence on health behaviours. For research, these evaluations provide valuable causal information on the determinants of health behaviours.

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Summary
Samenvatting

SUMMARY

Physical inactivity is among the most important and prevalent risk factors of many major diseases in developed countries. Although the health benefits of regular exercise and a physically active lifestyle are well known, many people are still relatively inactive. Understanding exactly why people are physically inactive is therefore of key importance in developing strategies to reduce major chronic diseases.

Physical activity (PA) is a complex behaviour influenced by many different factors. Psychosocial cognitions, such as attitude and self-efficacy, have often been linked to PA. However, because changes in individual determinants of PA cannot sufficiently explain the decline in PA and thus the increase in overweight and obesity over time, the focus of research on determinants of PA has shifted towards environmental determinants of PA. Environmental factors may also contribute to health inequalities as lower socioeconomic groups seem to be more likely to live in neighbourhoods that are less supportive for engaging in PA.

Individual and environmental determinants of PA are most likely interrelated. This is expressed in social-ecological models. Also many established health behaviour theories clearly imply reciprocal determinism with continuous interplay between the environment, the person, and the behaviour. Despite the acknowledgement of individual-environment interactions in theoretical models, empirical evidence is still relatively sparse.

In this thesis, associations of individual and neighbourhood factors with PA were studied with a particular focus on the interplay between individual and neighbourhood factors. Proposed are two underlying mechanisms that are expected to result in neighbourhood-individual interactions. First, in the synergetic mechanism, positive psychosocial cognitions and a supportive neighbourhood environment reinforce each other in stimulating PA. The other mechanism is that people who have less positive psychosocial cognitions towards PA benefit most by a supportive neighbourhood environment.

Socioeconomic status (SES) is an important individual factor that determines PA. Research has shown that low SES groups are often less physically active compared with high SES groups, and that this may be partly related to the less favourable neighbourhood circumstances of low SES groups. Empirical evidence also suggests that socioeconomic patterns may differ for different domains of PA, and by European region.

Consequently, the first research question is:

1. Are there socioeconomic inequalities in physical activity and are these inequalities similar for different domains of physical activity, and for different European regions?

In **chapter 3** a systematic review of the literature demonstrated that the different domains of PA had indeed different socioeconomic patterns. The most consistent socioeconomic inequalities were found for vigorous leisure-time PA, with the lower SES groups participating less in vigorous activities than higher SES groups. For overall leisure-time PA, similar inequalities were observed although less articulated. In contrast to PA during leisure time, PA at work was more frequently reported by lower SES groups. Many studies found significant associations of socioeconomic position with total PA and active transport, but the directions of these associations differed considerably between studies. The lack of a consistent direction in the socioeconomic inequalities in total PA might be caused by these contrasting socioeconomic patterns found for leisure-time PA and occupational PA, since both types of PA contribute largely to total PA. Because of these contrasting patterns, and because of the different effects certain types of PA may have on health, total PA may not be a suitable summary measure when investigating inequalities in PA and their effects on morbidity and mortality.

The socioeconomic patterns for the different PA types were quite consistent throughout Europe although they seem less pronounced in Eastern Europe for both occupational and leisure-time PA, and in Southern Europe for vigorous leisure-time PA.

The second research question in this thesis is:

2. How do psychosocial cognitions and neighbourhood factors interact in explaining physical activity?

Three studies on leisure-time PA were used to explore this question. Cross-sectional data from the 4th wave of the Dutch GLOBE study was used. More information on the design and aim of the GLOBE study are described in **chapter 2**.

In **chapter 4**, the direct associations of, and the interactions between perceived neighbourhood safety and individual psychosocial cognitions with sports participation were studied. First of all, people perceiving their neighbourhood as unsafe were less likely to participate in sports. In addition, people with a positive intention to be active, a strong self-efficacy, a positive attitude towards PA, and positive social influences regarding PA were more likely to participate in sports activities. Perceived neighbourhood safety interacted significantly with self-efficacy and attitude in explaining sports participation. Self-efficacy was stronger

associated with sports participation in those who perceived their neighbourhood to be unsafe. Attitude was stronger associated with sports participation in those perceiving their neighbourhood as safe. Social influence and intention did not interact with perceived neighbourhood safety in explaining sports participation.

In **chapter 5**, the associations of perceived social neighbourhood factors (social network, social cohesion, feeling at home), perceived neighbourhood safety, and psychosocial cognitions with leisure-time walking were studied, as well as their interactions. Both the associations and interactions were explored for any leisure-time walking (yes versus no) and for minutes walked among those who engaged in any leisure-time walking. Those who perceived a larger social network within their neighbourhood were more likely to participate in leisure-time walking. Similar to sports participation, the psychosocial cognitions towards PA were also positively associated with leisure-time walking. We observed several interactions with perceived neighbourhood safety. For participation in leisure-time walking, perceived neighbourhood safety interacted with attitude and social influence: in those who sometimes felt unsafe, a positive attitude and a positive social influence were significantly stronger associated with any leisure-time walking. This pattern was not observed for those who often felt unsafe. Additionally, those who perceived feelings of unsafety but had a positive intention to walk in leisure-time walked about 30 minutes per week more than persons who felt safe in their neighbourhood (regardless of intention) and persons who lacked intention to walk. The final interaction observed was between feeling at home and attitude, whereby feeling at home in your neighbourhood was stronger associated with engaging in leisure time walking in those with a below average attitude.

Chapter 6 describes leisure-time walking as well, but in this chapter the focus was on objectively measured neighbourhood factors. This cross-sectional study used an adaptation of a social-ecological model on the hierarchy of walking needs in order to evaluate how urban form characteristics and psychosocial cognitions were associated with leisure-time walking (any leisure-time walking and sufficient leisure-time walking according to the Dutch PA norm). Also interactions between psychosocial cognitions and urban form in relation to leisure-time walking were studied. The psychosocial cognitions (attitude, self-efficacy, social influence, intention) were again associated with leisure-time walking. For sufficient leisure-time walking, interactions between attitude and several urban form characteristics were found that indicated that positive urban form characteristics contributed towards leisure-time walking only in residents with a less positive attitude towards PA. Contrary, a good accessibility of the neighbourhood was more important for sufficient leisure-time walking in those residents who experienced a more positive social influence to engage in PA compared with those who reported less social influence. None of the urban form characteristics (accessibility, safety,

comfort, pleasurability) were associated directly with leisure-time walking and no evidence for an urban form hierarchy was found.

Overall, these three studies corroborate evidence in previous studies for the existence of individual-neighbourhood interaction in explaining PA. However, interactions are frequently *not* found as well and the results differ greatly per specific interaction studied. Two underlying mechanisms were proposed that are expected to result in neighbourhood-individual interactions. First, in the synergetic mechanism, positive psychosocial cognitions and a supportive neighbourhood environment reinforce each other in stimulating PA. The other mechanism is that people who have less positive psychosocial cognitions towards PA benefit most by a supportive neighbourhood environment. The studies described in this thesis provide evidence for both of these mechanisms. The variety in the findings may indicate that both mechanisms may exist, but that the specific mechanism depends on the specific combination of psychosocial cognition and environmental factor.

In order to actually intervene on environmental factors to improve PA, it is important to understand whether changes in the neighbourhood environment can actually cause changes in PA. Therefore, in **chapter 7**, the final research question was addressed:

3. Can neighbourhood changes cause changes in physical activity?

Chapter 7 describes a natural experiment of people moving into new housing developments in Perth, Australia. The uptake of cycling after residential relocation was studied among those that did not cycle in their old neighbourhood. The study showed that improvements in accessibility of facilities and in the physical lay-out of a neighbourhood may encourage non-cycling adults to initiate cycling. After relocation, participants who moved into neighbourhoods with greater residential density and better perceived access to parks and destinations were more likely to take up transport-related cycling. An increase in objectively measured street connectivity was associated with an uptake of recreational cycling. These findings were independent of the psychosocial cognitions of residents before relocation, which indicates that changes in cycling were not caused by a selection effect.

However, because neighbourhood influences on PA may be highly contextual, it is important to replicate these findings in other countries. In European cities, for example, where cycling is more prevalent and there is more established cycling infrastructure, other factors could be important in determining cycling behaviour which could inform countries only beginning to rekindle an interest in cycling such as the US and Australia.

Finally, in **chapter 8**, study findings were integrated and the main results for the three research questions were summarized and discussed with respect to previous research and methodological considerations. Implications of the results for research and practice are presented. One of the main conclusions was that evidence was found for both underlying interaction mechanisms but neither of the two came out as the dominant mechanism. Although there are indications that individual-environment interactions do exist, the exact relation remains relatively unclear and may depend on the specific combination of factors. More empirical evidence, possibly collected using existing studies, could help further discover the interaction mechanisms and their impact on public health.

SAMENVATTING

Lichamelijke inactiviteit is één van de belangrijkste en meest voorkomende risicofactoren van veel ziekten in ontwikkelde landen. Ondanks dat het welbekend is dat voldoende bewegen goed is voor de gezondheid, zijn nog steeds veel mensen lichamelijk inactief. Door beter te begrijpen wat mensen ertoe aanzet om voldoende te bewegen, kunnen effectieve strategieën ontwikkeld worden die een positief effect hebben op de algehele gezondheid van de bevolking.

Lichamelijke activiteit is een complex gedrag dat wordt beïnvloed door veel verschillende factoren. Psychosociale factoren zoals de houding ten opzichte van bewegen (attitude) zijn vaak in verband gebracht met voldoende bewegen. Echter, veranderingen in psychosociale factoren kunnen niet verklaren waarom mensen de afgelopen decennia steeds minder zijn gaan bewegen en waarom er een obesitasepidemie is in veel landen. Daarom zijn steeds meer onderzoekers zich, naast deze individuele factoren, ook gaan richten op omgevingsfactoren die mogelijk het beweeggedrag van mensen kunnen verklaren. Er wordt ook gedacht dat verschillen in de omgeving bijdragen aan de sociaaleconomische gezondheidsverschillen bij bewegen. Mensen met een lagere sociaaleconomische positie lijken in buurten te leven die minder uitnodigen tot voldoende beweging.

Sociaalecologische gezondheidsmodellen gaan er vanuit dat er een samenspel is tussen individuele factoren en kenmerken uit de omgeving in hun relatie tot lichamelijke activiteit. Ook in veel andere theoretische modellen met betrekking tot gezond gedrag wordt deze interactie verondersteld. Ondanks deze theoretische onderbouwing, is er nog weinig empirisch bewijs voor deze interacties.

In dit proefschrift is de invloed van individuele psychosociale factoren en kenmerken uit de buurtomgeving op het beweeggedrag van mensen onderzocht. Hierbij is specifiek gekeken naar de interactie tussen deze factoren. Twee onderliggende mechanismen worden voorgesteld, waarvan wordt verwacht dat zij leiden tot omgevings-individuele interacties. Ten eerste een mechanisme van synergie waarin de positieve invloed van een stimulerende buurtomgeving op beweeggedrag wordt versterkt door de positieve invloed van gunstige psychosociale cognities ten opzichte van bewegen. Het tweede mechanisme gaat ervan uit dat mensen met minder gunstige psychosociale cognities ten opzichte van bewegen meer profijt hebben, en dus sterker beïnvloed worden, door een stimulerende buurtomgeving.

Sociaaleconomische positie is een belangrijke individuele determinant van bewegen. Eerder onderzoek heeft aangetoond dat mensen met een lagere sociaaleconomische positie vaker fysiek inactief zijn dan mensen met een hogere sociaaleconomische positie en dat deze

verschillen in beweeggedrag waarschijnlijk deels verklaard kunnen worden door de minder gunstige buurtomgeving van deze sociaaleconomische groep. Daarnaast suggereren diverse studies dat er verschillen zijn in deze sociaaleconomische ongelijkheden per beweegdomein (bijvoorbeeld bewegen op het werk of bewegen in de vrije tijd) en per Europese regio. Daarom is de eerste onderzoeksvraag van dit proefschrift:

1. Zijn er sociaaleconomische ongelijkheden in beweeggedrag en verschillen deze ongelijkheden per beweegdomein en per Europese regio?

In **hoofdstuk 3** worden de resultaten van een systematische literatuurstudie beschreven die laten zien dat er inderdaad verschillen zijn in deze ongelijkheden per beweegdomein. Sociaaleconomische ongelijkheden werden het meest systematisch gevonden voor intensief bewegen in de vrije tijd zoals sporten; mensen met een lagere sociaaleconomische positie bewegen minder vaak intensief in hun vrije tijd dan mensen met een hogere sociaaleconomische positie. Deze sociaaleconomische ongelijkheid werd, in een iets minder uitgesproken vorm, ook gevonden voor bewegen in de vrije tijd in het algemeen. In tegenstelling tot bewegen in de vrije tijd, wordt bewegen op het werk vaker gedaan door mensen met een lagere sociaaleconomische positie. Veel studies die de totale lichamelijke activiteit of actief transport bestudeerden vonden sociaaleconomische verschillen maar de richting van deze verschillen varieerde per studie. Het gebrek aan een duidelijk sociaaleconomisch patroon voor totale lichamelijke activiteit zou veroorzaakt kunnen worden door de tegengestelde patronen voor bewegen in de vrije tijd en bewegen op het werk, beiden een onderdeel van totale lichamelijke activiteit. Door deze contrasterende sociaaleconomische ongelijkheden binnen verschillende beweegdomeinen, is totale lichamelijke activiteit wellicht geen goede maat om sociaaleconomische ongelijkheden te onderzoeken en de effecten hiervan op gezondheid. Eerder onderzoek toont bovendien aan dat de gezondheidseffecten van bewegen op het werk niet gelijk zijn aan die van bewegen in de vrije tijd.

De patronen in sociaaleconomische ongelijkheden in bewegen werden consistent in heel Europa gevonden, hoewel de verschillen in bewegen in de vrije tijd en bewegen op het werk iets minder gearticuleerd waren in Oost-Europa. De sociaaleconomische ongelijkheden in intensief bewegen in de vrije tijd waren iets minder duidelijk in Zuid-Europa.

De tweede onderzoeksvraag in dit proefschrift is:

2. Hoe is het samenspel tussen psychosociale factoren en kenmerken van de buurtomgeving in hun relatie tot beweeggedrag?

Om deze vraag te beantwoorden zijn er drie studies naar bewegen in de vrije tijd uitgevoerd. Hiervoor werd de cross-sectionele data van de 4e ronde van de Nederlandse GLOBE studie gebruikt. Meer details van deze Eindhovense cohortstudie zijn beschreven in **hoofdstuk 2**.

In **hoofdstuk 4** worden de directe invloeden en interacties van het gevoel van veiligheid in de buurt en psychosociale cognities op sportparticipatie bestudeerd. De kans dat mensen aan sport deden was kleiner wanneer ze hun buurt onveilig vonden. De kans om te sporten was groter bij mensen met een positievere attitude, een sterkere intentie om te bewegen, een hoge eigen-effectiviteit en een positieve sociale invloed wat betreft bewegen. In de groep mensen die zich onveilig voelden in hun buurt was de relatie tussen een hoge eigen-effectiviteit en sportparticipatie sterker dan bij mensen die zich veilig voelde in hun buurt. Een positieve attitude ten opzichte van voldoende bewegen was aan de andere kant juist sterker gerelateerd aan sportparticipatie wanneer mensen zich veilig voelde in hun buurt. Er werd voor sportparticipatie geen interactie gevonden tussen intentie en sociale invloed en het gevoel van veiligheid in de buurt.

In **hoofdstuk 5** werd het verband onderzocht tussen wandelen in de vrije tijd en sociale buurtkenmerken (sociaal netwerk, sociale cohesie, en het gevoel je thuis te voelen), het gevoel van veiligheid in de wijk en psychosociale cognities. Ook de interacties tussen deze cognities en buurtfactoren ten opzichte van wandelen in de vrije tijd werd onderzocht. Er werd zowel gekeken of mensen überhaupt wel eens wandelden in hun vrije tijd en bij de mensen die dit wel eens deden werd gekeken naar het aantal minuten per week. De psychosociale cognities waren, net als bij sportparticipatie, gerelateerd aan wandelen in de vrije tijd. Ook werd een verband gevonden tussen een groter sociaal netwerk in de buurt en wel eens wandelen in de vrije tijd. In de modellen voor 'wel eens wandelen in de vrije tijd' werden enkele interacties gevonden tussen psychosociale factoren en het gevoel van veiligheid in de buurt. Bij mensen die zich wel eens onveilig voelen in hun buurt was er een sterker verband tussen wandelen en het hebben van een positieve attitude ten opzichte van bewegen en tussen wandelen en het ervaren van een stimulerende sociale invloed dan bij mensen die zich nooit onveilig voelen in hun buurt. Dit patroon werd niet gevonden voor mensen die zich vaak onveilig voelden in hun buurt. Bij de mensen die überhaupt wel eens wandelden in hun vrije tijd, werd meer gewandeld wanneer zij zich wel eens onveilig voelden in hun buurt, maar wel een positieve intentie hadden om voldoende te bewegen. Deze mensen wandelden gemiddeld ongeveer een half uur per week meer dan mensen die zich veilig voelden in hun buurt (ongeacht intentie) en mensen die weinig intentie hadden om voldoende te bewegen. De laatste interactie die gevonden werd, was tussen attitude en het gevoel thuis te horen in je buurt. Het gevoel thuis te horen in je buurt was sterker gerelateerd aan wandelen in de vrije tijd wanneer mensen een minder dan gemiddeld positieve houding hadden ten opzichte van bewegen.

Hoofdstuk 6 beschrijft de laatste interactiestudie en gaat ook over wandelen in de vrije tijd. In plaats van sociale buurtfactoren, werd in deze studie gekeken naar objectief gemeten fysieke buurtkenmerken (toegankelijkheid, veiligheid, comfort, aantrekkelijkheid). In deze cross-sectionele studie werd gebruik gemaakt van een sociaalecologisch model dat een hiërarchie van 'wandelbehoeften' voorstelt. Het wandelgedrag werd gemeten als 'wel eens wandelen' en 'wandelen volgens de Nederlandse Norm Gezond Bewegen' (tenminste 30 minuten op tenminste 5 dagen in de week). Zowel de directe verbanden als de interacties tussen de buurtfactoren en psychosociale factoren werden onderzocht in hun relatie tot wandelen in de vrije tijd. Ook in deze studie waren de psychosociale factoren gerelateerd aan wandelen in de vrije tijd. Voor 'wandelen volgens de norm' werden er diverse interacties gevonden tussen fysieke omgevingskenmerken in de buurt en attitude. De fysieke omgevingskenmerken hadden een sterker verband met wandelen volgens de norm wanneer mensen een minder positieve attitude hadden ten opzichte van bewegen. In tegenstelling tot deze interacties met attitude, werd er een sterker verband gevonden tussen de toegankelijkheid van de buurt en wandelen wanneer mensen meer positieve sociale invloed ervoeren. Geen van de onderzochte fysieke omgevingskenmerken van de buurt had een direct verband met wandelen in de vrije tijd. Ook werd er geen bewijs gevonden voor de hiërarchie zoals in het theoretische model was voorgesteld.

Deze drie studies laten alle drie interacties zien tussen psychosociale factoren en buurtfactoren en versterken daarmee de resultaten van eerder onderzoek over het bestaan van deze interacties. Er worden echter ook vaak géén interacties gevonden en de resultaten variëren sterk voor de specifieke onderzochte interacties. Vooraf zijn twee mogelijke mechanismen voorgesteld. Ten eerste een mechanisme van synergie waarin de positieve invloed van een stimulerende buurtomgeving op beweeggedrag wordt versterkt door de positieve invloed van gunstige psychosociale cognities ten opzichte van bewegen. Het andere mechanisme gaat ervan uit dat mensen met minder gunstige psychosociale cognities meer profijt hebben, en dus sterker beïnvloed worden, door een stimulerende buurtomgeving. De studies die beschreven worden in dit proefschrift leveren aanwijzingen voor beide mechanismen zonder dat één van de twee duidelijk als belangrijkste naar voren komt. Dit kan betekenen dat beide mechanismen bestaan maar dat het mechanisme kan verschillen per beweegdomein en dat het afhankelijk is van de specifieke combinatie van psychosociale cognitie en omgevingsfactor. Meer onderzoek is nodig om inzicht te krijgen in deze interacties en in het belang ervan voor de publieke gezondheidszorg.

Om over te gaan tot handelen en de buurtomgeving aan te passen, is het nodig om te weten of veranderingen in de buurtomgeving daadwerkelijk voor een verandering in beweeggedrag kunnen zorgen. Daarom is in **hoofdstuk 7** de laatste onderzoeksvraag onderzocht:

3. Kunnen wijzigingen in de buurtomgeving het beweeggedrag veranderen?

Hoofdstuk 7 beschrijft de resultaten van een natuurlijk experiment van mensen die naar een nieuwe buurt verhuizen in Perth, Australië. Er werd onderzocht of mensen die niet fietsen vóór hun verhuizing wel fietsen ná hun verhuizing en welke veranderingen in de buurtomgeving hieraan bijdroegen. De studie liet zien dat verbeteringen in de toegankelijkheid van lokale faciliteiten en de fysieke opbouw van de wijk mensen kan aanzetten tot fietsen. Inwoners die verhuisden naar een buurt met een betere verbinding tussen de straten waren meer geneigd om recreatief te gaan fietsen. Inwoners die verhuisden naar een buurt met een grotere woningdichtheid en een betere toegang tot parken en recreatieve bestemmingen waren meer geneigd om functioneel te gaan fietsen (het gebruik van de fiets als transport middel). Deze bevindingen waren onafhankelijk van psychosociale cognities zoals houding en intentie ten opzichte van fietsen vóór verhuizing, wat een indicatie is dat de veranderingen niet werden veroorzaakt door een selectie-effect.

Het is belangrijk om vergelijkbare studies in andere landen uit te voeren omdat dit soort studies erg contextueel zijn en de verbanden tussen buurtkenmerken en bewegen in de ene omgeving niet per se gelden voor een andere omgeving. Bijvoorbeeld, in Europese steden waar fietsen al veel meer is ingeburgerd in het straatbeeld en de fietsinfrastructuur al verder is ontwikkeld, kunnen andere factoren in de buurtomgeving een belangrijke rol spelen in het beweeggedrag, wat landen als de VS en Australië, die pas recent een interesse in fietsen hebben ontwikkeld, kan informeren.

Ten slotte wordt in **hoofdstuk 8** een samenvatting gegeven van de gevonden resultaten en worden deze resultaten beschouwd in relatie tot eerder onderzoek en methodologische overwegingen. Ook worden implicaties voor onderzoek en praktijk besproken. Eén van de belangrijkste conclusies van dit proefschrift is dat er aanwijzingen zijn gevonden voor interacties tussen individuele en omgevingsfactoren. Er komt echter niet eenduidig één mechanisme naar voren en het bewijs voor deze omgevings-individuele interacties blijft beperkt. Het mechanisme lijkt afhankelijk te zijn van de specifieke combinatie van factoren. Meer onderzoek, bij voorkeur door gebruik te maken van bestaande studies, is nodig om inzicht te krijgen in deze interacties en in het belang ervan voor de publieke gezondheidszorg.

Dankwoord
About the author
Publications
Phd Portfolio

DANKWOORD

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Mariëlle

ABOUT THE AUTHOR

Mariëlle Anne Beenackers was born in Heerlen on the 7th of July 1983 and grew up in Schinnen. After graduating from secondary school at the Graaf Huyn College in Geleen, she started studying Communication Sciences at Twente University in Enschede. For her minor, she followed a semester of courses on Health and Society at Linköping University in Linköping, Sweden. In 2007 she obtained her Master of Science degree (with distinction) in Communication Science. In the meantime she enrolled as a Master student in Health Sciences at Maastricht University. In 2008, Mariëlle graduated with distinction majoring in Health Promotion and Health Education. In the same year she started working at the department of Public Health of the Erasmus MC in Rotterdam; first as a research assistant and after a small year as a junior researcher. Here she carried out the research presented in this thesis on the interplay between individual and neighbourhood factors on physical activity. In 2010 she worked three months as a visiting researcher at the Centre for the Built Environment and Health of the University of Western Australia in Perth, Australia. Since May 2012, she works as a post-doctoral researcher at the department of Public Health of the Erasmus MC in Rotterdam.

Mariëlle Anne Beenackers is geboren in Heerlen op 7 juli 1983; ze groeide op in Schinnen. In 2001 behaalde zij haar VWO diploma aan het Graaf Huyn College in Geleen waarna ze Toegepaste Communicatie Wetenschappen ging studeren aan de Universiteit Twente in Enschede. In het kader van haar minor volgde ze een half jaar lang vakken binnen de opleiding 'Health and Society' aan de Universiteit van Linköping in Zweden. In 2007 studeerde ze cum laude af voor de master 'Communication Sciences'. In de tussentijd begon ze aan de masteropleiding 'Health Education and Health Promotion' aan de Universiteit van Maastricht. Deze voltooide zij eveneens cum laude in 2008. In ditzelfde jaar startte zij haar baan bij de afdeling Maatschappelijke Gezondheidszorg van het Erasmus MC in Rotterdam; eerst als onderzoeksmedewerker en na een klein jaar als junior onderzoeker. Hier voerde zij het onderzoek uit dat is beschreven in dit proefschrift over het samenspel van individuele en omgevingsfactoren bij bewegen. In 2010 werkte zij drie maanden als onderzoeker bij het Centre for the Built Environment and Health van de University of Western Australia in Perth, Australië. Sinds mei 2012 is zij werkzaam als postdoctoraal onderzoeker aan de afdeling Maatschappelijke Gezondheidszorg van het Erasmus MC in Rotterdam.

LIST OF PUBLICATIONS

2013

Beenackers, M.A., Kamphuis, C.B.M., Mackenbach, J.P., Burdorf, A., & van Lenthe, F.J. *Why some walk and others don't: exploring interactions of perceived safety and social neighbourhood factors with psychosocial cognitions.* Health Education Research, Advance Access published February 7 2013; doi:10.1093/her/cyt002.

van Lenthe, F.J., Kamphuis, C.B.M., Beenackers, M.A., Jansen, T., Looman, C., Nusselder, W., & Mackenbach, J.P. *Cohort profile. Understanding socioeconomic inequalities in health and health behaviours: The GLOBE study.* International Journal of Epidemiology, forthcoming 2013.

Prins, R.G., Kamphuis, C.B.M., van Empelen, P., Beenackers, M.A., Brug, J., Mackenbach, J.P., & Oenema, A. *Explaining socio-demographic differences in disengagement from sports in adolescence.* The European Journal of Public Health, Advance Access published January 8 2013; doi:10.1093/eurpub/cks188.

2012

Beenackers, M.A., Kamphuis, C.B.M., Giskes, K., Burdorf, A., Kunst, A.E., Brug, J., & van Lenthe, F.J. *Socioeconomic inequalities in physical activity among European adults: a systematic review.* International Journal of Behavioral Nutrition and Physical Activity, 2012. 9(116); doi:10.1186/1479-5868-9-116.

Beenackers, M.A., Kamphuis, C.B.M., Foster, S., Titze, S., Divitini, M., Knuiman, M., van Lenthe, F.J., & Giles-Corti, B. *Taking up cycling after residential relocation. Built environment factors.* American Journal of Preventive Medicine, 2012. 42(6): 610; doi:10.1016/j.amepre.2012.02.021.

2011

Beenackers, M.A., Kamphuis, C.B.M., Burdorf, A., Mackenbach, J.P., & van Lenthe, F.J. *Sports participation, perceived neighborhood safety, and cognitions: how do they interact?* International Journal of Behavioral Nutrition and Physical Activity, 2011. 8(76); doi:10.1186/1479-5868-8-76.

2010

Prins, R.G., van Empelen, P., Beenackers, M.A., Brug, J., & Oenema, A. *Systematic development of an intervention targeting personal motivations and environmental opportunities to increase physical activity of Dutch adolescents.* BMC Public Health, 2010. 10(474); doi:10.1186/1471-2458-10-474.

van Osch, L., Reubsaet, A., Lechner, L., Beenackers, M., Candel, M., & de Vries, H. *Planning health behaviour change: Comparing the behavioural influence of two types of self-regulatory planning.* British Journal of Health Psychology, 2010. 15(1):133-149; doi:10.1348/135910709X436723.

2009

van Osch, L., Beenackers, M., Reubsaet, A., Lechner, L., Candel, M., & de Vries, H. *Action planning as predictor of health protective and health risk behavior: an investigation of fruit and snack consumption.* International Journal of Behavioral Nutrition and Physical Activity, 2009. 6(69); doi:10.1186/1479-5868-6-69.

Submitted

Beenackers, M.A., Kamphuis, C.B.M., Mackenbach, J.P., Burdorf, A., & van Lenthe, F.J. *Urban form characteristics and psychosocial cognitions: do they interact for leisure time walking?* Submitted.

PHD PORTFOLIO

Name:	Mariëlle Anne Beenackers
PhD Period:	2008-2012
Erasmus MC department:	Public Health
Promotor:	Prof.dr. A. Burdorf
Supervisors:	Dr. F.J. van Lenthe
	Dr. C.B.M. Kamphuis

	Year	Workload (hours/ECTS)
1. PhD training		
NIHES* courses, Rotterdam, The Netherlands		
Causal Inference	2011	0.7 ECTS
Conceptual Foundation of Epidemiologic Study Design	2011	0.7 ECTS
Cohort Studies	2011	0.7 ECTS
Survival Analysis	2011	1.9 ECTS
Principles of Genetic Epidemiology	2011	0.7 ECTS
Advances of Genomics Research	2011	0.4 ECTS
Introduction to data-analysis	2010	1.0 ECTS
Regression analysis	2010	1.9 ECTS
Principles of Research in Medicine and Epidemiology	2009	0.7 ECTS
Other courses		
General Medicine, Wageningen University, Wageningen, The Netherlands	2011	6 ECTS
Bayesian Methods and Bias Analyses, Rotterdam, The Netherlands	2010	16 hours
Methodologie van Patiëntgebonden Onderzoek en Voorbereiding Subsidieaanvragen, Erasmus MC, Rotterdam, The Netherlands	2010	8 hours
Biomedical English Writing and Communication, Erasmus MC, Rotterdam, The Netherlands	2009	4 ECTS
Mplus short course 1-2: advanced regression analysis, IRT, factor analysis and structural equation modelling (self-study)	2009	20 hours
Mplus short course 3-4: growth modeling, survival analysis, and missing data analysis (self-study)	2009	20 hours

Mplus short course 5-6: Categorical latent variable modeling, Freie Universitat, Berlin, Germany	2009	20 hours
Mplus short course 7-8: Multilevel modelling, Freie Universitat, Berlin, Germany	2009	20 hours

Presentations/posters

'Leefbare wijken' in Australië. Wat is het effect van het ontwerp van de wijk op het beweeggedrag van de bewoners? *CEPHIR*, Rotterdam, The Netherlands	2012	1 ECTS
Socioeconomic inequalities in physical activity among European adults: a systematic review. *Nederlands Congres Volksgezondheid*, Amsterdam, The Netherlands	2012	1 ECTS
Healthy commuting: individual cognitions and neighbourhood factors associated with walking and cycling to work. *International Congress of Epidemiology.* Edinburgh, Scotland, UK (poster)	2011	1 ECTS
Starting cycling after residential relocation: the RESIDE project. *10th Annual Conference of the International Society of Behavioral Nutrition and Physical Activity*. Melbourne, Australia (poster, presented by prof.dr. B. Giles-Corti)	2011	1 ECTS
Sports participation, perceived neighbourhood safety, and individual cognitions: how do they interact? *WEON 2011*. IJmuiden	2011	1 ECTS
Starting cycling after residential relocation: the RESIDE project. *Research meeting.* Department of Public Health, Erasmus MC, Rotterdam, The Netherlands	2011	1 ECTS
The interaction between individual cognitions and neighbourhood factors in explaining physical activity. *Research meeting.* Centre for the Built Environment and Health of the University of Western Australia, Perth, Australia	2010	1 ECTS
The interaction between individual cognitions and perceived neighborhood safety on sports participation in adults. (als onderdeel van symposium). *9th Annual Conference of the International Society of Behavioral Nutrition and Physical Activity*. Minneapolis, Minnesota, USA	2010	1 ECTS
The interaction between individual cognitions and neighbourhood factors in explaining physical activity. *Workgroup meeting 'Environment and Health'*. Rotterdam, The Netherlands	2009	1 ECTS

The interaction between individual cognitions and perceived neighbourhood safety on sports participation in adults. *Research meeting.* Department of Public Health, Erasmus MC, Rotterdam, The Netherlands	2009	1 ECTS
Workshop: Speed-daten met jonge onderzoekers over (beleids)interventies gericht op de obesogene omgeving. *Nederlands Congres Volksgezondheid*, Rotterdam, The Netherlands	2009	1 ECTS
Conferences		
WEON 2012, Rotterdam, The Netherlands	2012	16 hours
Nederlands Congres Volksgezondheid (NCVGZ), Amsterdam, The Netherlands	2012	8 hours
IEA - World Congress of Epidemiology, Edinburgh, Scotland, UK	2011	30 hours
WEON 2011, IJmuiden, The Netherlands	2011	16 hours
Annual meeting of the International Society of Behavioral Nutrition and Physical Activity (ISBNPA) - Minneapolis, Minnesota, USA	2010	24 hours
Annual meeting of the International Society of Behavioral Nutrition and Physical Activity (ISBNPA) - Cascais, Portugal	2009	24 hours
Nederlands Congres Volksgezondheid (NCVGZ), Rotterdam, The Netherlands	2009	16 hours
Workshops / seminars		
Department of Public Health seminars, Rotterdam, The Netherlands	2008-2012	1 ECTS
CEPHIR seminars, Rotterdam, The Netherlands	2008-2012	1 ECTS
Symposium 'Successen van preventie 1970-2010-2040', Rotterdam, The Netherlands	2011	4 hours
ISBNPA preconference workshop: 'Current Policy Solutions to the Obesity Crisis', Minneapolis, Minnesota, USA	2010	4 hours
Maatschappelijk café 'Lage inkomens over gezond leven', The Hague, The Netherlands	2010	4 hours
Symposium 'Public Health tussen genen en globalisering', Rotterdam, The Netherlands	2010	4 hours
Symposium 'Patients, People and Populations - 40 years of Epidemiology at Erasmus', Rotterdam, The Netherlands	2009	6 hours
ISBNPA preconference workshop: 'Conceptualizing and measuring built environment correlates of physical activity', Cascais, Portugal	2009	6 hours

Groen is Goud waard: Symposium over het gebruik en de toekomst van het stadsgroen, Amsterdam, The Netherlands	2009	4 hours
Propensity scores. Werkgroep Medische Statistiek, Utrecht, The Netherlands	2008	6 hours

2. Teaching activities

Lecturer medical students VO1 theme 3.C.2 (primary prevention)	2012	10 hours
Supervisor medical students theme 3.C.4 (community projects)	2011-2012	40 hours
Lecturer medical students VO theme 2.2 (life style)	2009	10 hours

3. Other activities

Editor Epistel (montly bulletin of VvE**)	2011-2012
Reviewer several international scientific journals (e.g. Journal of Sports Sciences, Scandinavian Journal of Public Health, International Journal of Behavioral Nutrition and Physical Activity)	2009-2012
Contributed to the NIHES accreditation reports (for VvE)	2012
Board member of Promeras (Association for PhD-students at Erasmus MC)	2008-2010

* Netherlands Institute for Health Sciences

** VvE = Vereniging voor Epidemiology (Dutch Epidemiological Society)

Physical inactivity is among the most important and prevalent risk factors of many major diseases. Although the health benefits of regular exercise and a physically active lifestyle are well known, many people are still not active. Understanding why some population groups are physically active and others are not is therefore of key importance in developing strategies to improve population health.

Physical activity is often believed to be influenced by both environmental factors, such as the neighbourhood lay-out, and individual factors, like personal beliefs about physical activity. Many theories also suggest that these factors interplay so that the role of individual factors for physical activity may depend on the environmental context. However, little is known about this interplay. In this thesis, associations of individual and neighbourhood factors with physical activity are studied, with a particular focus on the interplay between these individual and neighbourhood factors.

The results of this study provide new insights for public health researchers, policymakers, urban planners, and everyone else who is interested in physical activity and the interplay between individual and neighbourhood factors.